Adaptive Capacity of Woodland Dependent Households to Climate Change in the Central Rift Valley of Ethiopia

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Declaration

I, the undersigned, declare that this is my original work, has never been presented in this or any other University, and that all the resources and materials used for the dissertation, have been fully acknowledged.

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This dissertation has been submitted for examination with my approval as University supervisor.

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DISSERTATION APPROVAL

ADDIS ABABA UNIVERSITY

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This is to certify that the dissertation prepared by Demamu Mesfin entitled: “Adaptive Capacity of Woodland Dependent Households to Climate Change in the Central Rift Valley of Ethiopia” and submitted in fulfillment of the requirement for the Degree of Doctor of Philosophy in Development Studies (Environment and Development Studies) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

Ethiopia stands among the most vulnerable and worst affected countries in the world to the impacts of climate change mainly because of its low adaptive capacity. The Central Rift Valley (CRV) of Ethiopia is one of the most vulnerable areas in the country. However, studies to understand the perception and adaptive capacity of rural households to climate change in the semi-arid areas of the CRV are limited. This study examines the perception and adaptive capacity of rural households to climate change in the CRV. Mixed research methods approach was adopted to gather both quantitative and qualitative data. Household survey, focus group discussion (FGD), key informant interview (KII), field observation, and remote sensing and GIS techniques were used to collect data. The study found out that a large majority of households perceived climate change and its impacts and adopted an array of adaptation practices. It was also found that the adaptive capacity (AC) of households in the CRV was generally low and varies among households living in different Kebeles. From five major components that contributed to adaptive capacity, institutions and entitlements, knowledge and information, and innovation were found to contribute better than decision making and governance, and asset-base. Moreover, the composite indices for sub-components indicated that woodlands contributed to AC better than grazing land, farmland, and water resources, respectively. However, it was also found that woodlands are declining. Forty years ago, the study area was virtually covered with woodlands and forests (95%) and agriculture was just starting (1%). Now, it is reversed that agriculture covered nearly half of the study area (45%), while woodlands covered 42% and forests virtually disappeared. The socioeconomic and environmental impacts of these changes have also been perceived by households. Furthermore, seven proximate and ten underlying causes of woodland decline have been identified and ranked by households. It is concluded that adaptive capacity has broader dimensions and assessments and interventions need to be made in a holistic and integrated manner. Moreover, interventions need to acknowledge local differences and be tailored accordingly to suit local contexts.

***Key words**: Climate change, perception, adaptive capacity, woodland, impacts, proximate causes and driving forces.*

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Chapter One: Introduction

1.1. Background

Climate change is an issue of growing importance to people because of its ensuing effects on human beings and the living environment. It is arguably the greatest contemporary threat to the wellbeing of humankind, particularly to the viability of rural households who depend on natural resources for their livelihoods (Davidson et al., 2003a; Boon & Ahenkan, 2012; Pramova et al., 2012; Jacobs et al., 2015). It poses serious environmental, social and economic threats to the world (UNFCCC, 2006; Boyd et al., 2009; Field et al., 2014).

While climate change is a global phenomenon, its adverse impacts are not evenly distributed and will be more severely felt by societies in developing countries (Smit & Pilifosova, 2001; Adger et al., 2003; Huq et al., 2003; Field et al., 2014). Evidence are emerging that climate change poses a massive threat to the development of especially poor countries (Ayers & Huq, 2009; Boyd et al., 2009; Simoes et al., 2010; Kalame, 2011). Many developing countries find that climate-related hazards seriously constrain their hopes for development (Handmer, 2003; Davidson et al., 2003b; Scott, 2008; Dube & Phiri, 2013). Of the developing countries, Africa as a whole is considered to be among the most vulnerable regions (Desanker, 2002; Osman-Elasha et al., 2006; Boko et al., 2007; Niang et al., 2014). The high level of vulnerability in these countries in general is largely attributed to greater dependence on climate-sensitive sectors such as agriculture, water, and forests and low capacity to adapt to a changing climate (Thornton et al., 2006; OECD, 2009; Glantz et al., 2009; Van Bodegom et al., 2009; Addisu et al., 2016).

Ethiopia is among the most vulnerable and worst affected countries in sub-Saharan Africa and with the least capacity to adapt to the effects of climate change (Stige et al., 2006; Thornton et al., 2006; World Bank, 2006; Boko et al., 2007; Conway & Schipper, 2011). Currently, it is ranking as one of the countries at most “extreme risk” from the impacts of

climate change (Yirgu et al., 2013) and it is often cited as one of the most extreme examples (Thornton et al., 2006; Conway & Schipper, 2011; Yirgu et al., 2013). Ethiopia's extreme vulnerability is largely associated with its strong economic dependence on rain-fed agriculture and natural resources that are very sensitive to climate change and the poor capacity of rural households to adapt (World Bank, 2006; NMA, 2007; Verburg et al., 2010; FDRE 2011a, MEF, 2015). Moreover, existing developmental challenges such as widespread poverty, high population growth, environmental degradation, inadequate infrastructure, weak institutions, and low levels of awareness on climate change aggravate the country's vulnerability (Kidanu et al., 2009; Mahoo et al., 2013; MEF, 2015).

Ethiopia's economy is highly exposed to climate risks. Agriculture forms the basis of the national economy and is the mainstay of livelihoods for more than 83 percent of the population (UNEP, 2016). Agriculture contributes about 46 percent of the GDP of which forestry is estimated to contribute between three and four percent (MEF, 2015). However, UNEP (2016) revealed that past calculations of GDP underestimate the contribution of the forestry sector by about 42 percent and that its current contribution can reach up to 13 percent. Agriculture is also almost exclusively rain-fed with less than five percent of the potentially irrigable land under irrigation (World Bank, 2006; Mahoo et al., 2013).

Agriculture is thus the most vulnerable sector as fluctuations in rainfall affects its productivity and overall GDP (World Bank, 2010; Bewket et al., 2015; MEF, 2015). The correlation between rainfall and GDP is also strong (World Bank, 2006) and estimates suggest that climate change may reduce Ethiopia's GDP by up to 10 percent by 2045 (World Bank, 2010). In terms of livelihood, all rural livelihood systems—crop cultivation, pastoralism, and agro-pastoralism—are sensitive to climate change and variability, particularly to variations in rainfall and drought (WFP, 2013; USAID, 2016). Ecologically, the arid, semi-arid and dry sub-humid parts of the country are the most vulnerable areas (NMA, 2007; Kidanu et al., 2009).

Climate variability and its associated impacts are not new though and have a long history in Ethiopia (World Bank, 2006; Regassa et al., 2010; Mahoo et al., 2013). The country has experienced many climatic as well as environmental shocks over the last several thousands of years (NMA, 2007; Mahoo et al., 2013). The recent climatic perils are however associated with the impacts of anthropogenic climate change (NMA, 2007; Mahoo et al., 2013; IPCC, 2014a; MEF, 2015). And Ethiopia is already suffering from the impacts of increased rainfall variability, rising temperatures, and more intense and frequent extreme events such as drought and flood (NMA, 2007; World Bank, 2012; MEF, 2015; Bewket et al., 2015).

Responses to the impacts of climate change are therefore necessary of which adaptation is one of them. Failing to respond properly will affect livelihoods and constrain development particularly in poor countries like Ethiopia (Jones et. al., 2010; Verburg et al., 2010). For Ethiopia, adaptation to climate change impacts remains at the forefront of any sustainable development effort (Lim et al., 2005). Its ability to prosper under the effects of climate change relies on adaptation (Jacobs et al., 2015). Effective adaptation, in turn, entails a better understanding and strengthening of the adaptive capacity of both the natural and human systems as adaptations are manifestations of adaptive capacity (Vincent, 2007; Fisher et al., 2010; Pramova et al., 2012; Field et al., 2014).

The rural communities in Ethiopia can and will adapt and have been adapting to climate-related risks for centuries but often not in the most efficient manner possible as evidenced by some of the harsh experiences it had in the past. A wide range of adaptation strategies such as livelihood diversification, crop diversification, planting date changes, use of forest products and natural resource management including tree planting and soil and water conservation have been used but such efforts were at times not enough to withstand the vagaries of climate change (Osman-Elasha et al., 2006; Bryan et al., 2009; MEF, 2015; Bewket et al., 2015). This accentuates the fact that many societies in Ethiopia lack the capacity to adapt to the impacts of even the current climate.

Moreover, climate change poses novel risks often outside the range of historical experiences, such as impacts related to the intensity and frequency of drought (Adger et al., 2007; OECD, 2009). These risks are likely to add more pressure to the already distressing situation of many rural households in Ethiopia. Yet little is known as to what constitutes the adaptive capacity of rural households and communities at the local level and how development interventions are influencing their ability to adapt. Therefore, there is a need to better understand and improve the adaptive capacity of rural households in Ethiopia to current climate and to impacts of climate change that may fall outside of their historical experience (NMA, 2007; FDRE, 2011a; MEF, 2015; Bewket et al., 2015).

Assessing and understanding adaptive capacity are prerequisites for designing interventions to reduce the adverse effects of climate change (Vincent, 2007). They are essential for evaluating the need to strengthen the capacity of communities to future expected needs (Jacobs et al., 2015). Assessments of adaptive capacity provide information on the types of assets available to support livelihoods and constraints on the ability of communities to access, combine or apply these assets to adapt to change (Jacobs et al., 2015). They can also be used to identify opportunities for individuals, households and collective local action and/or government intervention to build adaptive capacity and facilitate adaptive actions (Bellamy et al., 2002). Support from government or other development actors will be required as many communities at the local level lack the necessary tools, resources or capacity to adapt or simply, some assets, such as public infrastructure, are beyond their scope (Bryan et al., 2009; Arnall, 2011; Jacobs et al., 2015). Thus, empirical assessment of adaptive capacity is needed to guide government policies and interventions as well as local adaptive actions (Vincent, 2007).

Assessing adaptive capacity is, however, a major challenge although in theory it can be identified and measured at various scales, from the individual to the nation (Adger & Vincent, 2005). Because of its latent nature and the fact that it is often locally defined, it is not amenable to direct measurement (Smit & Pilifosova, 2001; Brooks & Adger 2005; Jones et al. 2010; Engle, 2011; Lockwood et al. 2015). Most assessments of adaptive capacity involve identifying the factors that contribute to the capacity to adapt and the

ability to use them when needed (Jones et al., 2010; Arnall, 2011; Jacobs et al., 2015, Hogarth & Wójcik, 2016a,b).

This study took an evolutionary theoretical perspective as elaborated in Hogarth et al. (2014) to conceptualize adaptive capacity and adapted the Local Adaptive Capacity (LAC) framework as its conceptual framework. Hogarth and Wójcik (2016a,b) argue that the LAC framework, which characterizes adaptive capacity based on five components (asset base; institutions and entitlements; knowledge and information; innovation; and flexible forward-looking decision-making and governance) largely correspond with an evolutionary perspective on adaptive capacity. The LAC framework was developed by the Overseas Development Institute (ODI) in 2010 while conducting the Africa Climate Change Resilience Alliance (ACCRA) project. It had neither been applied in different contexts nor sufficiently grounded in academic theory until the Global Islands' Vulnerability Research Adaptation Policy and Development (GIVRAPD) project (Hogarth & Wójcik, 2016a,b). Therefore, this study, in addition to assessing the capacity of rural households in the CRV, provides further opportunity to assess whether the LAC framework captures the important elements of adaptive capacity.

1.2. Statement of the Problem

Ethiopia is rated among the most vulnerable sub-Saharan countries as a result of its low adaptive capacity. The CRV is one of the most environmentally fragile and vulnerable areas in Ethiopia experiencing the vagaries of climate change including recurrent drought and rainfall variability (Jansen et al., 2007; Gebrekirstos et al., 2008; Meshesha et al., 2012; Biazen, 2012; MEF, 2015). Despite this fact, attempts to understand and improve the adaptive capacity of rural households in Ethiopia, including the semi-arid areas of the CRV have been limited (NMA, 2007; ECSNCC, 2010; MEF, 2015).

In particular, studies that measure adaptive capacity to climate change at the household level are limited in Ethiopia. Although climate change adaptation research in Ethiopia is relatively young, most studies so far have focused on assessing vulnerabilities and

adaptation strategies rather than the constituents of adaptive capacity which can reduce vulnerability and guide adaptation practices and development interventions (Bryan et al., 2009; Deressa et al., 2009; Mahoo et al., 2013; Zeleke, 2014; Bewket et al., 2015; Simane et al., 2016; Amare & Simane, 2017; Asrat & Simane, 2017). In addition, most of these studies were conducted at national or other administrative levels, while managing climate risk, as highlighted by Heltberg et al. (2009), has traditionally been the responsibility of households, with the exception of large extreme events and natural calamities. These studies cannot capture many of the processes and contextual factors that influence adaptive capacity at the local level where most of the adaptation actions take place (Brooks & Adger, 2005; Adger & Vincent, 2005; Eriksen & Kelly, 2007; Kuriakose et al., 2009; Jones et al., 2010; Defiesta & Rapera, 2014).

A better understanding of what improves and/or limits adaptive capacity will allow addressing the different dimensions of adaptation and help in designing effective adaptation strategies (Brooks & Adger, 2005; Kuriakose et al., 2009; Magnan, 2010). Such understanding is vital because it is the system's adaptive capacity that ultimately determines the success and failure of adaptation (Lemos et al., 2013). And this can be achieved through more systematic empirical assessments (Engle, 2011). Thus, measures of adaptive capacity would provide valuable inputs in designing policies and interventions for effective climate change adaptation (Lemos et al., 2013; Defiesta & Rapera, 2014).

Moreover, although woodlands constitute an important part of the natural asset, empirical studies that assess their role in improving the adaptive capacity of rural households in Ethiopia are lacking. While all assets are important, natural assets such as woodlands are particularly important for the poorest and most vulnerable communities in the world (Burton et al., 2003; Locatelli et al., 2008; Fisher et al., 2010; Pramova, et al., 2012). Thus, they need to be included in the analysis of adaptive capacity.

Equally important is the assessment of the changes that the woodlands are experiencing and their implications for livelihood and the environment as well as the pressures exerted

on them and the associated driving forces. Assessing the status of woodlands provides information about the sustainability of the resource and the goods and services it renders to the community. It is when the woodlands are sustainably managed that they can significantly contribute to increasing the adaptive capacity of both the ecological and the social system (Robledo & Pfund, 2004; Pramova et al., 2012). This study, therefore, fills this gap by focusing on the understanding of adaptive capacity and its components at the household level in the woodland dominated lowlands of the CRV area.

1.3. Research Questions

The following are the core research questions of the study.

1) How does the climate trend look like and how do households perceive changes in climate, its impacts, and adaptation practices?
2) What constitutes the adaptive capacity of households and what role does each component, particularly woodlands, play in their adaptive capacity?
3) Are there differences in the adaptive capacity of households across the selected *Kebeles*?
4) How have the woodland resources of the area changed over time and what are their likely impacts on the livelihood of the households and the environment?
5) What are the proximate causes and driving forces of woodland cover change?

1.4. Objectives of the Study

1.4.1. General objective

The general objective of the study was to quantify the adaptive capacity of rural households in the CRV of Ethiopia and identify policy and development interventions for local adaptation actions.

1.4.2. Specific objectives

The specific objectives of the study were the following.

- To evaluate climate trends and households' perception of climate change, associated impacts, and their adaptation practices;
- To identify the components of adaptive capacity of households and assess the respective role of elements, particularly woodlands, in adaptive capacity;
- To compare the adaptive capacity of households across the selected *Kebeles;*
- To assess the changes that the woodlands of the area have experienced over the years and their associated impacts on the livelihood of the households and the environment;
- To explore the proximate causes and driving forces of woodland cover change.

1.5. Significance of the Study

This study has practical, policy and scientific significance. It is intended to benefit the local community, decision makers, and the scientific community who have the interest to work on the interface between the environment and development specifically in climate change adaptation. The findings of this study will help the local community to realize the different components of adaptive capacity and their relative contributions, to identify the opportunities and constraints to enhance their adaptive capacity, and to design adaptation strategies that suit their local contexts. For instance, the study highlights the role of natural assets, in particular, woodlands in building adaptive capacity and the challenges these resources are facing. This will provide insights to develop woodland management strategies that can ensure the continuity of woodlands while still providing the goods and services needed to enhance adaptive capacity. Thus, recognizing the attributes of adaptive capacity at household level will be an important vehicle for building adaptive capacity and facilitating adaptive action.

Moreover, the study provides inputs to improve policy and development interventions or decision making aimed at improving adaptive capacity at the local level. It gives valuable

information as to how adaptive capacity can be enhanced and how adaptation efforts can be supported. It will help decision makers on which components of adaptive capacity to focus on, to set priorities and design interventions. More importantly, it will prompt location and context specific policy and development interventions so as to enhance adaptive capacity and ultimately reduce vulnerability.

Finally, it is believed that this study adds to the scholarly research and literature in the field of climate change adaptation, particularly in local level adaptive capacity. This study utilized a newly emerging framework designed to capture more complex factors contributing to adaptive capacity at the local level. The framework enabled us to include factors that determine the process through which a system adapts on top of those that determine what it has that enable it to adapt. As a result, intangible processes such as knowledge and information, innovation, and decision making and governance which are imperative to supporting adaptive capacity were captured in addition to the commonly addressed assets. Eventually, this study captured and measured more dimensions of adaptive capacity than most previous studies, which focused on only one or two dimensions derived principally from asset-based frameworks, did.

For example, woodlands were included in the analysis as one of the important natural assets contributing to adaptive capacity. This demonstrates the role woodlands play in climate change adaptation and illuminates the link between them. Linking tropical forests and woodlands and adaptation, as pointed out by Locatelli et al. (2008), is a new frontier for science and policy in that adaptation is a new frontier for tropical foresters, and tropical forests are a new frontier for adaptation specialists. Thus, this work will add to the scant knowledge pool regarding the role of forests and woodlands in climate change adaptation. This is important as the adaptation role of forests has not been as prominent in the international discourse and actions as their mitigation role, as underscored by Kalame (2011).

Furthermore, the relative contribution of the major and sub-components of adaptive capacity was empirically assessed. Thus, the techniques used in the analysis will also

provide an opportunity for advancing the measurement and characterization of adaptive capacity which still is a major challenge. In a nutshell, this work illustrates the complexity and multidimensionality of adaptive capacity at the local level and broadens our understanding.

1.6. Scope and Limitation of the Study

This study is confined to the adaptive capacity of rural households to climate change in the woodland dominated semi-arid parts of the CRV. So, obviously, this study is spatially delimited to only one agro-ecology, the lowlands of the CRV area and hence it does not represent different agro-ecologies. Even within the semi-arid portion of the CRV, the study included areas which used to be covered with woodlands and still has some remnants. The unit of analysis is also limited to households and may not necessarily reflect adaptive capacities of individuals, communities, regions, nations, and the like. Succinctly, this research may not necessarily reflect the nature of adaptive capacity in other socioeconomic and environmental settings.

The theoretical and practical orientation of the researcher, the context of the area in terms of climate change, and most importantly the gaps in literature in the field contributed to the delimitation of the study context. Very few studies considered woodlands and forests as important components of natural assets contributing to adaptive capacity. Another reason for delimiting the study context is the need to examine adaptive capacity critically and in detail as it is multi-dimensional and complex in nature. It is believed that this approach is helpful to gain a deeper insight into the adaptive capacity of rural households.

Although adaptive capacity is location and context specific by nature, the conceptual understandings, the methods used as well as the major dimensions and associated contributions identified in this study can, however, be used in other similar socioeconomic and environmental contexts. It should also be noted that application of the findings of this study in other areas or settings may necessitate some level of adjustment

so as to suit prevailing conditions. Nevertheless, like many other studies, generalization to other areas and socioeconomic settings is not possible.

In addition, because of the relative infancy of scientific research on adaptive capacity and partly because of the capricious nature of adaptive capacity, theoretical frameworks, variables, and indicators to measure adaptive capacity are not well developed. Standard methods for combining biophysical and socioeconomic indicators and assessing adaptive capacity are not well established yet. Therefore, this study used an emerging framework, developed new variables, and employed the latest techniques such as the polychoric correlation coefficient to assign weights and measure the contribution of the different components of adaptive capacity.

Despite the efforts, however, further research may still be required to refine the variables and indicators and enhance the power, validity, and credibility of this approach. This was and remains to be a major methodological challenge and limitation to assess adaptive capacity at the local level. Although the components of adaptive capacity are very much interrelated, this research did not also capture their indirect effects to each other and on overall adaptive capacity. Despite its weaknesses, however, this approach has much to offer in terms of understanding adaptive capacity and providing inputs to design interventions aimed at improving adaptive capacity at the local level.

1.7. Organization of the Dissertation

This dissertation is organized into eight chapters. Chapter One introduces the research problem. It presents the background of the problem, statement of the problem, objectives of the study, research questions, significance of the study, and scope and limitation of the study. Chapter Two presents the review of pertinent theoretical and empirical literatures. Paradigms on adaptive capacity as well as theoretical and conceptual frameworks are also presented. Chapter Three describes the research methodology, including description of the study area, research approach, philosophical worldviews, research design, and research methods. Chapter Four to Eight provides the main findings of the study. They

are presented as an independent chapter with their own introduction, methods, and conclusions. Chapter Four presents climate trends and households' perception of climate change, impacts, and adaptation practices. Chapter Five provides an assessment of rural households' adaptive capacity. Chapter Six presents woodland cover change and its associated impacts on the livelihood of the local people and the environment. Chapter Seven explores the proximate and underlying causes of woodland cover change. The last chapter provides summary of the findings, concluding remarks, and policy implications.

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Chapter Two: Theoretical and Empirical Literature Reviews

2.1. Climate Change and Its Impacts

2.1.1. Global perspectives

It is now apparent that the world's climate is changing at an unprecedented rate at both a global and a national scale (IPCC, 2007; UNFCCC, 2007; Swart et al., 2009; Roggema, 2009; Deeb et al., 2011; Collings, 2014). The IPCC (2007) strongly confirmed that climate change is happening and that its impacts are likely to be serious. The report also dispelled many uncertainties about climate change and concluded that warming of the climate system is now unequivocal.

Natural factors such as changes in the Earth's orbit around the sun, volcanic eruptions, ocean currents or even periods of heightened or diminished solar activity can play a role in changing Earth's climate (IPCC, 2007; Pittock, 2009; Deeb et al., 2011). However, the current trend of global warming – the increase in average temperature of the Earth's atmosphere – which persists for at least the past fifty years has been primarily linked to anthropogenic factors that include, among others, the burning of fossil fuels, clearing of forests, and agricultural practices that lead to increased GHG concentration in the atmosphere (King, 2005; IPCC, 2007; UNFCCC, 2007; Pittock, 2009; Bizikova et al., 2009; Stone & Leon, 2010; Deeb et al., 2011; Collings, 2014). The current level of GHG concentration in the atmosphere is the highest it has been for the past 500,000 years (IPCC, 2007). King (2005) further stated that the concentration of carbon dioxide alone, which is the most prevalent of the human-generated GHGs, is at a higher level than at any other time in the past 750,000 years. In addition, the IPCC reported that 70% of the total GHG accrued only between 1970 and 2004, which is exceptionally a quick growth.

Eventually, the planet Earth is now a warmer place. In fact, the global climate system as a whole, which comprises the atmosphere, the oceans, the ice sheets, the biosphere, and the

land surface, has become warmer (UNISDR, 2008; Pittock, 2009; Stone & Leon, 2010; Deeb et al., 2011). The planet temperature in 2015 was 0.9^{o}C higher than the 20th-century average, which is nearly halfway to the generally agreed-on severe climate effects threshold of 2^{o}C (World Bank, 2016). Average global air and ocean temperatures are higher than they have been at any other time during at least the past half millennium and perhaps for more than a millennium (IPCC, 2007). Land surfaces have also warmed faster than the oceans (Deeb et al., 2011).

More worryingly, the IPCC, based on detailed projections for the 21st century, reported that the globe will continue warming at an accelerated rate. Warming of the Earth will continue even if countries reduce their GHG emissions (Easterling et al., 2004; King, 2005; IPCC, 2007; UNFCCC, 2007; Twomlow et al., 2008; Pittock, 2009; Pramova et al., 2012). Whatever actions ultimately lead to the decarbonization of the global climate system, it will be many years before they have a discernible effect on climate (King, 2005; Pielke et al., 2007; Pittock, 2009). Solomon et al. (2009) also reported that the climate change that takes place due to increases in GHG concentration is largely irreversible for at least 1,000 years after emissions stop. Moreover, historical emissions indicate that climate change is unavoidable. Even the most optimist emissions projections indicate an increase in global GHG concentrations for the foreseeable future (Pielke et al., 2007).

Furthermore, Perlmutter and Rothstein (2011) stated that "many forecasts of climate change have already proved to be too optimistic, that is to underestimate the magnitudes of actual events, it is possible that the window of opportunity could close more rapidly than we now expect" (p. 2). They reckon that we have "a 10 – 20-year window of opportunity to develop policies that will be effective in facilitating adaptation to existing levels of global warming and mitigating the worst effects of a long-term and very dangerous increase in global temperatures" (p. 2). Similarly, Collings (2014) argued that estimates about climate change have turned out to be too optimistic citing the fact that "the climate was reacting far more quickly than most researchers had previously projected" (p. 7). Based on his analysis, he added that "the year 2020, it seems, is the new

2100" (p. 8). In line with these arguments, Roggema (2009) also reported that "the predictions on climate change are more than once overtaken by reality" (p. 1). He further stated that "climate change seems to accelerate: sooner, faster, stronger" (p. 1). Thus, according to his argument, this, in turn, means that uncertainties on future changes in climate are large.

Obviously, the Earth's climate has varied significantly in the past. Irrefutably, the climate has changed greatly over the course of human history but that change was known to happen over a geological timescale (Pittock, 2009; UNISDR, 2008). The difference now is that the temperature of the globe has increased unusually rapidly and consistently over the past few decades (IPCC, 2007; UNISDR, 2008; Pittock, 2009; Roggema, 2009; Stone & Leon, 2010; Collings, 2014). As a result, the Earth is now experiencing a sustained warming trend that can only be explained by the increase in GHGs in the atmosphere (King, 2005; UNFCCC, 2007; IPCC, 2007, 2014).

The global average temperature has increased by 0.76^{o}C over the last 150 years and much of this increase has occurred since 1970 (Dawson & Spannagle, 2009; Deeb et al., 2011; Centritto et al., 2011). This is the largest and fastest warming trend that scientists have been able to discern in the Earth's history (UNFCCC, 2007). Moreover, eleven of the twelve warmest years on record have happened only in twelve years between 1995 and 2006 (IPCC, 2007). Indeed, the global temperature has been continuously rising since records began in 1850 (Kirby, 2009; Dawson & Spannagle, 2009), in particular since the early 1860s – the height of the industrial revolution (Deeb et al., 2011). However, the speed of change now is so fast that the average global temperature over the past two decades has accelerated to an equivalent rate of 1.0^{o}C per century (Solomon et al., 2007). Furthermore, the IPCC predicted that the Earth, under a business as usual scenario, could warm by 3^{o}C this century (Solomon et al., 2007).

Warming of the global temperature will also cause many other climatic patterns to change at speeds unprecedented in modern times (IPCC, 2007; Pittock, 2009; Roggema, 2009; Stone & Leon, 2010; Deeb et al., 2011; Collings, 2014). Indeed, the impacts of

global warming are already evident (King, 2005; Bizikova et al., 2009; Deeb et al., 2011; IPCC, 2014a). For example, due to changes in land surface and ocean temperatures changes in rainfall have been observed worldwide (Stone & Leon, 2010). Scientists have already observed that the type, amount, intensity and frequency of rainfall have all changed (Deeb et al., 2011). Areas experiencing drought, or periods of extremely dry weather, have increased globally since the 1970s (IPCC, 2007). Increased frequency of extreme weather events including floods, droughts, cyclones or heavy rainfalls, melting glaciers, sea level rise, and changes in plant growth are other examples reflecting the effect of global warming (IPCC, 2007; Deeb et al., 2011).

The frequency and magnitude of observed and anticipated changes are also expected to rise even with a relatively small increase in average temperature (Schipper & Pelling, 2006; IPCC, 2007; Dawson & Spannagle, 2009; Deeb et al., 2011). In conjunction with this, Deeb et al. (2011) noted that small changes in global temperature can result in ice ages or warm periods. In addition, there are many other changes that are not described here but are consistent with the warming of the globe observed over the past several decades (Deeb et al., 2011).

Now, the impacts of climate change on human societies are already being felt (IPCC, 2007; UNFCCC, 2007; Pittock, 2009; Bizikova et al., 2009; Pelling, 2011; Deeb et al., 2011; OECD, 2013; Collings, 2014; Field et al., 2014). In certain cases, these changes impose new challenges and exacerbate existing challenges. For example, the growing frequency of storms, floods, and droughts affect communities across the globe, while rising sea levels pose a direct threat to settlements in low-lying coastal areas (Deeb et al., 2011). Furthermore, the IPCC predicts that there will be serious effects including reduced crop yields in tropical areas, spread of climate-sensitive diseases such as malaria, and an increased risk of extinction of 20 – 30 per cent of all plant and animal species even with a temperature rise of 1– 2.5°C (IPCC, 2007). In the same report it is also predicted that by 2020 up to 250 million people in Africa could be exposed to greater risk of water stress. In the aggregate, climate change is already imposing its effects and projected to have wide-ranging effects on people, the environment, and related sectors, including human

health, agriculture and food security, water resources, terrestrial ecosystems including forest ecosystems and biodiversity and coastal zones (UNFCCC, 2007).

2.1.2. The Ethiopian context

2.1.2.1. Climate change in Ethiopia and the Central Rift Valley

While climate change and its impacts are global in scope and unprecedented in scale, its negative impacts are more severely felt by poor people and poor countries (Boko et al., 2007; UNFCCC, 2007; UNISDR, 2008; Pittock, 2009; OECD, 2013; Niang et al., 2014; World Bank, 2016). And it is well documented that the world's poorest and least developed nations are found in developing countries many of which are in Africa (Osman-Elasha et al., 2006; Field et al., 2014). Thus, these countries are generally considered as the most vulnerable to the effects of climate change as they lack the necessary resources to adapt (Thornton et al., 2006; IPCC, 2007; UNFCCC, 2007; McSweeney et al., 2010; Noble et al., 2014). The IPCC predicted that billions of people, especially those in developing countries, face greater risks to health and life and shortages of water and food over the next decades as a result of a changing climate (IPCC, 2007). Moreover, climate change is anticipated to have discernible effects on the sustainable development of developing countries including the attainment of the United Nations Millennium Development Goals (UNFCCC, 2007).

Ethiopia is one of the poorest and most vulnerable developing countries most affected by the impacts of climate change (Thornton, 2006; NMA, 2007; Conway & Schipper, 2011; FDRE, 2011a; Mahoo et al., 2013; Tessema et al., 2013; MEF, 2015). It ranks among the top twelve countries in the world in terms of the climate change hit list (World Bank, 2009). The country has already suffered from the impacts of historical climate variability and extreme events (World Bank, 2010; Mahoo et al., 2013; Bewket et al., 2013; MEF, 2015). However, the pronounced impacts of the recent climate-related hazards such as more frequent and intense drought and flood in Ethiopia are associated with the effects of the recent global warming (NAMA, 2007; Mahoo et al., 2013; MEF, 2015). It is argued

that the occurrence and impact of these extreme events are manifestations of a changing climate the most evident of which are the ever rising temperature and increased rainfall variability in the country (World Bank, 2006; Funk et al., 2012; Mahoo et al., 2013; MEF, 2015; USAID, 2016).

Historical climate trends in Ethiopia indicate that mean annual temperature has increased by 1^{o}C since the 1960s, which is equivalent to an average rate of about 0.25^{o}C per decade (FDRE, 2011a; MEF, 2015; USAID, 2016). The current mean annual temperature in Ethiopia ranges from 15-20^{o}C in the high altitude regions to 25-30^{o}C in the lowland regions (McSweeney et al., 2008; MEF, 2015; USAID, 2016). While most reports regarding the trend and magnitude of observed temperature in Ethiopia are consistent, the same cannot be said about rainfall trends. Because of strong inter-annual and inter-decadal variability, it is difficult to detect long-term rainfall trends in Ethiopia (McSweeney et al., 2008; Conway & Schipper, 2011; USAID, 2016). Reports with regard to rainfall trends are, therefore, mixed as they are highly influenced by the time period used in the analysis (Bewket & Conway, 2007; Conway & Schipper, 2011). For instance, trend analysis that includes or excludes rainfall data in the 1980s and/or 1990s will end up with different results since decreases in rainfall in the 1980s – the driest decade on record – have shown recovery in the 1990s – the wettest decade on record – as well as the 2000s (Bewket & Conway, 2007; McSweeney et al., 2008).

Nevertheless, many studies reported that mean annual rainfall trends show no marked emergent changes when averaged over the entire country (NMA, 2007; McSweeney et al., 2008; Conway & Schipper, 2011; Mahoo et al., 2013; Bewket et al., 2015). However, there are also reports that indicate declining trends in rainfall. For example, Aragie (2013) reported a decreasing trend in precipitation since the 1990s. WFP (2013) also reported trends of overall declines in rainfall between March and September from 1980 to the present. Similarly, Mahoo et al. (2013) reported that a tendency towards lower rainfall during the main growing season (March–May and December–February) has been the most prominent trend. On the other hand, MEF (2015), based on a 60-year period analysis (1951 – 2010), reported a slightly decreasing trend in mean annual rainfall in the

country although there were fluctuations over the period. Other recent studies also suggest that precipitation will decrease as a result of local circulation effects even in East Africa including Ethiopia, where most climate change models indicate increased rainfall (Funk et al., 2008; Funk et al., 2012). Thus, rainfall trends in Ethiopia are non-uniform and inconclusive.

In addition, rainfall in Ethiopia exhibits high spatial and temporal variability and hence national level figures do not necessarily reflect local conditions (World Bank, 2006; Bewket & Conway, 2007; Conway et al., 2009; Conway & Schipper, 2011; MEF, 2015; Bewket et al., 2015). Being a large complex country, Ethiopia has extremely complex rainfall patterns (MOARD, 2011; Funk et al., 2012). The spatial distribution of mean annual rainfall over the country ranges from more than 2700 mm in the southwestern highlands to less than 200 mm in the north and southeastern lowlands and to less than 100 mm in the northeastern lowlands (World Bank, 2012).

Likewise, rainfall trends show high differences across regions and a decline in spring and summer rains of up to 20 percent has been reported in some parts of the country since the mid-1970s (Funk et al., 2012, MEF, 2015). Lowlands receive minimal rainfall and show high variability in excess of 50 percent especially in the southeastern and northeastern parts of the country (MEF, 2015). Moreover, the lowlands are the most affected areas by the impacts of rising temperatures as well as frequent and prolonged droughts (World Bank, 2006; MEF, 2015). Thus, the lowlands epitomize the most vulnerable and affected parts of the country (Aragie, 2013; MEF, 2015).

Apparently, the lowlands of the CRV, where this study was conducted, are one of the most vulnerable and affected areas in Ethiopia (NMA, 2007; Funk et al., 2012; Aragie, 2013; Kassie et al., 2014; MEF, 2015). Due to these climate-related challenges, the CRV is identified as one of the hotspot areas in Ethiopia (Verburg et al., 2010; Funk et al., 2012; MEF, 2015). The lowland areas of the CRV are generally characterized by high temperature, low and erratic rainfall distribution, and the occurrence of recurrent

droughts (Jansen et al., 2007; Reaugh-Fowler, 2011; Meshesha et al., 2012; Biazen, 2012; Belay et al., 2013; Kassie et al., 2014; Biazen, 2014; MEF, 2015; Belay et al., 2017).

Although the figures vary, most studies conducted in the CRV, in particular in the lowlands of the CRV, indicate that rainfall is declining and the temperature is rising. For example, Kassie et al. (2014) reported a slightly declining trend in rainfall for the entire CRV between 1977 and 2007. They also reported a high coefficient of variation of rainfall (36%) for Langano station, the nearest meteorological station to this study area. In addition, they observed a significant warming trend of 0.12 – 0.54^{o}C per decade. Furthermore, Gizachew and Shimelis (2014) predicted a temperature increase of 3.5^{o}C and a rainfall reduction of over 11 percent in the 2050s in one of the districts in the CRV, namely, Arsi Negele district, where our study area is also found.

On the other hand, Biazen (2012) stated that recurrent droughts associated with low annual rainfall records have been observed in the lowlands of the CRV during the last three decades (1981 – 2010). He also described that the majority of the lowest rainfall records (78%) have been observed after 1990. Furthermore, he reported that mean annual potential evapotranspiration over the same period was over 1700 mm. Similarly, Reaugh-Fowler (2011) reported low annual rainfall and a further 10 percent reduction over the next 50 years in the CRV. She added that temperature has increased by 1.4^{o}C over the last 30 years and a further increase of 2^{o}C is expected in the next 50 years. Jansen et al. (2007) also reported a maximum daily temperature increase of 1.5^{o}C in the CRV over a 37-year period analysis (1968 – 2005) but they could not find hard evidence to report about long-term rainfall trends over the period.

2.1.2.2. Climate change projections for Ethiopia

With regard to future projections of temperature and precipitation in Ethiopia, there is a high degree of uncertainty (MEF, 2015). While most climate models are consistent in predicting temperature rise in Ethiopia (IPCC, 2007; McSweeney et al., 2008; Conway & Schipper, 2011; FDRE, 2011b; Funk et al., 2012; IPCC, 2014a; MEF, 2015), the

magnitude of increase is uncertain, ranging from 1^{o}C to 2^{o}C by the 2050s relative to today (FDRE, 2011b). Rainfall predictions are even more uncertain (Schneider et al., 2008; Verburg et al., 2010; World Bank, 2010; FDRE, 2011b). Climate models show different projections of mean annual precipitation over Ethiopia, with some projecting more rain, others less, or more or less constant (NMA, 2007; Conway & Schipper, 2011)). According to FDRE (2011b), rainfall projections for Ethiopia range from 25 percent reduction to 30 percent increase in the 2050s.

Most global climate models project some increase in precipitation in both dry and wet seasons of Ethiopia (NMA, 2007; Mahoo et al., 2013; MEF, 2015). The Fifth Assessment Report of the IPCC, for example, projects a small increase in annual precipitation although its influences are likely to be overshadowed by the expected increase in temperature and evapotranspiration rates. The IPCC's mid-range (A1B) emission scenario projections show that compared to the 1961 – 1990 normal total annual rainfall in Ethiopia will increase modestly by 1.4 – 3.4% in 2030, 3.1 – 6.4% in 2050, and 5.1 – 10% in 2080. Likewise, mean annual temperature will increase by 0.9 – 1.1^{o}C in 2030, 1.7 – 2.1^{o}C in 2050, and 2.7 – 3.4^{o}C in 2080. Ethiopia's Climate Resilient Green Economy (CRGE) document also indicates that temperature over Ethiopia is likely to increase by 0.5 – 1.5^{o}C in 2020 and 1.5 – 3^{o}C in the 2050s, compared to the 1960 – 1990 base period (FDRE, 2011b). Despite the IPCC's (2007, 2014) projections that warming in Sub-Saharan Africa is expected to be greater than the global average, the warming trend projected for Ethiopia is broadly consistent with the global trend, which is projected to increase by 1.4^{o}C in 2030, 2.1^{o}C in 2050, and 3^{o}C in 2080.

However, reports based on more detailed regional climate models indicate that the expected rainfall increase in Ethiopia is uncertain (Schneider et al., 2008; Conway & Schipper, 2011; Mahoo et al., 2013; Bewket et al., 2015; MEF, 2015). Conversely, it is more certain that rainfall variability is likely to increase (World Bank, 2006, 2010; Conway & Schipper, 2011; Mahoo et al., 2013; Bewket et al., 2015). Consequently, temperature projections are more certain than those of rainfall and considerable variations exist across the country (Mahoo et al., 2013).

The observed and projected increase in temporal and spatial variability of rainfall in combination with the continued warming of the climate is more likely to lead to increases in the occurrence and magnitude of droughts, floods, and heavy rains in many parts of the country (McSweeney et al., 2008; Schneider et al., 2008; Conway & Schipper, 2011; Funk et al., 2012; WFP, 2013; MEF, 2015). Moreover, both drought and flood can occur in the same growing season, with a combined devastating effect on crop as well as livestock production and this typifies the nature of climate risk in Ethiopia (WFP, 2013).

Nonetheless, despite the erratic nature of rainfall and the frequent occurrence of drought in some parts of the country, most areas of Ethiopia will maintain moist climate conditions and remain climatically secure (Funk et al., 2012; MEF, 2015). Although such climatic events will tend to affect most people living in climatically marginal areas such as the CRV, better productions in climatically secure areas could help offset reduced production in other areas (Funk et al., 2012). Thus, Ethiopia is not expected to face a catastrophic national failure of rainfall, but rather regional hotspots with a tendency towards more frequent droughts (Funk et al., 2012; MEF, 2015). Yet, these changes will have serious consequences on the lives and livelihoods of the people living in climatically vulnerable areas especially if no appropriate measure is taken.

2.1.2.3. Climate change impacts in Ethiopia

Although quantitative estimates about the impacts of climate change on various socioeconomic sectors in Ethiopia are still limited, it is quite evident that climate change is already imposing a significant challenge to the country (NMA, 2007; Mahoo et al., 2013; Bewket et al., 2015; MEF, 2015). NMA (2007) reported that climate change is affecting food security, water and energy supply, poverty reduction and sustainable development efforts, as well as the natural resources of the country. On the other hand, MEF (2015) summarized the major adverse impacts of climate change that Ethiopia has been experiencing as follows.

- Food insecurity arising from occurrences of droughts and floods;
- Outbreak of diseases such as malaria, dengue fever, waterborne diseases (such as cholera and dysentery) associated with floods and respiratory diseases associated with droughts;
- Land degradation due to heavy rainfall;
- Damage to infrastructure by floods; and
- Loss of life and property. (p. 193)

Moreover, climate change is expected to have adverse impacts on the ecological, social, and economic sectors of the country (World Bank, 2006, 2010; Conway & Schipper, 2011; Mahoo et al., 2013; Kassie et al., 2014; Bewket et al., 2015; MEF, 2015). The Ethiopian economy, which is heavily dependent on rain-fed agriculture, is found to be strongly linked and hence highly vulnerable to hydrological variability (World Bank, 2006). Evidence indicate that increased rainfall variability and associated droughts are already affecting the country's Gross Domestic Product (GDP) and hence it's macroeconomic development (World Bank, 2006, 2010; Conway & Schipper, 2011; Aragie, 2103; MEF, 2015; USAID, 2016).

The World Bank reported in 2006 that current hydrological variability, particularly rainfall variability and drought, reduced the potential annual economic growth of Ethiopia by 38 percent and increased poverty rates by 25 percent over a 12-year period. It is also estimated that climate change may reduce the country's GDP by up to 10 percent by 2045 mainly through its effect on agricultural production (MEF, 2015). On the other hand, Aragie (2013) indicated that Ethiopia has lost a cumulative level of 13 to 40 percent of its current agricultural output between 1991 and 2008. Aragie also stated that his finding is consistent with the finding of Yesuf et al. (2008), who reported a 10 to 29 percent difference in output between households who have adapted to climate change and those who have not. He further noted that the country will lose about USD two billion (32.5% of the current real agricultural GDP) in the next few years due to rainfall variability alone unless the observed climate trends are reversed or effective adaptations are made.

While estimates about the current and future impacts of climate change on various sectors vary, they all signify that climate change is a big threat to Ethiopia. It is also more likely that climate change can restrain the country's economic development or threaten to reverse the hard-won development gains of recent decades (Davidson et al., 2003b; McSweeney et al., 2008; Vincent, 2010; FDRE, 2011a; World Bank, 2016). Despite recent progress in development, there is already distressing social and economic condition in Ethiopia and climate change is more likely to worsen it (World Bank, 2010; FDRE, 2011a; Bewket et al., 2015; USAID, 2016). The recent annual report of the World Bank warns not only poor countries like Ethiopia but also the entire world that without rapid action, climate change could push more than 100 million people into poverty within the next fifteen years (i.e., by 2030) (World Bank, 2016).

Therefore, urgent action is required to attenuate the impacts of climate change in Ethiopia (NMA, 2007; Boko et al., 2007; Niang et al., 2014; MEF, 2015). Moreover, for the responses to be effective, the impacts of climate change and adaptation need to be integrated within the broader milieu of national development plans and programs and be implemented at the local level (Schipper & Pelling, 2006; Schipper, 2007; Bizikova et al., 2009; Ayers & Dodman, 2010; Verburg et al., 2010; OECD, 2013; Mahoo et al., 2103; MEF, 2015).

2.2. Adaptation to the Impacts of Climate Change

2.2.1. Adaptation options and types

A wide range of options and opportunities are available to adapt (Smit & Pilifosova, 2001; Adger et al., 2007, UNFCCC, 2007; Noble et al., 2014). They range from technological options to behavioral changes at the individual levels (UNFCCC, 2007). For example, adaptation options such as building sea defenses and flood-proof houses on stilts fall on the technology category, while reducing water use in times of drought and using insecticide-sprayed mosquito nets falls on the behavioral change category. Other

options include early warning systems, water management systems, risk management systems, insurance mechanisms, and biodiversity conservation (UNFCCC, 2007).

Adaptations occur in many different forms. They have been differentiated into different types based on the attributes they possess (Smit & Pilifosova, 2001). The types of adaptation indicate how adaptation occurs in the system. Adaptations, therefore, can vary according to the system in which they occur, the climatic stimuli that prompts them, who undertakes them, and their timing, forms, functions, and effects. Although there are many distinctions, the common source of identification is their purpose or timing.

Accordingly, we are familiar with the so-called autonomous and planned adaptation as well as proactive and reactive adaptation. "Autonomous or spontaneous adaptations are considered to be those that take place—invariably in reactive response (after initial impacts are manifest) to climatic stimuli—as a matter of course, without the directed intervention of a public agency" (Smit & Pilifosova, 2001, p. 883). Planned adaptations, on the other hand, can be either reactive or anticipatory (undertaken before impacts are apparent). Many adaptations are undertaken autonomously, that is, without consciously planned interventions (Smit & Pilifosova, 2003). However, Smit and Pilifosova (2001) indicated that autonomous adaptation tends to be reactive, costly and a response that would usually incur some residual damages.

Adaptations can also be differentiated as localized or widespread and short-term or long-term depending on their spatial scope and temporal scale, respectively. They can also be identified by the functions they serve or the forms they take in different systems (Table 1).

2.2.2. Adaptation measures and strategies

Globally, many potential adaptation measures are available to be adopted in response to climate change. The IPCC in its Second Assessment Report, for example, described over 200 different adaptation measures (IPCC, 1996). These measures will vary depending on

where they are applied (location), at which scale they are applied (global, regional, national or local), for which activity or industry they are applied, and over time. Pittock (2009), for instance, stated that local farmers, in general, will adapt on a year-to-year basis to drier or warmer conditions, while district, state or national level adaptations will need long-term planning. Farmers may vary planting dates, use irrigation or different crop varieties to adapt to drier or warmer conditions, while improving water conservation techniques, breeding better-adapted crop varieties or developing more irrigation supplies may be needed at higher levels. Moreover, governments may have to aid farmers if the worst happens, or even assist them to leave the industry if it is becoming unsupportable (Pittock, 2009).

Table 1 Bases for differentiating adaptations

Attributes	**Examples of terms**
System type	Natural—human
	Public—private
Purposefulness	Autonomous—planned
	Passive—active
Timing	Anticipatory—responsive
	Proactive—reactive
Temporal scale	Short-term—long-term
	Tactical—strategic
Spatial scope	Localized—widespread
Functional/effects	Retreat—accommodate—protect
	Prevent—tolerate—spread—change—restore
Form	Structural—legal—institutional
	Regulatory—financial—technological
Performance	Cost-effectiveness—efficiency
	Implementability—equity

Source: Smit & Pilifosova (2003, p. 19)

Based on the classification and description of Burton et al. (1993) and Feenstra et al. (1998), Pittock (2009) summarized the different adaptation measures into eight alternative but not exclusive strategies:

1. *Bear losses*. This is the baseline response of 'doing nothing'. Bearing loss occurs when those affected have failed to act until it is too late, or have no capacity to respond in any other way (for example, in extremely poor

communities) or where the costs of adaptation measures are considered to be high in relation to the risk or the expected damages. The big problem with this solution is that losses may become unbearable.

2. *Share losses*. This involves a wider community in sharing the losses. Sharing takes place in traditional societies and in the most complex, high-tech societies. In traditional societies, mechanisms include sharing losses with extended families, villages or similar small-scale communities. In societies organized on a larger-scale, losses are shared through emergency relief, rehabilitation, and reconstruction paid for by government funds or public appeals, or through private insurance. However, insurance usually applies only when the risk is considered random and uncertain for the individual insured, not when it is predictable. Even with shared losses, the accumulated loss to society may eventually become unacceptable, at which point other actions must be taken.

3. *Modify the threat*. For some risks, it is possible to exercise a degree of control over the specific environmental threat. For 'natural' events such as a flood or drought, possible measures include flood control works (dams, dikes, levees) or water storages. For climate change, attempts to modify the threat through such measures may quickly become too expensive, and the more sensible modification to reduce the threat is to slow the rate of climate change by reducing global greenhouse gas emissions and eventually stabilizing greenhouse concentrations in the atmosphere. (Note, however, that in Intergovernmental Panel on Climate Change (IPCC) terminology, measures that reduce climate change are referred to as 'mitigation' of climate change, in distinction to 'adaptation', which is reserved for an optimal response to a given climate change.)

4. *Prevent effects*. A frequently used set of adaptation measures involves steps to prevent the effects of climate change and variability. Examples for agriculture would be changes in crop management practices such as increased irrigation, additional fertilizer, and pest and disease control.

5. *Change use*. Where the threat or reality of climate change makes the continuation of an economic activity impossible or extremely risky, consideration can be given to changing the use. For example, a farmer may choose to switch to crop varieties more adapted to lower soil moisture. Similarly, agricultural land may be returned to pasture or forest or other uses may be found such as recreation, tourism, wildlife refuges, or national parks.

6. *Change location*. A more extreme response is to change the location of economic activities. For example, major crops and farming regions could be relocated away from areas of increased aridity and heat to areas that are currently cooler and which may become more attractive for some crops in the future. This may be possible in some countries, but not in others where migration to cities or other countries may be the only alternatives.

7. *Research*. Possibilities for adaptation can also be opened up by research into new technologies and methods of adaptation, such as greater water use efficiency, cheap water desalinization, or new crop cultivars.

8. *Educate, inform, and encourage behavioral change*. Dissemination of knowledge through education and public information campaigns can lead to adaptive behavioral change. Such activities have been little recognized and given little priority in the past, but are likely to assume increased importance as the need to involve more communities, sectors, and regions in adaptation becomes apparent. Water conservation and fire prevention campaigns and regulations are already major adaptive trends in countries such as Australia. Discouragement of maladaptive trends such as development in low-lying coastal areas is another useful strategy. This may involve planning rules or other 'carrots and sticks'. (pp. 135-136)

The most common adaptation strategies in Ethiopia include the use of different crops or crop varieties, planting trees, soil conservation, changing planting dates, and irrigation (Bryan et al., 2009; Deressa et al., 2009). Saving, diversification, changing the growing season, mobility, wood sale, livestock sale, and social interconnectedness are also stated as copying strategies to climate change impacts by societies in West Arsi Zone in

Ethiopia (Senbeta, 2009). According to Senbeta (2009), governmental institutions also provide awareness raising opportunities, credit service, emergency aid, a safety net to some lowlanders, and disseminate appropriate technologies to the local people as coping strategies to the impacts of climate change such as drought and crop failure due to erratic and uneven rainfall distribution.

Society's responses to climate change or their choice of adaptation methods are, however, dictated by a range of socioeconomic and environmental factors. The choice of adaptation strategies by farmers in Ethiopia is influenced by the level of education, gender, age, and wealth of the head of household; access to extension and credit; information on climate, social capital, agro-ecological settings, and temperature (Deressa et al., 2009; Bryan et al., 2009). Although there are efforts to adapt to climate change the existing local and institutional strategies are not sufficient and sustainable to cope with climatic vagaries (Senbeta, 2009). Senbeta (2009) also reported that the impact of climate change is more serious for the poor, landless, children, women, large sized family, and predominantly pastoralists albeit all households in the zone are vulnerable. In addition, he stated that the vulnerability of the society is further exacerbated by the unavailability and unaffordability of agricultural inputs, landlessness and unemployment, and water shortage.

It is also noteworthy that there are barriers to climate change adaptation. A large percentage of farmers in Ethiopia, though they perceive changes in temperature and rainfall, did not make any adjustments to their farming practices because of lack of access to land, lack of information on adaptation methods, and financial constraints including credit schemes (Bryan et al., 2009; Deressa et al, 2009). These challenges call for appropriate measures to be taken so as to help the people better adapt to the adverse effects of climate change.

2.3. Adaptive Capacity and Its Growing Significance

2.3.1. Origins and conceptual advancement of adaptive capacity

Adaptive capacity can simply be described as the ability to adapt. It constitutes the underlying conditions that enable adaptation (Tompkins & Adger, 2004; Nelson et al., 2007; Kofinas & Chapin, 2009; Engle, 2011; Adger et al., 2011; Newman, 2013). Its historical underpinnings are found in earlier works in organizational and business management and sociology (Engle, 2011). However, the use of the term adaptive capacity has proliferated in recent years along with the term climate change adaptation (Engle, 2011; Nyamwanza, 2012). The conceptual advancement of adaptive capacity is, therefore, highly tied up with the term adaptation.

To understand the origin, meaning, and development of the term adaptive capacity, it is important to briefly touch on the term adaptation upon which it is based. However, it should also be acknowledged that adaptation and adaptive capacity have a myriad of meanings emanating basically from a diverse intellectual ancestry and associated perspectives (Plummer & Armitage, 2010). Even within the climate change literature, some authors relate the definitions of these terms purely to humans, while others include the adaptive responses of natural systems (Dawson & Spannagle, 2009).

The term adaptation has its roots in the natural sciences, particularly in evolutionary biology (Butzer, 1980; O'Brien & Holland, 1992; Smit & Wandel, 2006; Gallopin, 2006; Adger et al., 2009). The foundation of biological adaptation extends at least as far back as the seminal work of Charles Darwin on evolution and natural selection (Schipper, 2007; Engle, 2011). According to Darwin, adaptation was an organism's response to the environment, or "special climate", within which it lived (Darwin, 2009). Similarly, adaptation was also defined as "a process whereby the members of a population become suited over the generations to survive and reproduce" (Futuyuma, 1979, p. 308, quoted in O'Brien & Holland, 1992). On the other hand, Burton et al. (1993) and Smith and Petley (2009) argued that biological adaptation has enabled the human species to evolve through a process of natural selection and resist disease for over millions of years. Thus, biologically, adaptation is an organism's response to its surrounding environment (Engle,

2011) and adaptability (or adaptive capacity)[1] is an ability to become adapted (i.e., to be able to live and to reproduce) to a certain range of environmental contingencies (Gallopin, 2006).

Although there are numerous definitions of adaptation in the evolutionary biology literature (O'Brien & Holland, 1992), it is broadly defined as "the development of genetic or behavioral characteristics which enable organisms or systems to cope with environmental changes in order to survive and reproduce" (Smit & Wandel, 2006, p. 283). The range of definitions within the natural sciences signifies that various approaches are possible for understanding adaptation even within specialized disciplines.

The biological idea of adaptation was then transferred to human systems. The anthropologist and cultural ecologist Julian Steward is credited for transferring the idea by introducing the theory of cultural ecology, defined as "the study of the processes by which a society adapts to its environment" (Steward, 1968, p. 337). Steward used the term "cultural adaptation" to describe the adjustment of "culture cores" to the natural environment through subsistence activities (Butzer, 1989). The "success" or survival of a culture is thus equated with the genetic characteristics of organisms in the natural sciences (Smit & Wandel, 2006). According to this Darwinian view of cultural adaptation, a group which does not have adequate methods of coping with environmental stress will not be able to compete for scarce resources and will fail to continue. This general idea was then taken up by social scientists in human ecology, geography, anthropology, sociology, and related fields in an effort to understand cultural responses to environmental changes (Smit & Wandel, 2006; Engle, 2011).

Consequently, the ideas of adaptation and adaptive capacity have become a central theme in various environmental and resource studies and applied areas such as risks and hazards, political ecology, climate change studies, resilience thinking, and social-ecological systems (Berkes et al., 2003; Smit & Wandel, 2006; Chapin et al., 2009a;

[1]Adaptability and adaptive capacity are usually considered as synonymous (IPCC, 2001; Smit & Wandel, 2006; Gallopin, 2006; Chapin et al., 2009; Plummer and Armitage, 2010; IPCC, 2014).

Plummer & Armitage, 2010). For example, the geographer Butzer (1980) connected the insights from anthropology to the emerging literature on environmental change and wrote a remarkable paper on adaptation to global environmental change (Janssen et al., 2006).

2.3.2. Meanings of adaptive capacity and adaptation

Multiple perspectives arising from diverse schools of thought gave rise to different meanings of adaptation and adaptive capacity albeit they did not develop in complete isolation (Orlove, 2005; Smit & Wandel, 2006; Schipper, 2007; Chapin et al., 2009a; Dawson & Spannagle, 2009; Plummer & Armitage, 2010). Although the terms have more specific interpretations in particular fields such as ecology, social science, and climate change, they have much in common (Smit et al., 2000). Smit et al. (1999), for instance, stated that all definitions of adaptation in the climate change literature refer to adjustments in a system in response to (or in light of) climate stimuli. However, these definitions also indicate differences in scope, application, and interpretation of the term adaptation.

In light of the different perspectives from different disciplines, Chapin et al. (2009b) stated that adaptation to anthropologist means the cultural adjustment to environment, while to sociologists it means the behavioral adjustment to environment. Similarly, to ecologists, it means the genetic changes in a population to adjust to their environment. Adaptation was also defined in its most general sense as an adjustment to a change in environment (Chapin et al., 2009a). Yet, adaptation in the context of human dimensions of global change was defined as "a process, action or outcome in a system (household, community, group, sector, region, country) in order for the system to better cope with, manage or adjust to some changing condition, stress, hazard, risk or opportunity" (Smit & Wandel, 2006, p. 282).

It should also be noted that adaptation in human systems, unlike biological systems, goes far beyond "being able to live and reproduce" (Gallopin, 2006). Humans are inherently adaptive creatures capable of learning, experimenting, and innovating solutions in

complex social-ecological circumstances (Folke et al., 2003; Plummer & Armitage, 2010; Engle, 2011). This ability of human beings to learn from the past and plan for the future contrasts with the theory of evolution, which shapes the properties of organisms based entirely on their genetic responses to past events (Tompkins & Adger, 2005; Chapin et al., 2009b). According to Chapin et al. (2009b), humans are creative and can look into the future, while evolution has no forward-looking component.

Smithers and Smit (1997) also noted that the responses of human systems to perturbations are both reactive and proactive, while the responses of biological systems are purely reactive. Thus, adaptation in human systems includes the viability of social and economic activities and processes that allow societies to survive, flourish, and improve the quality of life (Gallopin, 2006; Smit & Wandel, 2006). The quality of life is also more than just human health and wealth; it includes happiness, a sense of fate control, and community capacity (Kofinas & Chapin, 2009).

According to Schipper (2007), the main difference between biological and human adaptation is the level of planning and consciousness by which adjustments are made. Thus, adaptation has gone "from being considered something done by plants and animals in evolution as a response to environmental changes to being promoted as a concept for guiding policy to ensure sustainable development, reduce vulnerability and minimize risk to humans from climate change" (Schipper, 2007, pp. 4-5). On the other hand, O'Brien and Holland (1992) argued that biological adaptation "must be viewed in a historical sense" (p. 38). However, they further clarified that "in [the] case of humans, because of their ability to transmit information intra-generationally, the historical development of adaptations may be short-lived" (p. 38). Such abilities of human beings set them apart from other organisms. As a result, human beings can also look forward to future changes in the environment and attempt to make not only reactive but also anticipatory adjustments (Smithers & Smit, 1997; Schipper, 2007; Chapin et al., 2009b).

O'Brien and Holland (1992) further described the different perspectives with regard to human and biological adaptations as follows.

> Most anthropologists would readily agree that the lack of congruence between biological and anthropological views of adaptation is epistemologically sound since humans are such extraordinary organisms that as subjects they require a completely different philosophical and methodological approach. We argue, however, that human adaptedness and adaptation do not make us immune from natural selection and that despite historically based reasons for doing so, we cannot continue to equate the creative ability of humans with some bizarre, extraordinary means of escaping selective environments. (p. 37)

Eventually, adaptability or adaptive capacity in human systems was defined by Gallopin et al. (1989) as the capacity of any human system from the individual to humankind to increase (or at least maintain) the quality of life of its individual members in a given environment or range of environments. However, akin to adaptation, adaptive capacity has also been given different meanings by different scholars. In fact, just as O'Brien and Holland (1992) noted about the number of definitions given for adaptation in the evolutionary biology literature, definitions of adaptive capacity in the climate change literature "are so numerous that they would easily fill the space taken up by this paper" (p. 38). Thus, just a few examples of the definitions of adaptive capacity are selected and presented below.

Chapin et al. (2009b), for instance, defined adaptive capacity (or adaptability) as "the capacity of actors, both individuals and groups, to respond to, create, and shape variability and change in the state of the system" (p. 23). Nelson et al. (2007), on the other hand, defined adaptive capacity as "the preconditions necessary to enable adaptation, including social and physical elements and the ability to mobilize these elements" (p. 397). Adaptive capacity has also been defined in economic terms as "a vector of resources and assets that represent the asset base from which adaptation actions and investments can be made" (Adger & Vincent, 2005, p. 400). Conversely, Plummer and Armitage (2010) defined adaptive capacity broadly as:

> …The capability of a social-ecological system to be robust to disturbance, and to adapt to actual or anticipated changes (whether exogenous or endogenous). From a social systems vantage point adaptive capacity is determined by the suite of resources (technical, financial, social, institutional, political) held, and the social processes and structures through which they are mediated (i.e. governance). (p. 6)

2.3.3. Prominence of adaptive capacity in climate change science

Although organizational theory and sociology provide its historical underpinnings, adaptive capacity has gained greater attention and become most apparent through its use in the climate change field (Engle, 2011). Indeed, its use in the context of climate change particularly in conjunction with adaptation has proliferated in recent years (Engle, 2011; Nyamwanza, 2012). According to Brooks and Adger (2005), adaptive capacity is:

> …The property of a system to adjust its characteristics or behavior, in order to expand its coping range under existing climate variability or future climate conditions. In practical terms, adaptive capacity is the ability to design and implement effective adaptation strategies or to react to evolving hazards and stresses so as to reduce the likelihood of the occurrence and/or the magnitude of harmful outcomes resulting from climate-related hazards. They also defined the adaptive capacity inherent in a system as the set of resources available for adaptation, as well as the ability or capacity of that system to use these resources effectively in the pursuit of adaptation. (p. 168)

In more recent usage in climate change science, adaptive capacity is broadly defined as "the ability of systems, institutions, humans, and other organisms to adjust to potential damage, to take advantage of opportunities, or to respond to consequences" (IPCC, 2014b, p. 118).

In summary, adaptive capacity and adaptation in the face of environmental change are nothing new both as a theoretical construct and an empirical reality although they may

not always be identified by these names and have been given many different meanings (Smithers & Smit, 1997; Easterling et al., 2004; Dietz et al., 2004; Lim et al., 2005; Orlove, 2005; Dawson & Spannagle, 2009; Adger et al., 2009; Engle, 2011; Pelling, 2011). As described above, the term adaptation has a long pedigree in the natural sciences. Conversely, the study of the adaptation of humans to their environment has its roots in anthropology (Janssen et al., 2006; Engle, 2011). It has been the focus of anthropologists since the early 1900s (Janssen et al., 2006). On the other hand, adaptive capacity has its roots in organizational theory (Engle, 2011).

In the 1990s, scholars began to use the term adaptation in the context of global climate change and its impacts without explicitly relating it back to the conceptual origins of anthropology (IPCC, 2001; Adger et al., 2005; Janssen et al., 2006). Since then, adaptive capacity has gained prominence in the climate change arena mainly in connection with adaptation (Nelson et al., 2007; Engle, 2011; Nyamwanza, 2012). This is understandable as adaptive capacity is a critical element of the process of adaptation (Adger & Vincent, 2005) and adaptation is a manifestation of adaptive capacity (Smit & Wandel, 2006; Piya et al., 2012).

So, what is new today is that these concepts are re-emerging in the unique context of climate change and that there is the need for more concerted efforts to advance innovative solutions to meet contemporary climate change challenges (Lemos et al., 2007; Schipper, 2007; Plummer & Armitage, 2010; Rodrigo, 2015). Burton (1996) stated already two decades ago that “the practical science of adaptation to climate change is new, whereas the practice of adaptation to climate is very old” (p. 56). Thus, the concept of adaptation and adaptive capacity is only relatively new to the climate change research community (Smit et al., 1999).

As stated above, adaptation and adaptive capacity have a long history of use in other fields such as ecology, natural hazards, and risk management. However, climate change poses new challenges. The contemporary context of environmental challenges in general and climate change, in particular, are characterized by complexity, discontinuity,

surprise, and change (Plummer & Armitage, 2010). Adger et al. (2011) also accentuated that the speed, severity, and complexity of known and unknown changes in climate will challenge the ability of society to generate fitting responses. Moreover, adaptation to climate change has now become part of the contemporary discourse about the politics and economics of global climate change in a new, deliberate and self-conscious way (Adger et al., 2009).

Therefore, the past decade has seen a growing attention given to adaptation both in its politics and practice although the focus of much of the earlier international climate change studies and policy debates in the 1990s and early 2000s was on mitigation (Smit & Pilifosova, 2001; Pielke et al., 2007; Locatelli et al., 2008; Munroe et al., 2012; IPCC, 2014a). Indeed, the issue of climate change adaptation in the earlier stages, as Schipper (2006) describes, has been the poor cousin of climate change negotiations. It is only recently that "adaptation has managed to claw back some of the attention as more people realize that climate change is inevitable no matter what efforts are made to reduce emissions and that all countries will suffer impacts and will need to adapt to these impacts" (Schipper & Burton, 2009, p. 223). Yet, despite gaining increasing attention and being a critical enabling factor in efforts to enhance adaptation to climate change, adaptive capacity is still poorly understood (Magnan, 2010; Plummer & Armitage, 2010).

2.3.4. Determinants of adaptive capacity

A distinct literature on adaptive capacity in the field of climate change is limited yet emerging (Mendis, 2003). Existing knowledge on adaptive capacity is insufficient for reliable prediction of adaptations and for rigorous evaluation of planned interventions (Smit & Pilifosova, 2001).

The vast majority of literature proliferated over the last two decades has mostly dealt with the impacts of climate change (e.g., Morton, 2007; Molula, 2009; Hein et al., 2009; Tadesse, 2010; Boon & Ahenkan, 2012; Dube & Phiri, 2013; Zolin & Rodrigues, 2016), vulnerability to the impacts of climate change (e.g., Luers et al., 2003; Eakin & Luers,

2006; Adger, 2006; Thornton et al., 2006; Eakin & Bojórquez-Tapia, 2008; Heltberg et al., 2009; Hahn et al., 2009; Tschakert et al., 2013), adaptation to the impacts of climate change (e.g., Butzer, 1980; Smithers & Smit 1997; Smit et al., 1999; Kane & Yohe, 2000; Smit & Pilifosova, 2001; Berkes & Jolly, 2001; Adger et al., 2003; Eakin & Lemos, 2006; Thomas et al., 2007; Mertz et al., 2009; Collins & Ison, 2009; Bauer & Scholz, 2010; Pelling, 2011), and a combination of some or all of these aspects of climate change (e.g., IPCC, 2001; Burton et al., 2002; Smit & Pilifosova, 2003; Osman-Elasha et al., 2006; O'Brien et al., 2006; Smit & Wandel, 2006; UNFCCC, 2007; IPCC, 2007; Wandel et al., 2009; Mary & Majule, 2009; Pittock, 2009; Wilbanks & Kates, 2010; EEA, 2012; Field et al., 2014).

As adaptation is increasingly becoming an important component of any response to climate change, the need to understand the factors that enhance or constrain the adaptive capacity of a system to respond to the impacts of climate change is also increasing (Smith et al., 2003; Boko et al., 2007; Engle, 2011; Lemos et al., 2013; Noble et al., 2014; Elrick-Barr et al., 2014). Such understanding is particularly important for developing countries like Ethiopia where the negative impacts of climate change will likely exacerbate other stressors already affecting those most vulnerable (Adger et al., 2003; Thornton et al., 2006; Mertz et al., 2009; Kidanu et al., 2009; MEF, 2015). Understanding adaptive capacity, in turn, requires understanding the various features and conditions through which it is shaped (Smit & Wandel, 2006) including how it is constituted and how it is translated into adaptation (Brooks, 2003). Thus, research focusing on characterizing and measuring adaptive capacity has grown steadily in the past few years (Tol & Yohe, 2007; Gupta et al., 2010; Engle & Lemos, 2010; Hill & Engle, 2013).

In the adaptive capacity literature, most studies have tended to focus either on broader national level assessments or detailed case studies at the local level (Vincent, 2007; Engle & Lemos, 2010; Elrick-Barr et al., 2014) albeit the focus of much of the earlier studies was at the national level (Adger & Vincent, 2005; Jones et al., 2010). Some authors have focused on the adaptive capacity of nations (Haddad, 2005; Brooks et al., 2005; Engle & Lemos, 2010; Keskitalo et al., 2011; Bryan et al., 2015), of local communities (Wall &

Marzall, 2006; Swanson et al., 2009; Nelson et al., 2010; Newman, 2013; Hogarth & Wójcik, 2016a,b), and of households (Sietchiping, 2007; Hayden et al., 2011; Piya et al., 2012; Nantui et al., 2012; Notenbaert et al, 2013; Mwamba, 2013; Penalba & Elazegui, 2013; Defiesta & Rapera, 2014; Rodrigo, 2015; Msomba, 2016), while others have tended to focus on generic or conceptual underpinnings of the term (Yohe & Tol, 2002; Smith et al., 2003; Folke et al., 2003; Adger et al., 2004; Brooks & Adger, 2005; Smit & Wandel, 2006; Gallopin, 2006; Jones et al., 2010; Armitage & Plummer, 2010; Magnan, 2010; Nyamwanza, 2012; Keskitalo, 2013; Lemos et al., 2013; Hill & Engle, 2013; Elrick-Barr et al., 2014).

The ultimate goal of most of these studies is the identification of attributes or elements that enhance the adaptive capacity of the system to climate-related hazards. The elements or components that influence the ability of the system to adapt are declared to be the drivers or determinants of adaptive capacity (Smit & Pilifosova, 2001; Adger, 2003; Smit & Wandel, 2006; Vincent, 2007; Matthews & Sydneysmith, 2010). Thus, there are a number of works that seek to categorize the analytical dimensions of adaptive capacity (Matthews & Sydneysmith, 2010).

However, because of its latency, contextual and multidimensional nature[2] as well as the relative infancy of research on adaptive capacity its characteristics and elements at national, community, or household level are not entirely agreed (Smit & Wandel, 2006; Vincent, 2007; Jones et al., 2010; Wilbanks & Kates, 2010; Arnall, 2011; Hogarth et al., 2014; Hogarth & Wójcik, 2016a,b). It is generally understood that the precise composition of the diverse set of elements or driving forces of adaptive capacity varies across scales (countries, regions, communities, social groups, households, and individuals) and over time (Smit & Pilifosova, 2003; Smit & Wandel, 2006; Adger et al., 2007; Vincent, 2007; Matthews & Sydneysmith, 2010). To date, knowledge of determinants of adaptive capacity has not moved beyond broad categories (Smit & Wandel, 2006, Plummer & Armitage, 2010; Hill & Engle, 2013).

[2] Adaptive capacity is multidimensional means that it is determined by complex inter-relationships of a number of factors at different scales (Vincent, 2007)

Nevertheless, there is considerable understanding that adaptive capacity relates to the extent to which people have the necessary conditions that allow them to adapt successfully (Smit & Pilifosova, 2001; Nelson et al., 2007; Arnall, 2011; Field et al., 2014). Although scholarship on adaptive capacity in the field of climate change is limited, the main features of societal adaptability can be drawn from the fields of hazards, resource management, and sustainable development (Smit et al., 2000; Smit & Pilifosova, 2001; Mendis, 2003).

Accordingly, the IPCC (2001) identified economic resources, technology, information and skills, infrastructure, institutions, equity, and social capital as principal determinants of adaptive capacity (Smit & Pilifosova, 2001). These broad categories of determinants are commonly used by many researchers although a distinction was not made by the IPCC for which scale of analysis they were suggested (Jones et al., 2010). However, there are a number of efforts to identify the determinants of adaptive capacity at various scales since the IPCC report (Vincent, 2007) albeit much of the lists overlap (Nelson et al., 2007; Matthews & Sydneysmith, 2010; Newman, 2013). Table 2 summarizes the theoretical determinants commonly identified in the adaptive capacity literature, while Table 3 summarizes those empirically tested in various contexts.

Table 2 Theoretical determinants of adaptive capacity

Smit & Pilifosova (2001, pp. 895-897)	IPCC (2001) as quoted in Alberini et al. (2006, p. 124)	Yohe & Tol (2002, p. 26)	Folke et al. (2003, p. 355)
Economic wealth Technology Information and skills Infrastructure Institutions Social capital Equity	Available technological options Resources The structure of critical institutions and decision making authorities The stock of human capital The stock of social capital including the definition of property rights System's access to risk spreading processes Information management and the credibility of information supplied by decision makers Public's perception of risks and exposure	Available technological options Available resources and their distribution across the population Structure of critical institutions and the allocation of decision-making authority Stock of human capital Stock of social capital Access to risk spreading mechanisms Way in which decision makers maintain and distribute information Public's attribution of the source of stress Significance of exposure in the local situation	Learning to live with change and uncertainty (evoke disturbance, learn from crises, expect the unexpected) Nurturing diversity for reorganization and renewal (nurture ecological memory, sustain social memory, enhance socio-ecological memory) Combining different types of knowledge for learning (combine experiential and experimental knowledge, integrate knowledge of structure and function, incorporate process knowledge into institutions, encourage complementarity of knowledge systems) Creating opportunity for self-organization (reorganize relationship between diversity and disturbance, deal with cross-scale dynamics, match scales of ecosystems and governance, account for external drivers)
Haddad (2005, p. 166)			
Wealth Technology Education Information Skills Infrastructure Access to resources Management capabilities			
Nelson et al. (2007, p. 400)	Eakin & Lemos (2006, P. 10)	Paveglio et al. (2009, p. 1089)	Brooks & Adger (2005, p. 168)
Economic capital Technology and infrastructure Information Knowledge Institutions The capacity to learn Social capital	Human capital Information and technology Material resources and infrastructure Organization & social capital Political capital Wealth and financial capital Institutions and entitlements	Demographic and structural characteristics Access to scientific and technical knowledge Informal interactions and relationships among residents Place-based knowledge & experience	Resources Financial capital Social capital (e.g., strong institutions, transparent decision-making systems, formal and informal networks that promote collective action) Human resources (e.g., labor, skills, knowledge, and expertise) Natural resources (e.g., land, water, raw materials, biodiversity)

Source: Modified from Matthews & Sydneysmith (2010, p. 226) and Newman (2013, p. 10)

Table 3 Empirical determinants of adaptive capacity used by different authors at various scales

Wall & Marzall (2006) and Rodrigo (2015)	Sietchiping (2007)	Vincent (2007) (National Level)	Vincent (2007) (Household Level)
Social resources Human resources Institutional resources Natural resources Economic resources	Socio-cultural components Economic components Institutional & infrastructural components	Economic well-being & stability Demographic structure Global interconnectivity Institutional stability & well-being Natural resource dependence	Economic well-being & stability Demographic structure Interconnectivity in higher level processes Natural resource dependence Housing quality
Keskitalo et al. (2011)	Swanson et al. (2007, 2009)	Eakin & Bojo-Tapia (2008) and Defiesta & Rapera (2014)	Nelson et al. (2010), Penalba & Elazegui (2013), Piya et al. (2012), and Bryan (2015)
Economic resources Technology Information & skills Infrastructure Institutions Equity	Economic resources Technology Infrastructure Information, skills, & management Institutions & networks Equity	Human resources Physical and natural resources Financial and institutional resources Information and social capital Livelihood diversity	Human capital Social capital Natural capital Physical capital Financial capital
Msomba et al. (2016)	Newman (2013)	Hogarth &Wojcik (2016a,b)	Mwamba (2013
Social aspects Economic aspects Physical aspect Natural aspect Human capital Transforming structures	Interactional and organizational capacities Professional knowledge and extra local networks Local knowledge, resources, and skills	Asset base (financial, human, natural, physical, and social capitals) Institutions & entitlements Knowledge & information Innovation Decision-making & governance	Economic well-being and stability Dependency burden Interconnectivity in higher level processes Housing quality Awareness level & actions taken Institutional & infrastructural environment

Source: Author's review

2.4. Woodland and Climate Change Adaptation

Woodlands, along with forests and trees, play a crucial role in climate change. They are key options for both mitigation of and adaptation to climate change (Locatelli et al., 2008; Robledo et al., 2008; Malmsheimer et al., 2008; CPF, 2008; van Bodegom et al., 2009; Chidumayo et al., 2011; Pramova et al., 2012; FAO, 2016). Of course, they provide a wide range of economic, social, cultural, and environmental benefits beyond those related to climate change (Malmsheimer et al., 2008; Seppala et al., 2009; Chidumayo et al., 2011; FAO, 2012; CPF, 2012; Boon & Ahenkan, 2012; FAO, 2016). They have tremendous potential to protect people and their livelihoods from some of the harmful effects and to create a foundation for more sustainable economic and social development (Sunderlin et al., 2005; Seppala et al., 2009; van Bodegom et al., 2009; Chidumayo et al., 2011; CPF, 2012; FAO, 2016).

From the perspective of climate change, however, forests and woodlands have so far been mostly considered in the context of mitigation through afforestation, reforestation, and avoided deforestation and forest degradation (Guariguata et al., 2008; Locatelli et al., 2008). Indeed, it is now well established that forests and woodlands can play an important role in the global carbon budget as they can be either sinks or sources of atmospheric carbon (Watson et al., 1996, 2000; Pielke et al., 2002; Denman et al., 2007; Bravo et al., 2008; Robledo et al., 2008; Locatelli et al., 2008; Malmsheimer et al., 2008; van Bodegom et al., 2009; Chidumayo et al., 2011; FAO, 2012). Thus, using forests and woodlands to address climate change may look less familiar yet equally important to those which are most commonly advocated to reduce GHG emissions, such as increasing energy conservation and efficiency, and using of cleaner, alternative energy sources (Malmsheimer et al., 2008).

Among all the possible remedies, forests and woodlands are unique in that they can both prevent and reduce GHG emissions. They can prevent GHG emissions through wood substitution, biomass substitution, modification of wildfire behavior, and avoiding land use change, while they can also reduce GHGs through carbon sequestration in forests and

storage in wood products (Malmsheimer et al., 2008). These roles of forests, woodlands, and their products in mitigating climate change have been recognized and incorporated in international agreements and market-based policy instruments (Locatelli et al., 2008; Malmsheimer et al., 2008). Yet, with billions of people across the globe dependent (in one way or another) on them for the goods and services they provide, including those who use them for livelihood, and in some cases even for survival, they can also play a vital role in social adaptation (Shvidenko et al., 2005; Locatelli et al., 2008; CPF, 2008; van Bodegom et al., 2009; Seppala et al., 2009; Boon & Ahenkan, 2012; FAO, 2016). In fact, their role in human adaptation to the impacts of climate change is also rapidly gaining significance (Locatelli et al., 2008; World Bank, 2009; UNFCCC, 2011; Pramova et al., 2012; Noble et al., 2014).

Pramova et al. (2012) reviewed scientific literature related to climate change adaptation and highlighted five cases in which forests, woodlands, and trees can support adaptation:

> (1) Forests and trees provide goods to local communities facing climate threats;
>
> (2) Trees in agricultural fields regulating water, soil, and microclimate for more resilient production;
>
> (3) Forested watersheds regulating water and protecting soils for reduced climate impacts;
>
> (4) Forests protecting coastal areas from climate-related threats; and
>
> (5) Urban forests and trees regulating temperature and water for resilient cities. (p. 581)

While the first case addresses the provisioning services that forests, woodlands, and trees can provide to people, the rest of the cases emphasize the contribution of the regulatory services to societal adaptation. Regulatory services such as climate and water regulation are often at least “as important as provisioning services” (Knoke & Hahn, 2013, p. 570). However, in contrast to the provisioning services, there is still a knowledge gap and hence lack of concrete evidence with regard to the role of the regulatory services to

societal adaptation (Locatelli et al., 2008; Seppala et al., 2008; van Bodegom et al., 2009; World Bank, 2009; Pramova et al., 2012; Munroe et al., 2012).

Conversely, there exists substantial evidence that forests and woodlands, through their provisioning services, can sustain livelihoods and reduce sensitivity and/or increase the adaptive capacity of society to climate change (Locatelli et al., 2008; Somorin, 2010; Pramova et al., 2012; Munroe et al., 2012). The provisioning services include food, fuel, fiber, fodder, building material, medicine, and timber that are necessary for human well-being (MEA, 2005). They play a vital role in the livelihoods of particularly the rural poor (e.g., Shackleton et al., 2002; Dovie et al., 2002; Lowore, 2006; Vedeld et al., 2007; Shackleton et al., 2007; Babulo et al., 2008; Mekhado et al., 2009; Salehi, et al., 2010; Tesfaye et al., 2010; Walelign, 2013; IFAD, 2013). There are also considerable reports that suggest that rural households rely on forest resources to cope with the adverse impacts of climate change (Eriksen et al., 2005). Yet again, quantitatively rigorous and empirically strong evidence about the role of these resources in societal adaptation are limited (Paumgarten, 2005; Fisher et al., 2010).

Fisher et al. (2010), McSweeney (2004), and Takasaki et al. (2004) assessed the role of forests and forest products in the adaptation of rural households to climate change and found out that the rural poor use them as natural insurance and coping strategies. Paumgarten (2005), Somorin (2010), and Pramova et al. (2012) also confirmed in their review that rural households turn into the forest, woodland, and tree products in times of need. Similarly, FAO (2010) and Kleine et al. (2010) reported that a large portion of the population of particularly the developing countries is highly dependent on forest goods and services for the supply of basic needs, employment, and livelihoods and as an economic safety net or buffer in times of hardship due to a changing climate. Therefore, through the provisioning services, forests and woodlands provide important safety nets, livelihood diversification, and integral source of income for many rural communities, making them relevant for climate change adaptation (Pramova et al., 2012).

However, a distinction should be made between using forests and woodlands as safety nets for coping strategies (i.e., in reaction to stresses) and as part of the livelihood diversification portfolio for adaptation strategies (i.e., in anticipation of stresses) although, in practice, it is not always clear (Levina & Tirpak, 2006; Smit & Wandel, 2006; Morton, 2007; Kirrane, 2012; Pramova et al., 2012). Pramova et al. (2012) pointed out that it is difficult to position certain strategies on the continuum between coping and adapting. For example, forest products can be used by households as part of their daily livelihoods or modified depending on specific events, making classification difficult. Moreover, coping strategies started in exceptional years can also develop into long-term adaptation strategies (Adger et al., 2004; Morton, 2007; Kirrane, 2010). Likewise, Levina and Tirpak (2006) stated that "coping capacity can be increased with adaptation measures, while adaptive capacity already includes coping capacity plus adaptation measures and cannot be increased beyond a certain point" (p. 13).

Irrespective of the difficulties, however, the differentiation is important as the sustainability of the resources will be under threat if they are used in response to current climate calamities and no long-term management objectives are set in place to safeguard them. According to Pramova et al. (2012), governance is the key to understand why some ecosystem goods are used as safety nets, with less investment in management, while others are managed to ensure long-term sustainability and resilient livelihoods. They added that "governance will determine how coping strategies using forest products can be transformed into sustainable adaptive strategies, ensuring livelihood security under climate change" (p. 583). Thus, forests and woodlands and their safety net roles can become part of a portfolio of adaptation activities.

In terms of their direct contribution to livelihood, forests and woodlands are known to provide billions of people worldwide with raw materials that include food, fuel, fodder, and shelter (Locatelli et al., 2008). More than 2 billion people rely on wood energy for cooking and/or heating, largely in households in developing countries (FAO, 2012). Over 1.6 billion people living in poverty use forests, woodlands and homestead trees for all or part of their livelihoods (WRI, 2005; UN, 2011; FAO, 2012). About 350 million of the

poorest people in the world, including over 60 million indigenous people, live in forests and use them intensively for their livelihood and survival (Shvidenko et al., 2005; CBD Secretariat, 2009; Seppala et al., 2009; UN, 2011; FAO, 2012). A further 150 million people obtain significant protein from bush meat (Mayers & Vermeulen, 2002). Roughly, 75–90 percent of people in developing countries use forests and woodlands as their main source of traditional medicine (FAO, 1996). Forests and woodlands also offer income and job opportunities to millions more (UN, 2011; FAO, 2012).

These multiple roles of forests and woodlands are in addition to the ecosystem services that they provide, including water regulation, erosion control, drought and flood protection, carbon sequestration and storage, and biodiversity conservation (Locatelli et al., 2008; Seppala et al., 2009; Chidumayo et al., 2011; FAO, 2010; 2012; 2016). Therefore, there is a need for forests and woodlands to continue providing these essential raw materials and ecosystem services into the future, and in the face of a changing climate (Malmsheimer et al., 2008; Locatelli et al., 2008; Seppala et al., 2009; Kleine et al., 2010; Chidumayo et al., 2011; FAO, 2012; Pramova et al., 2012; FAO, 2016).

2.5. Theoretical Perspectives on Adaptive Capacity

Understanding the different elements that enhance or inhibit adaptation is highly contested. Our understanding of hazards and associated responses has also changed markedly. For instance, in the earliest times, great catastrophes were seen as ‘Acts of God’ and thus damaging events were viewed as a divine punishment for moral misbehavior rather than a consequence of the human use of the earth (Smith & Petley, 2009). This perspective generally encouraged an acceptance of hazards and disasters as external inevitable events and hence practical actions to overcome the impacts of these events were limited.

Then comes the time for providing engineering solutions to natural hazards in around 4000 years ago (Smith & Petley, 2009). According to Smith and Petley (2009), the main responses within this engineering paradigm have been scientific weather forecasting and

large structures designed and built to defend against natural hazards. These responses have been made based on making all built structures sufficiently strong to withstand a direct hazard confrontation. Eventually, more organized attempts were made to limit the damaging effects of natural hazards and to be able to live with them which in turn led to different paradigms on how to understand and enhance a system's adaptive capacity. The following sub-sections summarize three different perspectives – behavioral, structural and evolutionary perspectives on the factors that promote and inhibit adaptation of humans to environmental change, in particular, climate change.

2.5.1. Behavioral paradigm

The behavioral paradigm emerged with the work of an American geographer Gilbert White in the 1930s and 1940s. It was the dominant paradigm between 1950 and 1970, while the engineering paradigm was the dominant one pre-1950, as touched upon above (Smith & Petley, 2009). Thus, the interactions between environmental hazards and people were little understood before the mid-twentieth century (Smith & Petley, 2009). White (1936, 1945) saw the relationship between natural hazards and people and highlighted that natural hazards are not purely physical phenomena outside of society but are linked to countless individual decisions. He argued that "Floods are 'Acts of God,' but flood losses are largely acts of man" (White, 1945, p. 2). White recognized the role played by human actions in exacerbating hazards. He observed that societal vulnerability is exacerbated by numerous, often-irrational decisions by economic agents. For example, misperception of risks and development of urban settlements on flood-prone lands, construction of susceptible buildings and infrastructure, deforestation and overgrazing of land by 'folk' societies were thought to contribute to the disaster.

Therefore, Gilbert White introduced a social perspective (human ecology) in understanding natural hazards and finding remedies (Smith & Petley, 2009). Smith and Petley (2009) stated that "this approach eventually produced a blended approach whereby earth scientists continued to investigate extreme natural events, and engineers built structures designed to control the most damaging forces, whilst social scientists explored

a wider agenda of disaster reduction through human adjustments, such as disaster aid and better land planning" (p. 5).

Consequently, the behavioral paradigm viewed a system's adaptive capacity predominantly as a function of agents' ability to accurately interpret risks posed by hazards and make rational decisions based on those interpretations (Hogarth et al., 2014; Hogarth & Wójcik, 2016b). This paradigm draws on psychological and economic theories of choice and (mis)perception of risks to explain human behavior in the face of hazards (Smith and Petley 2009). Earlier studies within this paradigm used the neoclassical economics' "rational choice" model as a starting point for analysis (Hogarth et al., 2014; Hogarth & Wójcik, 2016b). In this model, agents are assumed to be rational and expected to choose each course of action based on the expected utility that they will gain. When agents' decision-making is not optimal explanations were given.

Hogarth et al. (2014) identified three problems understood to inhibit rational decision-making that is particularly relevant to adaptation to extreme events. These include:

> (1) *Inadequate information* concerning the risk of hazard and methods of protecting against them;
> (2) *Myopia*, or the tendency of agents to be short-sighted; and
> (3) Difficulties in coordinating *collective action* in regard to management of natural resources, the provision of education, healthcare, and other social services, and the development of infrastructure. (P. 68)

In more recent studies within the behavioral paradigm, more nuanced theories of human choice and action have been developed (Hogarth et al., 2014; Hogarth & Wojcik, 2016b). For example, Eiser et al. (2012) underscored that decision-making under conditions of uncertainty is inadequately described by traditional models of 'rational choice' and discussed the importance of experience, personal feelings and values, cultural beliefs and interpersonal and societal dynamics in shaping people's interpretation of risks and decision-making. The paper draws on the concept of cognitive heuristics emerging from the critique of the 'rational choice' approach. As stated by Hogarth et al. (2014), this

model holds that individuals make decisions based not according to what is statistically rational, but on their own experience or the observed experience of others. This, in turn, will lead people to over-generalize from their own relatively small datasets of experiences or observations (Hogarth et al., 2014, Hogarth & Wojcik, 2016b). This can also lead to underestimation of the risk of low-frequency events and overconfidence in the effectiveness of safety procedures, the reliability of buildings and infrastructure and the like that have not been fully tested (Eiser et al., 2012).

Smith and Petley (2009) summarized the critiques of the behavioral paradigm as follows.

> This paradigm covers many methods of practical loss reduction. It remains dominant in some countries but has been described as an essentially Western interpretation. Critics of this approach see it as a materialistic and deterministic approach that reflects undue faith in technology and capitalism and leads to 'quick fix' remedies. It has also been faulted for over-emphasizing the role of individual choice in hazard-related decisions, for neglecting environmental quality and for being slow to recognize the role of human vulnerability in disaster impacts. (p. 6)

2.5.2. Structural perspectives

Structural perspectives on vulnerability and the capacity to respond to environmental hazards emerged in the late-1970s out of discontent with lack of progress in reducing disaster losses in developing countries (Hogarth et al., 2014; Hogarth & Wojcik, 2016b). The context of the drought-induced famine in the Sahel (the semi-arid region along the southern border of the Sahara desert) in the early 1970s attracted the attention of many scholars, particularly social scientists, and shaped the way they conceptualize natural disasters, vulnerability, and the capacity to respond to such hazards. Indeed, it served to shift focus away from irrational economic behavior towards structural explanations for human vulnerability and the capacity to adapt to environmental hazards (Hogarth et al., 2014).

After the Sahel incidence, a number of renowned social scientists began to question the dominant view that “the famines could be attributed to the so-called advance of the Sahara syndrome in which irrational economic behavior of the local population led to overgrazing, deforestation and soil erosion” (Hogarth et al., 2014, p. 70). They presented numerous examples including a highly specialized traditional society in the Sahel that managed to adapt extremely rational behavior to cope with the challenges posed by the local climate through co-evolution with the local ecosystem. They also mentioned the healthy and longstanding symbiotic relationship that existed between pastoralists and subsistence farmers.

However, the scholars argue that the existing systems had been disrupted in recent years by structural changes. As a result, agents were no longer seen as having choice within a wide range of theoretical adjustments to geophysical events (Hogarth et al., 2014; Hogarth & Wojcik, 2016b). Instead, their choice of action was restricted by a large number of socio-economic factors which include “their social status, level of cultural literacy, access to credit sources, such as those embedded in kinship networks, technical expertise, size and diversity of assets, employment options, household labor requirements, membership in voluntary organizations, productive capacity of capital, and commitment to cultural values and religious conventions” (Torry, 1979, pp. 371-372).

Since then, the search for identifying the factors that constrain or enable the capacity of human systems to adapt to environmental challenges has increased. It is widely recognized that structural variables enable or constrain adaptive capacity (Brooks et al., 2005; Adger et al., 2009; Pahl-Wostl, 2009; Agrawal, 2010; Plummer & Armitage 2010; Engle & Lemos, 2010; Engle 2011; Pramova et al., 2012; Berman & Paavola, 2012).

Furthermore, it is highlighted that structural change is path dependent and often irreversible: “The collapse of the traditional methods of fighting economic problems arising from periodical droughts may have played an important part in making the dry Sahel region more vulnerable to drought in recent years than it need have been. On some of these changes corrective policy actions are worth considering, but many of these

developments are difficult to reverse" (Sen, 1981, cited in Hogarth et al., 2014, p. 69). Hogarth et al. (2014) added that "piecemeal technical solutions to such structural problems, such as the drilling of boreholes, will often prove inadequate and may even exacerbate the problem" (p. 69). Instead, problems such as "deforestation, grass burning, erosion, overgrazing, overstocking, population growth, water resource management, and the like must be looked at systemically" (Glantz, 1977, p. 78). This, in turn, means that addressing vulnerability and enhancing the capacity to adapt to natural hazards requires a holistic understanding of the structural root causes (Hogarth et al., 2014).

According to Wisner et al. (2004, 2012), the underlying "root causes" of vulnerability include globalization, social inequalities, and colonization and they place "dynamic pressures" on human systems through forces such as political and economic marginalization, corruption, armed conflict, and ecological degradation. Eventually, local vulnerability and adaptive capacity can have its roots in macro-scale forces and historical factors (Hogarth et al., 2014).

2.5.3. An evolutionary perspective

Hogarth et al. (2014) developed an evolutionary theory of adaptive capacity based on the earlier works of Joseph Schumpeter (1942), a pioneer of evolutionary economic thought, and Nelson and Winter (1982), which the later authors take up the ideas of the first just after forty years and elaborated them in their seminal work "An Evolutionary Theory of Economic Change". An evolutionary theory offers an alternative perspective on adaptive capacity to behavioral and structural theories. It states that human systems have a capacity to adapt to local environmental and climatic conditions but that capacity is constrained by structural and historical factors (Hogarth et al., 2014). Hogarth et al. (2014) further describe that human systems, akin to ecosystems and biological organisms, have the capacity to evolve to become more suited to local environmental and climatic conditions. Therefore, the main tenet of an evolutionary perspective is that "adaptation is driven by human agency—the behavior, creativity, and entrepreneurialism of individuals

and organizations. However, it is also structured by socio-economic, ecological, and historical factors." (Hogarth et al., 2014, p. 65).

Although socioeconomic, ecological, and historical factors structure agents' ability to adapt, it is evident that an evolutionary perspective places more significance to the ability of human agents to innovate and adopt behaviors and technologies that are more suited to local conditions. Hogarth et al. (2014) stressed that an evolutionary view of adaptive capacity must give weight to agents' abilities to both shape different adaptive capacities and vulnerability trajectories within current structural environments and to alter structural environments through political processes, social movements and the like. Consequently, a complete understanding of a human system's adaptive capacity will require an examination of how structure and agency interact to create locally specific adaptive capacities and vulnerability trajectories (Hogarth et al., 2014; Hogarth & Wojcik, 2016b).

With respect to the interaction between human agents and structural factors, Schumpeter (1942) argued that the actions of agents are conditioned by structural factors, but the primary driver of economic evolution is the innovative capacity of economic agents. Giddens (1986), in his theory of structuration, also argued that instead of focusing purely on an agency or solely on a structure the two should be conceived as a duality. On the other hand, Nelson and Winter (1982) argued that instead of constantly re-evaluating their actions to capture the greatest returns agents tend to act according to routines. This concept aligns well with that of cognitive heuristics rather than neoclassical economics. However, Hogarth et al. (2014) stated that "beyond these routines, agents will aim to gain a competitive advantage through activities designed to 'search' for new, more efficient routines or technology, such as research and development or market analysis" (p.77). Therefore, from an evolutionary perspective, "adaptation occurs when a behavioral routine, an institution or a technology that provides a competitive advantage within local conditions is selected and retained" (Hogarth & Wojcik, 2016a, p. 250). This process is at times path dependent and irreversible as past events and decisions will limit future adaptive options (Nelson & Winter, 1982).

Regarding the evolutionary process of adaptation, Hogarth et al. (2014) argued that

> …as increasingly competitive features are selected and retained, adaptation is thought to progress towards an optimal state in which no potential features exist that are more competitive. However, at best, optima can only exist within local selection environments and can only be temporary. (p. 77)

Over time, higher-level changes such as climatic, ecological, technological, cultural or institutional changes will lead to a different selection environment in which current routines and technologies are less well adapted or even maladapted (Hogarth & Wojcik, 2016a). For example, adaptations like large infrastructure investments that limit flexibility in response to unforeseen changes in the selection environment are particularly liable to lead to maladaptation (Hogarth et al., 2014; Hogarth & Wojcik, 2016b). Such shifts in selection pressures can be gradual or rapid. They can occur at the local level, for example, through local environmental degradation or cultural change but they can also be triggered by processes that occur at different scales such as jurisdictional, spatial, and institutional scales (Hogarth & Wojcik, 2016a,b). Shifts may also occur within one scale or across many scales, and hence multiple shifts may occur concurrently making it difficult, if not impossible, to predict local outcomes (Rammel & van den Bergh, 2003; Hogarth et al., 2014).

From an evolutionary perspective, a system's diversity is also an important element that influences adaptive capacity (Hogarth et al., 2014; Hogarth & Wojcik, 2016a,b). For instance, excessive specialization within current selective pressures reduces adaptive capacity as it reduces the range of options that a system could use to cope with future pressures (Rammel & van den Bergh, 2003). Thus, diversity within economic, socio-cultural, institutional, and technological spheres is an essential element in the adaptation of human systems just as genetic diversity is in the process of biological evolution (Boyd & Richerson, 1985; Matutinuvic, 2001; Rammel & van den Bergh, 2003, cited in Hogarth et al., 2014). The famine case in the Sahel briefly described below by Hogarth et al. (2014) demonstrates this phenomenon.

> The traditional pastoral and agricultural society of the Sahel had adapted a highly specialized system of reciprocity to deal with the adverse ecological conditions of the desert. However, when structural changes caused the selection environment to shift, the pastoralists found their nomadic lifestyle to be maladapted to the new conditions. (p. 77)

In addition, Hogarth et al. (2014) argued that the adaptive flexibility of its current components particularly institutions and government structures in response to agents' attempts to alter them is central to the adaptive capacity of human systems. For example, Dietz et al. (2003) argued the following regarding the importance of governance of ecological resources.

> Devising effective governance systems is akin to a coevolutionary race. A set of rules crafted to fit on [a] set of sociological conditions can erode as social, economic, and technological developments increase the potential for human damage to ecosystems and even to the biosphere itself. Furthermore, humans devise ways of evading governance rules. Thus, successful commons governance requires that rules evolve. (pp. 1907-1908)

Adaptive governance involves managing a number of institutional types nested together and operating at multiple scales (Dietz et al., 2003). Properly designed institutions can promote rational forward-looking decision-making, better economic opportunities, and conservation of diversity, whereas poorly designed institutions can lock-in maladaptive behavior, undermine the functioning of organizations, and promote irrational and myopic decision-making (Hogarth & Wojcik, 2016b). Dietz et al. (2003) argued that institutions should decisively be designed to be flexible and responsive to changing conditions through mechanisms that ensure appropriate feedback of information and the systematic deliberation of various informed stakeholders.

Therefore, a framework for assessing adaptive capacity need to provide a structure that embraces components other than the most commonly used asset base. Important components such as the adaptive flexibility of institutions and governance structures, the

ability of agents to generate and disseminate knowledge about hazards and adaptive options, the ability to retain diversity, and the innovative skills of agents need to be included. To this end, Jones et al. (2010) developed the LAC framework and this dissertation has adopted it as it captures important elements that are central to understand adaptive capacity at the local level. This study also views adaptive capacity as an expression of agents within a constantly changing set of structural conditions and this conceptualization makes it in line with an evolutionary perspective of adaptive capacity. Table 4 presents the different elements that make up the LAC framework. All the elements were used to assess the adaptive capacity of rural households in the CRV of Ethiopia.

Table 4 Components of the Local Adaptive Capacity framework

Characteristic	Description
Asset Base	Tangible (natural, physical and financial) and intangible (human and social) capitals
Institutions & entitlements	Equitability of access to key assets and the process through which institutions evolve
Knowledge & information	The system's ability to generate and disseminate information
Innovation	Degree to which the system fosters and retains novel behavior, technology and institutions
Decision-making & governance	Degree to which governance and decision-making systems anticipate change and respond accordingly

Source: Jones et al. (2010), description as modified by Hogarth & Wojcik (2016a)

2.6. Theoretical Framework for Adaptive Capacity

Frameworks are useful to guide analysis and attain a fuller understanding of the components of a system and their relationships. The majority of adaptation inquiry originated within the frameworks of either vulnerability or resilience (Engle, 2011; Newman, 2013). Adaptation is not necessarily at the center of either vulnerability or resilience studies but the concept of adaptive capacity unites these two paradigms (Engle, 2011). Adaptive capacity is integral to both frameworks and thus credited for both reducing vulnerability and increasing resilience. It is a unique and universally positive attribute that humans can shape and manipulate (Engle, 2011).

Most researches on adaptive capacity so far have been largely focused on larger scales with little applicability at local levels where the majority of adaptation action inevitably occurs (Yohe & Tol, 2002; Adger & Vincent, 2005; Brooks et al., 2005; Vincent, 2007; Eriksen & Kelly, 2007). Among a few of the studies that focused on subnational levels are the works of Wall and Marzall (2006), Gbetibouo and Ringler (2009), Nelson et al. (2010), and Piya et al. (2012). These studies focus on characterizing the elements or components of adaptive capacity.

A number of studies geared towards understanding adaptive capacity have been rooted in the IPCC's categorization of the determinants of adaptive capacity identified as economic resources, technology, information and skills, infrastructure, institutions and equity (Smit & Pilifosova, 2001). This IPCC's report identified adaptive capacity as a component of vulnerability. However, no distinction was made between determinants at the national and local levels where appropriate determinants and indicators must be tailored to each case (Brooks & Adger, 2005). National-level indicators generally fail to capture many of the processes and contextual factors that influence adaptive capacity at the local level (Eriksen & Kelly, 2007). Apparently, it is not possible to apply a national-level index into a smaller scale of analysis (Vincent, 2007). Smit and Wandel (2006), for example, reported that the conditions that interact to shape adaptive capacities, and hence create opportunities for adaptation, are community specific.

In addition, the indicators enumerated in most studies are generally based on assets and resources which reflect the sustainable livelihood framework (Brooks et al., 2005; Daze et al., 2009; Dulal et al., 2010; Elrick-Barr et al., 2014). The 'function-based approach' followed by the World Resources Institute is a notable exception (WRI, 2009). While asset-based approaches are useful in helping us to understand the resources at the disposal of a system to cope with and adapt to changing environments, they typically mask the role of processes and functions in supporting adaptive capacity (Jones et al., 2010; Elrick-Barr et al., 2014). The various intangible processes, which are far harder to measure, play an integral part in determining the ability of a system to adapt to shock and

stress (Jones et al., 2010). Recent assessments also argue that the underlying social and institutional factors such as social capital and governance that create capacity have been underplayed in earlier studies (IPCC, 2007; Elrick-Barr et al., 2014). This entails the need to move away from simply looking at what a system has that enables it to adapt, to recognizing what a system does to enable it to adapt (WRI, 2009). Thus, a number of scholars have defined and treated adaptive capacity differently since TAR and have subsequently expanded on and redefined the initial characterization (Engle, 2011).

This paper used the Local Adaptive Capacity (LAC) framework developed by the Africa Climate Change Resilience Alliance (ACCRA) as the conceptual framework underpinning deductive construction of an adaptive capacity index (Jones et al., 2010). The framework provides sufficient recognition to the important and overlapping role of both assets and processes and functions that are so imperative to supporting adaptive capacity at the local level. It attempts to incorporate into the analysis of both the intangible and dynamic dimensions of adaptive capacity as well as capitals and resource-based components. This makes it different from other frameworks which focused on assets as direct indicators of adaptive capacity (Brooks et al., 2005; WRI, 2009; Park et al., 2012).

The LAC framework lays out five distinct, albeit interrelated, characteristics of adaptive capacity with the underlying assumption that positive impacts on these characteristics should enhance the system's capacity to adapt. These are the asset base; institutions and entitlement; knowledge and information; innovation; and flexible and forward-looking decision-making and governance (Figure 1). Asset base is further classified into five sub-components, as stipulated in many previous works, namely, natural, physical, financial, human, and social assets. The natural asset in this study includes farmland, grazing land, woodland and water resources.

For analytical purpose, the major features were considered as principal components and the rest as sub-components, if any, that constitute their respective principal components. Consequently, indicators/sub-indicators and indices were developed for each of them in

order to empirically measure the dimensions of adaptive capacity at the household level. Adaptive capacity was then measured both in terms of aggregate and composite indices using Principal Component Analysis (PCA) technique to reflect the relative contribution of each component to the adaptive capacity of the households and to make comparisons across the four study sites. Detailed descriptions are given in the next section.

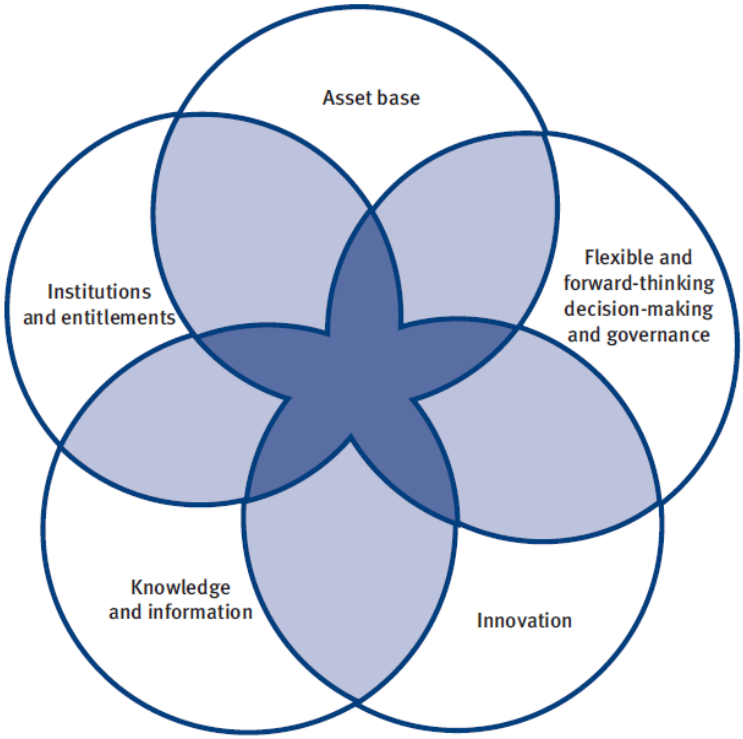

Figure 1 Framework for adaptive capacity at the local level

Source: Jones et al. (2010) (based on ACCRA's LAC framework)

2.7. Conceptual Framework of the study

This study developed its conceptual framework based on Smithers & Smit (1997) and Jones et al. (2010) frameworks. Jones et al. (2010) developed the LAC framework, which is helpful in understanding adaptive capacity at the local level, as described in the theoretical framework section. The framework of Smithers and Smit (1997) portrays the basic relationship between climate change, impacts and response measures.

The conceptual framework of this study envisages that adaptation response to counteract the adverse impacts of climate change and exploit opportunities depends on the capacity to adapt. The capacity to adapt at the local level, in turn, depends on asset base, innovation, knowledge and information, institutions and entitlements, and flexible and forward thinking decision-making and governance. Moreover, this study conceptualizes that these components form an integrated and systematic part of the adaptive capacity of households. They determine the degree to which a community or a household is resilient and responsive to climate-related changes (Jones et al., 2010). They can be related to each other across a range of spatial and temporal scales and the processes that shape them are very much interdependent (Sietchiping, 2007; Jones et al., 2010). One component can facilitate, strengthen or hinder the contribution of the other. For example, Jones et al. (2010) highlighted that accurate and applicable knowledge and information facilitate flexible forward-looking decision-making and effective and supportive institutions mediate access to and control of assets and drive successful innovation. Nevertheless, each component serves a very important and distinct role in enhancing the adaptive capacity of rural households to climate-related hazards.

Apparently, the current conceptual framework goes beyond asset-based approaches to adaptive capacity and that assets are considered as one of the five major components of adaptive capacity. Yet, they are fundamental to build adaptive capacity and the usual five assets, namely, human, physical, natural, financial, and social assets constitute the asset base of households. Consequently, the contribution of assets, particularly natural assets to adaptive capacity is dependent on their status. Our ability to manage natural systems and thus maintain the ecosystem services on which our life depends influences the success of adaptation of the human system (Noble et al., 2014). Thus, assessing the status of one of the important natural assets in the area, i.e., woodland, and the factors that influence its status is conceptualized in this study. Figure 2 provides a pictorial representation of the conceptual framework underpinning the different components addressed in this study.

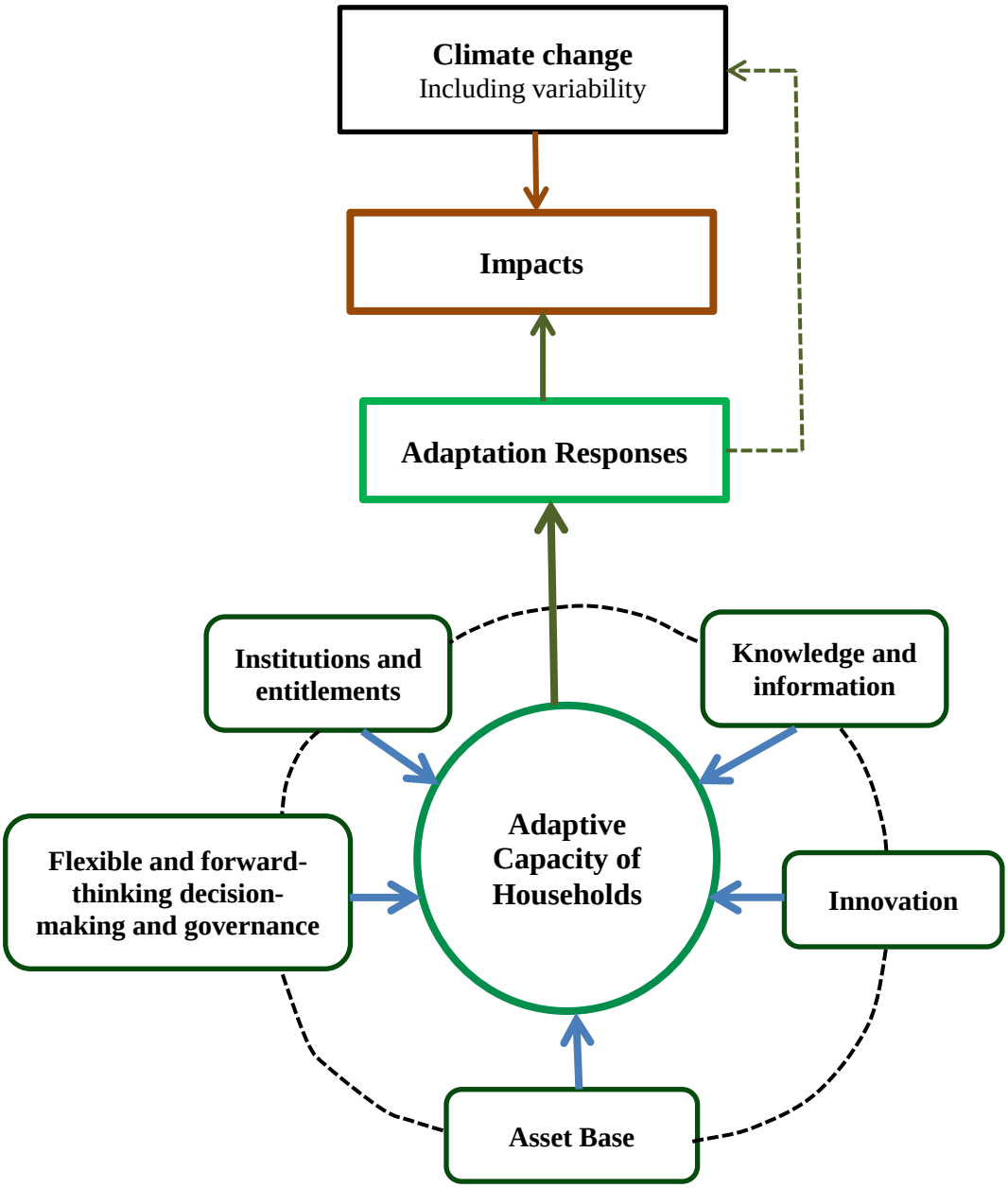

Figure 2 Conceptual framework of the study

Source: This framework is adapted from Smithers and Smit (1997) and Jones et al. (2010). Hard lines indicate direct effects, while broken lines depict secondary or indirect effects.

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Chapter Three: Research Methodology

Research methodology is concerned with the logic of scientific inquiry. So, this chapter basically introduces the methods employed in this research as well as the logic behind using them. In effect, research methodology involves making decisions about which research approach to follow to best understand a research problem. Therefore, this chapter begins with a description of the study area. Then, the research approach followed in this study is described. This part includes a description of the philosophical worldview that influenced the practice of this research, the research design followed in this study and the specific techniques and procedures used to collate and analyze the data (the research methods).

3.1. Description of the Study Area

3.1.1. Location and extent

This study was conducted in the Central Rift Valley of Ethiopia (7° 22' – 7° 42' N, 38° 25' – 38° 47' E, Figure 3). Administratively, this section of the CRV is found in the Oromiya Regional State, West Arsi Zone, Arsi Negele District, about 200 km south of the capital Addis Ababa. It is bounded by three lakes: Lake Langano in the East, Lake Abijata in the West, and Lake Shalla in the South and Southwest. It covers an area of 416 km^2 of which 1 km^2 is occupied by the Abijata-Shalla Lakes National Park. The altitude varies from 1560 m a.s.l. at the Lake Shalla shoreline to 2061 m a.s.l. at the peak of Mount Fiqe, which is found between Lake Abijata and Lake Shalla.

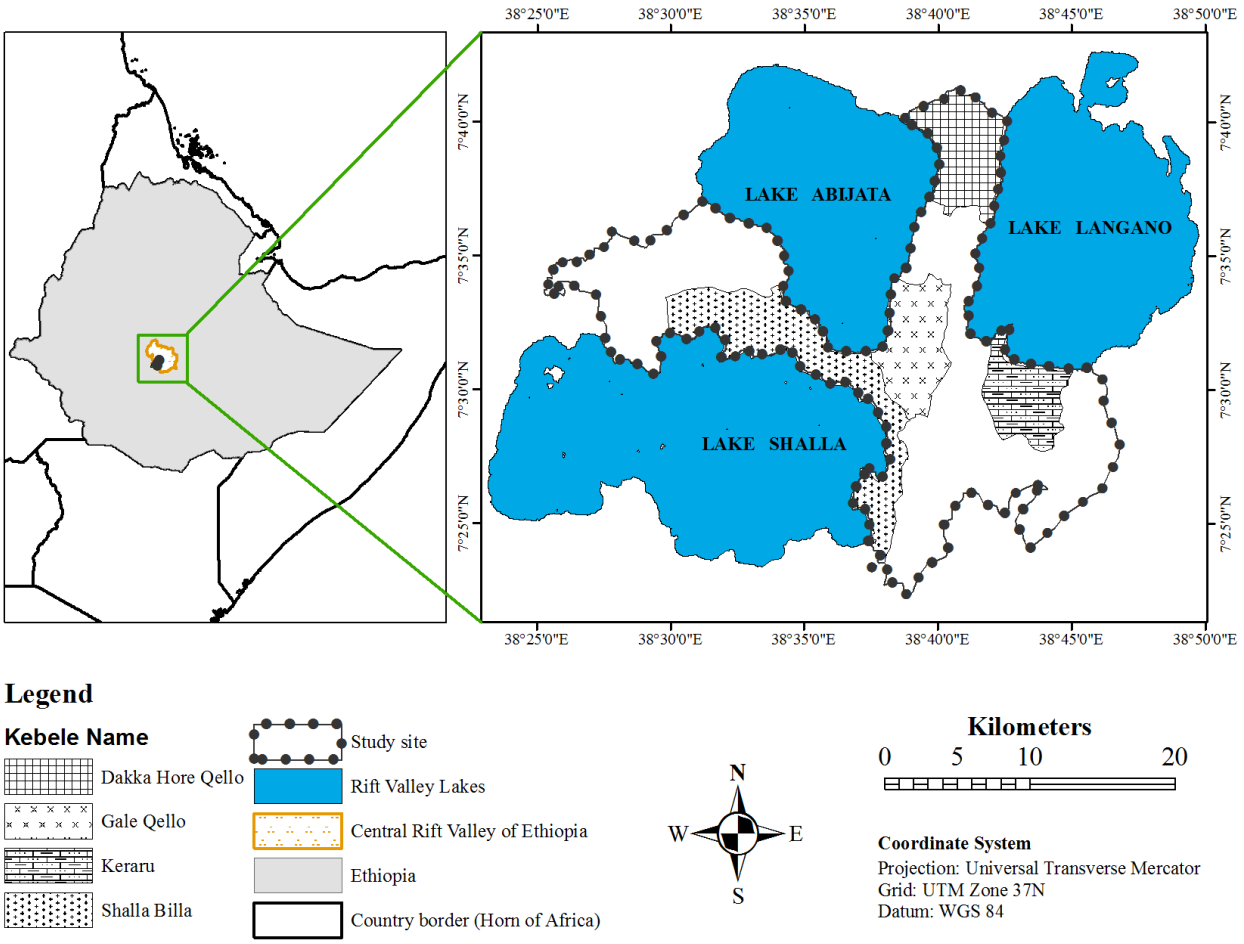

Figure 3 Map of the study area

3.1.2. Climate

The study area is characterized by a semi-arid climate (Sagri et al., 2008; Temesgen et al., 2013; Tilahun et al., 2016; Yohannes et al., 2017). The modern MER climate is influenced by the annual movements of the Intertropical Convergence Zone (ITCZ) and by physiography (Benvenuti et al., 2002; Sagri et al., 2008). In fact, the climate of Ethiopia, in general, is controlled by the seasonal migration of the ITCZ and its associated atmospheric circulations as well as by the complex physiography and marked differences in elevation among the different parts of the country (Fazzini et al., 2015). It is, therefore, important to note that altitude has also a significant influence on Ethiopia's climate, which it often means less rain and warmer in the lowlands and more rain and

cooler in the highlands (Itanna, 2005; Ayenew, 2007; Jansen et al., 2007; McSweeney et al., 2010; Meshesha et al., 2012; Fazzini et al., 2015).

Consequently, the climate of the study area, akin to most parts of Ethiopia, is characterized by seasonal rainfall distributions and hence alternating wet and dry seasons during summer and winter periods, respectively. Hence, the study area has a bimodal rainfall pattern. The main rainy season, locally termed as *Kiremt*, starts from June and extends up to September. It is followed by a long dry season that stretches from October to January (*Bega*), and then the small rainy season starts from February and extends up to May (*Belg*).

The *Kiremt* rain is the result of an inland convergence of moist airstreams from the Indian Ocean and the Congo Basin and the northernmost position of the ITCZ during the boreal summer, whereas the *Belg* rain is the result of the northward migration of the ITCZ during the boreal spring (Benvenuti et al., 2005; Sagri et al., 2008). The *Kiremt* rain is thus influenced by both the Atlantic and Indian Oceans and covers most parts of the country. The *Belg* rain is caused by the movement of moist easterly and south-easterly winds from the Indian Ocean and covers certain areas, including the study area (Rosell, 2011). On the other hand, the dry season (*Bega*) is the result of the southernmost shift of the ITCZ during the boreal winter (Benvenuti et al., 2005). This happens "when a subtropical high stands to the north of Ethiopia and dry north-easterly winds blow from the Arabian Peninsula" (Sagri et al., 2008; p. 82).

In general, the study area receives much of its rainfall during the summer season, while *Belg* rainfall, though important, is often light, intermittent, and less reliable. Moreover, there is often a short dry spell between the cessation of the *Belg* rain and the onset of the *Kiremt* rain. The mean annual rainfall of the area taken from Langano station for a period between 1981 and 2009 is 679 mm, whereas the mean annual minimum and maximum temperatures are 14.2°C and 28.7°C, respectively.

The mean annual evapotranspiration rate (1700 mm) (Biazen et al., 2011) and the coefficient of variability in rainfall (40%) are also high, further witnessing the unreliability of rainfall in the area. Therefore, precipitation in the study area, in general, is erratic and often well-below long-term average, making crop production difficult (Jansen et al., 2007; Meshesha et al., 2012; Biazen, 2012). Recurrent drought associated with low rainfall is also one of the recently increasing challenges of the area with the majority of low rainfall records being observed after 1990 (Biazen, 2012).

3.1.3. Geomorphology, geology and soils

The study area, CRV, is part of the central portion of the Main Ethiopian Rift (MER), which in turn is part of the Great East African Rift system. This spectacular rift is one of the largest tectonic structures on Earth (Ayenew, 2004; Muzein, 2006; Billi, 2015; Ayenew & GebreEgziabher, 2015), extending from North Jordan in the Middle East through Ethiopia and other East African countries to Mozambique in Southern Africa. Practically, it covers almost the length of Africa (Muzein, 2006). It is at times referred to as the Afro-Arabian rift (Ayenew, 2004, Nyssen et al., 2008). It is also one of the most attractive regions of the whole continent for its unique natural environments and geomorphological relevance (Billi, 2015). The MER constitutes the northernmost part of this Great East African Rift Valley (Benvenuti et al., 2002; Acocella et al., 2003; Abebe et al., 2007; Fubelli & Dramis, 2015).

The MER stretches from the Kenyan border in the south up to the Red Sea in the North (Ayenew, 2007). It dissects the Ethiopian plateau into two uplifted blocks (the northwestern and the southeastern plateaux), progressively widens out in the North into the complex Afar triple junction, and eventually opens up into two branches to form the Gulf of Aden and the Red Sea rifts (Acocella et al., 2003; Ayenew, 2004, 2007; Abbate et al., 2015; Fubelli & Dramis, 2015). The main trunk of the Ethiopian rift is endowed with many natural lakes of tectonic or volcano-tectonic origin (Billi, 2015). The major ones are Ziway, Langano, Abijata, Shalla—the deepest one with a depth of 266 m (Ayenew, 2004), Awassa, Abaya—the largest of all in the MER with an area of 1,162 km^2 (Billi,

2015)—and Chamo Lakes. There are also other lakes outside of the MER, the most notable one being Lake Tana, which is by far the largest highland lake in Ethiopia with a surface area of more than 3,600 km^2 (Billi, 2015).

According to Billi (2015), the MER is geomorphologically divided into three main sections:

> (i) the southern portion, from the border with Kenya to the hydrological divide between Abaya and Awassa Lake; (ii) the main portion, commonly indicated also as the Great Lakes Region of Ethiopia, stretching as far as the Awash River; and (iii) the northern portion, from the Awash to the apex of the Afar triangle and its northern branch, the Danakil depression. (p. 24)

This study focuses on the main portion of the MER, also called the CRV. The CRV in the MER consists of four major hydrologically interconnected lakes: Ziway, Langano, Abijata, and Shalla (Benvenuti et al., 2005; Benvenuti & Carnicelli, 2015; Yohannes et al., 2017). The three lakes—Langano, Abijata, and Shalla—are close to each other, whereas Lake Ziway is relatively far and separated from its nearest lake, Lake Langano, by a dormant volcanic mountain range (Temesgen et al., 2013).

Around 9240 years ago, all the four modern lakes were united together as one big lake (Grove & Goudie, 1971). The closest three lakes were still together about 5630 years ago. The present lakes are thus relics of a once large lake that, at times, covered most of the MER floor (Benvenuti et al., 2002; Sagri et al., 2008). The size and volume of these lakes also changed on time scales of decades to millennia (Benvenuti et al., 2002, 2005; Ayenew & GebreEgziabher, 2015).

The lakes took their present state as a result of the separation of the Ziway–Shalla paleolake because of tectonic events that also diverted the course of Awash and Mojo rivers towards the east, depriving the Ziway–Shalla basin of large volumes of water, and a further desiccation as a result of an increase in aridity of the area during the late Holocene period (Wodajo & Belay, 1984; Benvenuti et al., 2002; Sagri et al., 2008). The

lowering of the water level in the basin since the last 5000 years (Benvenuti et al., 2002; Sagri et al., 2008; Nyssen et al., 2008) is also one of the reasons for the establishment of woodlands around the four lakes (Temesgen et al., 2013). Thus, the woodland dominated area between the three nearest lakes was included in this study.

The geological setting of the MER, in general, involves volcanism, rifting, fluctuation of Quaternary lake levels, and deposition of fluvial and volcano-lacustrine sediments (Ayenew & GebreEgziabher, 2015). The central sector of the MER and its flanks are made of Tertiary to Quaternary volcanites and pyroclastic rocks, whereas the majority of the rift floor is covered by upper Quaternary volcano-lacustrine, lacustrine, fluvio-lacustrine, and colluvial deposits (Benvenuti et al., 2002; Sagri et al., 2008; Billi, 2015). The study site, in particular, is covered by volcanic and volcaniclastic rocks, such as Plio-Pleistocene Rhyolitic ignimbrites, basalts, and lava flows, and sedimentary deposits, including early-mid and late Holocene fluvio-lacustrine palustrine and upper Pleistocene-Holocene colluvial and alluvial deposits (Benvenuti et al., 2005; Sagri et al., 2008).

Apparently, the soil types of the study area are closely related to the underlying parent material and its degree of weathering. Thus, soils of volcanic origin dominate the study area (Itanna, 2005). Indeed, soils derived from volcanic ash cover most of the study area and the ash occurs as lacustrine sediments as it has often been reworked (Temesgen et al., 2013). They are developed mainly from the recent volcanic deposits and lake sediments, which are formed largely from ash and pumice (Sagri et al., 2008; Billi, 2015).

The major soil type of the study area is classified as Andosol (Zewdie, 2004; Muzein, 2006; Nyssen et al., 2008). Andosols are developed on Lake Deposits of different ages interbedded with pumice (Makin et al., 1975; Temesgen et al., 2013). In some places, these soils are found mixed with Vertisols forming Virtic Andosols and their clay content tends to increase with distance from the lakes (Muzein, 2006). However, there are also other types of soils, such as Haplic Solonetz, which is found around the Bulbula area where human influence is very small (Itanna, 2005). Exposed areas or rock outcrops of

cemented lapilli tuff (Nyssen et al., 2008) and pumice gravels also occur in the area especially on escarpments and hill tops (Makin et al., 1975).

The soils are course textured varying from loamy sand to sandy loam on higher terraces and highly alkaline (Makin et al., 1975; Muzein, 2006; Nyssen et al., 2008; Biazen et al., 2011) with a pH of 7.6 to 8.2 (Temesgen et al., 2013). The color of the soil in most parts of the study area is pale, while it is brownish in the western edge (Algae and some parts of Mudhi Arjo *Kebeles*). The brownish color of the soil is because of the deposition of thick alluvium that contains reworked ignimbrites by Jido River (Dainelli et al., 2001).

Generally, the soils in the study area are characterized by low bulk density and weaker structure, making them vulnerable to wind and water erosion (Nyssen et al., 2008) as well as drought (Biazen et al., 2011). They are also susceptible to surface capping once the protective cover of the acacia woodland has been removed (Eshete, 1999; Biazen, 2012). In addition, they are less fertile with a low organic matter, moderate moisture retention capacity, and deficiencies in plant nutrients, particularly phosphate (Makin et al., 1975; Temesgen et al., 2013).

3.1.4. Vegetation

Phytogeography is influenced by a number of environmental factors, including climate, soil, and elevation that also dictate climate particularly rainfall. Thus, the study area permits the growth of semi-climax perennials that are primarily adapted to dry conditions (Muzein, 2006). Accordingly, the most common species along the rift floor are deciduous Acacia, while a wide variety of both deciduous and coniferous trees are found on higher elevations and areas with better soil and moisture conditions.

Consequently, the natural vegetation of the study area can generally be characterized as open Acacia woodland albeit patches of dense woodlands and forests can also be found. Acacia species as available in the woodland consists of *Acacia tortilis*, *Acacia senegal*, *Acacia seyal*, and *Acacia etbaica*. These tree species, particularly the first two, are the

dominant acacia species in the CRV area (Makin et al., 1975; Eshete & Stahl, 1998). Other tree species found in the study area include *Balanites aegyptiaca*, *Maytenus senegalensis*, *Dichrostachys cinerea*, *Euphorbia candelabrum*, *Ziziphus mucronata*, *Croton macrostachys*, *Cordia africana* and *Ficus vasta*.

In addition, several semi-evergreen shrubs, such as *Carissa edulis*, *Croton dichogamous*, *Solanum schimperianum*, *Sclerocarry birrea*, *Terminalia browni*, *Harisonia abyssinica*, *Capparis tomentosa*, and *Acokanthera schimperi*, are found especially on rocky and degraded sites either scattered over the study area or mixed with the dominant Acacia trees (Eshete, 1999; Muzein, 2006; Biazen, 2012; Temesgen et al., 2013). The lowest vegetation level of the woodlands is usually covered by different species of grasses, such as *Cenchrus, Cynodon, Dactyloctenium, Digitaria* and *Sporobolus* (Makin et al., 1975), which are important both for livestock and wild animals. In most parts of the study area, the stocking and species diversity of the woodland appears to be severely affected due to human interference.

3.1.5. Livelihood and farming systems

The inhabitants in the study area are predominantly Oromo people who came from the surrounding highlands. Nearly all are Muslim and polygamy is common. In the past, these people used to be pastoralists, that is, Silvopastoralism. Nowadays, mixed-farming system that integrates cropping, livestock rearing and charcoal and fuel wood extraction is practiced in the area, which is a kind of Agrosilvopastoral system (Nyssen et al., 2008).

However, livestock rearing is still the most common livelihood strategy, although subsistence crop production is progressively expanding. Thus, livestock and crop production are the two major sources of livelihood. Number of livestock, in particular cattle, is also used as a sign of not only economic wealth but also social status. The more number of cattle a household owns the more prestigious he/she is considered to be. The major livestock resources are cattle and goat with free grazing system. The major crops

grown in the area include maize (*Zea mays*), teff (*Eragrostis tef*), sorghum (*Sorghum vulgare*), and haricot bean (*Phaseolus vulgaris*).

Crop production is primarily rain-fed and hence sensitive to drought and rainfall changes. The most common coping strategies practiced by farmers in times of hardship are selling livestock and charcoal production and marketing. Wood extraction from woodlands, either for charcoal production or fuel, has contributed to the degradation of the once dense acacia woodland of the area. Productive Safety Net Programs (PSNPs) and Relief are also common in the area as it is often affected by recurrent drought and rainfall variability.

3.2. Research Approach

The choice of research approaches involves the intersection of the philosophical worldviews that the researchers bring to the study, the research design that is related to the worldview, and the specific research methods that translate the approach into practice (Creswell, 2014).

Consequently, this research followed a mixed research methods approach to collect both quantitative and qualitative data needed to address the research problem. The core assumption for using the approach is that it provides a more complete understanding of the problem than either approach alone (Creswell, 2014).

3.2.1. Philosophical worldview and research design

Research is guided by a set of beliefs. This set of beliefs or worldviews that guide research action is commonly known as a paradigm. A paradigm or a philosophical worldview, as some call it, is basically a way of thinking about the world. Spratt et al. (2004) defined it as "a set or cluster of commonly held beliefs or values within the research or scientific community about a field of study" (p. 6). A paradigm shapes the position or stance of researchers toward the nature of reality (ontology), how researchers

know what they know (epistemology) and what methods to use and how the results should be interpreted (methodology). The choice of a stance on each of these assumptions also has practical implications for designing and conducting research.

On the other hand, ontology, epistemology, and methodology are always closely related and co-dependent. They are so interrelated that ontology dictates epistemology which dictates methodology which dictates methods. At the same time, all these elements (ontology, epistemology, methodology, and methods) need to make sense with the research question since, in reality, the question derives everything (Grix, 2002). However, the research paradigm or the underlying philosophical ideas that influence the practice of research are often hidden as they are so implicit, assumed, and taken for granted (Babbie, 2013; Creswell, 2014) and need to be made clear.

This study espouses a pragmatic worldview. Pragmatism is a position that argues that the most important determinant of the research philosophy adopted is the research question and one may be more appropriate than the other for answering particular research questions (Saunders et al., 2009). Therefore, pragmatism is not committed to any one type of philosophy and argues that it is possible to work within both positivist and interpretivist positions (Saunders et al. 2009; Creswell, 2014). It focuses on the outcomes of the research—the actions, situations, and consequences of inquiry— rather than antecedent conditions (as in postpositivism) (Creswell, 2007). It puts emphasis on the research problem and uses all approaches and methods available to understand or solve the problem (Saunders et al., 2009; Creswell, 2014). So, pragmatism, compared with other philosophies such as positivism and interpretivism, allows researchers to design flexible methods to collect both qualitative and quantitative data and hence enable them to better address the research problem (Saunders et al., 2009).

This research, which is primarily aimed at examining adaptive capacity at the household level, covered a wide range of issues from socioeconomic to biophysical aspects and needed both quantitative and qualitative data. Therefore, pragmatism should be the most appropriate philosophical paradigm for this research.

Moreover, this study adopted a convergent parallel mixed methods design, where both quantitative and qualitative data are collected at about the same time and converged to provide a comprehensive analysis of the problem. The term research design is used here in the sense defined by Creswell (2014) as a type of inquiry within quantitative, qualitative, and mixed methods approach that provide specific direction for procedures in a research study. In some literatures, it is addressed as strategies of inquiry.

3.2.2. Research Methods

3.2.2.1. Sampling procedure, site selection, and sample size

Remote sensing and GIS techniques were used to collect the biophysical data, mainly woodland cover change, while a survey method was employed mainly to collect the socioeconomic data. The survey followed a multistage sampling procedure. The first stage involved the selection of the study site. The study site in the CRV was purposely selected for the following reasons:

(1) It is one of the most vulnerable areas to climate change (Jansen et al., 2007; Meshesha et al., 2012; Kassie et al., 2014; MEF, 2015);

(2) It is one of the most environmentally fragile areas in Ethiopia that small changes in natural resources can have far reaching consequences on ecosystem goods and services, and potentially undermine the role they play for the society and the environment, including their role in adaptive capacity (Ayenew, 2004; Jansen et al., 2007; Meshesha et al., 2012);

(3) It was known for its dense acacia woodland (Eshete, 1999; Feoli & Woldu, 2000; Shibru & Woldu, 2006; Garedew et al., 2009) to the extent that it was not possible to see the three Lakes while driving along the main road that passes through them just a couple of decades ago (Mesfin, personal observation) and hence the people who are dependent on woodlands for goods and services will be more vulnerable to woodland changes both socially and economically (Locatelli et al., 2008);

(4) It is an area typical of a rapidly changing landscape in Ethiopia, if not in Africa (Olson et al., 2008; Garedew et al., 2009; Mesfin, personal observation);
(5) There is a national program to, among others, establish Acacia Woodland Reserve and Community Based Carbon Sequestration Project in the Ethiopian Rift Valley System as national adaptation options (NMA, 2007) and hence this study shall provide some information about the acacia woodlands of the CRV and their likely contributions particularly to the local people and the environment.

The second stage involved selection of the *Kebeles* in the study area. The study area covers 416 km^2 and 12 *Kebeles*. While the entire area is used for land use and land cover change analysis, four representative *Kebeles*, namely, Dakka Hore Qello, Shalla Billa, Keraru, and Gale Qello, were purposely selected for the household survey (Figure 3).

The final stage is the selection of the desired number of households from the respective *Kebeles*. Before selecting sample households the list of households in each *Kebele* was revised and updated. Then, the sample size was determined using the following equation adapted from Watson (2001).

$$n = \frac{\left[\frac{Z^2 * N * p(1-p)}{e^2 * N * Z^2 * p(1-p)}\right]}{R}$$

Where, n is sample size required, N is total number of households, p is estimated variance in population, as a decimal (0.5 for 50-50), e is precision desired, expressed as a decimal (0.05 for 5%), Z is value of the statistic based on confidence level (1.96 for 95% confidence), and R is estimated response rate, as a decimal (0.8 in this survey).

The equation provided a sample size of 414 households and we conveniently made it 420 to compensate for some more nonresponses and/or incomplete information and managed to include 413 households in the survey (17.4% of the total households). Households in each *Kebele* were classified into three wealth categories (poor, medium, and better-off) based on locally set criteria (Table 5) and samples were proportionally allocated (Table

6). The local criteria were developed by a group of selected key informants from the respective *Kebeles* and development agents of the area and the households were classified accordingly. Eventually, households were selected randomly from each wealth group with the help of a "Randbetween" function. The random selection of households within each stratum was also made in the presence of the key informants who classified households into wealth categories.

Table 5 Criteria used to classify households into wealth categories

Criteria	**Poor**	**Medium**	**Better-off**
Number of cattle	<5	5–20	>20
Saving money	No saving	No or some saving	Enough saving
Type of house	Thatch roof	Thatch roof or iron sheet	Roof with iron sheet

Source: A group of key informants selected from the respective *Kebeles*

Table 6 Number of sampled households per *Kebele*, stratified by wealth status.

Name of sample *Kebeles*	Number of households				Sample size allocation			
	Total	By wealth status			By wealth status			**Total**
		Poor	Medium	Better-off	Poor	Medium	Better-off	
Dakka Hore Qello	575	357	147	71	58	31	12	101
Shalla Billa	717	516	153	48	89	26	10	125
Keraru	711	225	411	75	42	66	10	118
Gale Qello	377	218	100	59	39	20	10	69
Total	**2380**	**1316**	**811**	**253**	**228**	**143**	**42**	**413**

Source: Author

3.2.2.2. Data collection methods

A number of data collection methods were used in this study, including remote sensing and GIS, household survey, focus group discussion (FGD), key informant interview (KII), and field observation. The details of each method are described under the specific chapters in which they are employed.

3.2.2.3. Data processing and analysis

The survey data was entered and processed with the help of SPSS (Statistical Package for the Social Sciences). The data was checked and meticulously edited before being subjected for analysis. Descriptive statistics, regression analysis, PCA (principal component analysis), satellite image analysis using remote sensing and GIS techniques, and narratives were used to analyze the quantitative and qualitative data. SPSS version 20 and psych, FactoMineR and missMDA packages of R-programming language were used to analyze the data. Akin to the data collection method, the details of each analysis method are provided in the respective chapters.

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Chapter Four: Climate Trends and Household's Perception on Climate Change, Its Impacts, and Adaptation Practices

Abstract

Despite a widespread debate regarding the impact of climate change in the Central Rift Valley (CRV) of Ethiopia, little is known about households' perception of the change and its impacts and the adaptation measures they take. This study examined households' perception about climate change and its impacts, types of adaptation practices, and barriers to adaptation. Precipitation and temperature data (1981-2009), household survey, and FGDs were used for this study. A large majority (98.1%) of the surveyed households perceived a change in climate. Regarding the pattern of change, 94.2% and 87.2% of the households believed that temperature had increased and rainfall had declined over the last 30 years, respectively. However, the climate data show no evidence that corroborates the households' claim that rainfall had reduced. Drought, shortage of rain, and change in rainfall timing were the top three climate-related hazards identified to have affected the household. More than three-quarters of the households perceived that drought had resulted in loss of income, loss of assets, death of livestock, reduced consumption, decline in crop yield, and food insecurity. In response to these impacts, households have adopted a wide range of adaptation practices. Lack of knowledge about adaptation options, lack of information on climate, lack of water, lack of money, and shortage of land and labor were perceived to be the barriers to undertake effective adaptation measures. A better understanding of the views of households could serve as a useful entry point to craft policies and interventions aimed at enhancing adaptive capacity and promoting successful climate change adaptation at the local level.

***Key words**: Climate change, perception, impact, adaptation practices, households*

4.1. Introduction

It is now evident that climate change is becoming a major challenge to mankind and that its impacts are more severe in developing countries. It is expected to have serious impacts, particularly on rural households in developing countries like Ethiopia whose livelihoods depend largely on natural resources and rainfall (Davidson et al., 2003a; Morton, 2007; Thomas & Twyman, 2005; Thomas et al., 2007; Maharjan et al., 2011; Pramova et al., 2012). A high dependence on natural resources and rain-fed agriculture in Ethiopia coupled with high poverty, high population growth, inadequate institutional capacity, and limited capital to invest in adaptation means that any change in the

environment affecting resource availability will result in distress (Thomas & Twyman, 2005; MEF, 2015). This in turn means that such livelihood systems increase the vulnerability of rural households to the adverse effects of climate change (Thomas & Twyman, 2005; Thomas et al., 2007; Mertz et al., 2009).

Consequently, the high vulnerability of people in Ethiopia as well as in Africa is attributed largely to their greater dependence on climate sensitive sectors and limited capacity to adapt to a changing climate (Thornton et al., 2006; Hassan & Nhemachena 2008; Glantz et al., 2009; Addisu et al., 2016). Therefore, improving the adaptive capacity of rural households in Ethiopia and elsewhere in Africa as well as other developing countries with similar conditions is essential in order to reduce vulnerability and thwart the negative impacts of climate change (Osman-Elasha et al., 2006; Engle & Lemos, 2010; Nantui et al., 2012; Penalba & Elazegui, 2013; Lemos et al., 2013).

The semi-arid parts of the CRV is one of the most vulnerable areas in Ethiopia experiencing the brunt of climate change, including high rainfall variability, rising temperature, and frequent drought (Jansen et al., 2007; Biazen, 2012; Belay et al., 2013; Biazen, 2014; Kassie et al., 2014; Belay et al., 2017). Despite some scientific reports and a widespread debate concerning the impact of climate change in the study area, not much is known about households' perception of the change and its impacts as well as the measures they are taking. Thus, we need to understand how the local people perceive, experience, and respond to such changes to guide effective climate change adaptation strategies. A better understanding of how rural households perceive, respond, and adapt to changes in climatic events is also helpful in crafting policies and interventions aimed at building adaptive capacity and promoting successful adaptation to climate change.

Rural households in the CRV already have an in-depth knowledge and experience of the local climate as well as an innate capacity to adapt to changes in climate. They have been able to deal with a fluctuating environment and develop livelihood strategies that, to a large extent, enabled them to cope with and adapt to an erratic climate (Senbeta, 2009; Biazen, 2014; Belay et al., 2017). However, an increase in the pace and magnitude of

climate change in recent years means that local knowledge and experience alone will not be enough to thwart the undesirable effects of climate change. Tersely, it is more likely that climate change will bring new challenges and create conditions beyond households' knowledge and experience (Belay et al., 2017). Thus, additional measures will be needed.

Nevertheless, the knowledge and perception of households should remain the foundation for any local level intervention. While scientific knowledge on the nature and impact of climate change is essential, understanding how it is perceived, interpreted, and handled by the local people is also vital. Such understanding would provide a useful entry point for decision makers and policy analysts to learn how and where to enhance the adaptive capacity of households and to develop appropriate policies and response measures.

Therefore, in order to gain the full engagement of households and become successful in climate change adaptation, interventions and adaptation strategies should focus, at least at the start, on factors that households already judge important (Boissiere et al., 2013). This is central because households' knowledge, perceptions, and beliefs influence the way they respond to climate policies and adaptation measures (Gbetibouo, 2009; Egbe et al., 2014). In addition, there is a growing awareness that scientific knowledge on the causes of climate change is becoming inadequate in providing solutions to the phenomena (Egbe et al., 2014). Thus, the views of the local people need to be considered in climate change initiatives.

This study seeks (1) to observe long-term climate trends (precipitation and temperature) and examine variations, (2) to evaluate households' perception of climate change and its impacts, and (3) to identify the adaptation measures being practiced by households and the factors affecting the adaptation process.

4.2. Data Collection

This study used mainly quantitative data generated from the household survey and climate data. However, qualitative data were also generated and integrated with the

quantitative data to build on their complementarities for cross-checking information obtained from the interviewed households. Studies on perceptions of households on climate change and its impacts as well as adaptation practices were gathered through the household survey and complemented or supplemented by focus group discussions (FGDs). Both structured and semi-structured questionnaires were used as tools to gather data from households and focus group discussants, respectively. Households and FGD members were asked whether they have noticed long-term changes in mean precipitation, mean temperature, extreme climatic events, such as drought and flood, and what impact they have brought on their livelihoods over the past 30 years. They were also asked what adaptation measures they are taking in response to the perceived changes in climate parameters and what barriers they perceive to undertake adaptation practices.

Historical climate data on precipitation and temperature, covering the period from 1981 to 2009, for Langano station were sourced from the National Meteorological Services Agency (NMA) of Ethiopia to observe long-term climate trends and examine variations over the years. Langano station, the nearest meteorological station to the study area, was selected to minimize the impact of spatial variability. The meteorological data were also analyzed and compared with the findings of the household survey in order to ascertain whether households' perceptions of climate change correspond to actual long-term climate trends. This method is often used to confirm local people's assessments (Deressa et al., 2009, Fisher et al., 2010; Egbe et al., 2014) or refute them (Meze-Hausken, 2004; Maddison, 2007, Bryan et al., 2009; Moyo et al., 2012; Boissiere et al., 2013).

4.3. Data Analysis

The quantitative data, i.e., data collected from both the meteorological station and the household survey were analyzed by using the Statistical Package for Social Sciences (SPSS) version 20 and Microsoft excel analytical packages. Simple descriptive statistics such as percentages, averages, standard deviations, coefficient of variations, graphs, tables, and figures were used to present the results. The qualitative data obtained from the FGDs were noted when the consensus among the discussants was reached. The data

captured in this manner were then interpreted and narrated to complement and/or supplement the quantitative data collected from the meteorological station and household interviews.

4.4. Results and Discussion

4.4.1. Observed climate trends

4.4.1.1. Precipitation

The mean annual precipitation observed in the study area between 1981 and 2009 was 679 mm (Figure 4). It varied between 221 mm recorded in 1981 and 1616 mm recorded in 2008. The standard deviation and coefficient of variation were 270 mm and 40 percent, respectively. The mean annual precipitation exhibited an oscillating pattern and hence there was no clear indication of long-term reduction or increase. Apart from some close and below average records in some years (e.g., between 2003 and 2007), reductions in some years were followed by increases in the following years or vice versa.

Analysis of decadal precipitation patterns did not also justify long-term reductions or increases. The first decade of the analysis period (1981-1990) recorded a mean annual precipitation of 667 mm, while the latter two recorded 612 mm and 766 mm, respectively. However, the coefficient of variation increased from the first decade (34.8%) to the second (39.4%) and the latest decades (44.2%). Thus, although precipitation in the study area, in general, is low, problems associated with precipitation may be better explained in terms of high inter-annual and inter-decadal variability and unreliability rather than a mere amount of rainfall.

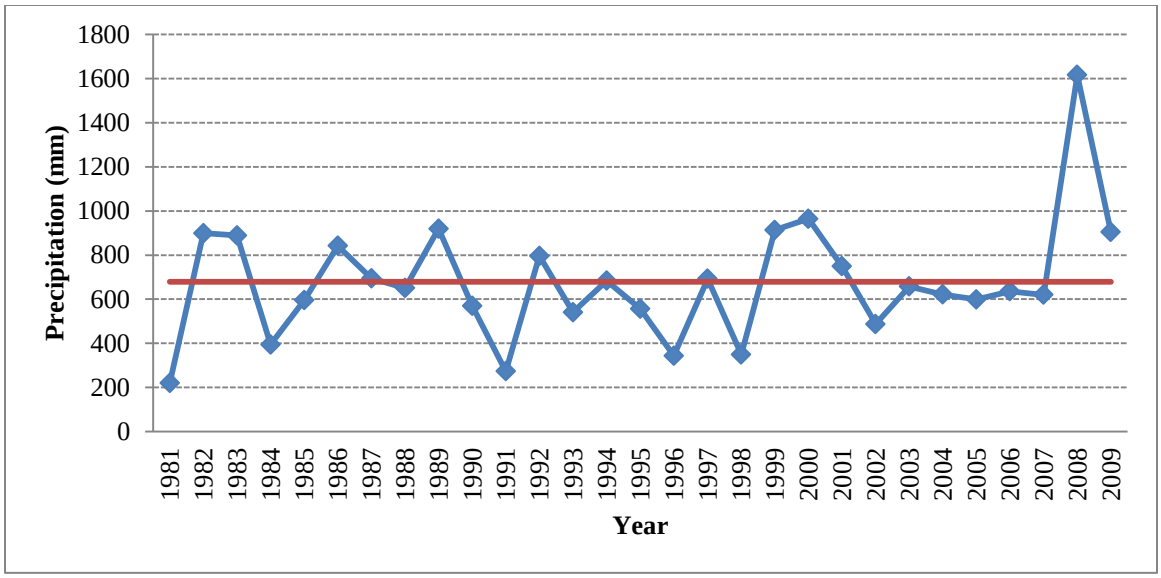

Figure 4 Annual precipitation of the study area (1981–2009), Langano station.

The horizontal line indicates mean annual precipitation for the period 1981–2009.

Source: Data is obtained from the National Meteorological Services Agency (NMA) of Ethiopia; analysis is by the author.

4.4.1.2. Temperature

Analysis of temperature data between 1988 and 2009 yielded a mean annual temperature of 21.4^{o}C for the study area (Figure 5). The mean maximum and minimum monthly temperatures for the same period were 28.7^{o}C and 14.2^{o}C, respectively. The minimum monthly temperatures were more variable than the maximum temperatures, with a range between 11.9^{o}C and 15.8^{o}C, and a coefficient of variation of 7.3 percent. The range and coefficient of variation for the mean maximum monthly temperatures were 27.7^{o}C — 30.8^{o}C and 2.6 percent, respectively. The mean monthly temperatures for the period between 1990 & 2000 and 2001 & 2009 were also calculated to get a glimpse of decadal temperature changes and yielded 21.34^{o}C and 21.69^{o}C, respectively. These figures show that there was a difference of 0.35^{o}C between the two decades and that is probably an indication of a forthcoming warming trend.

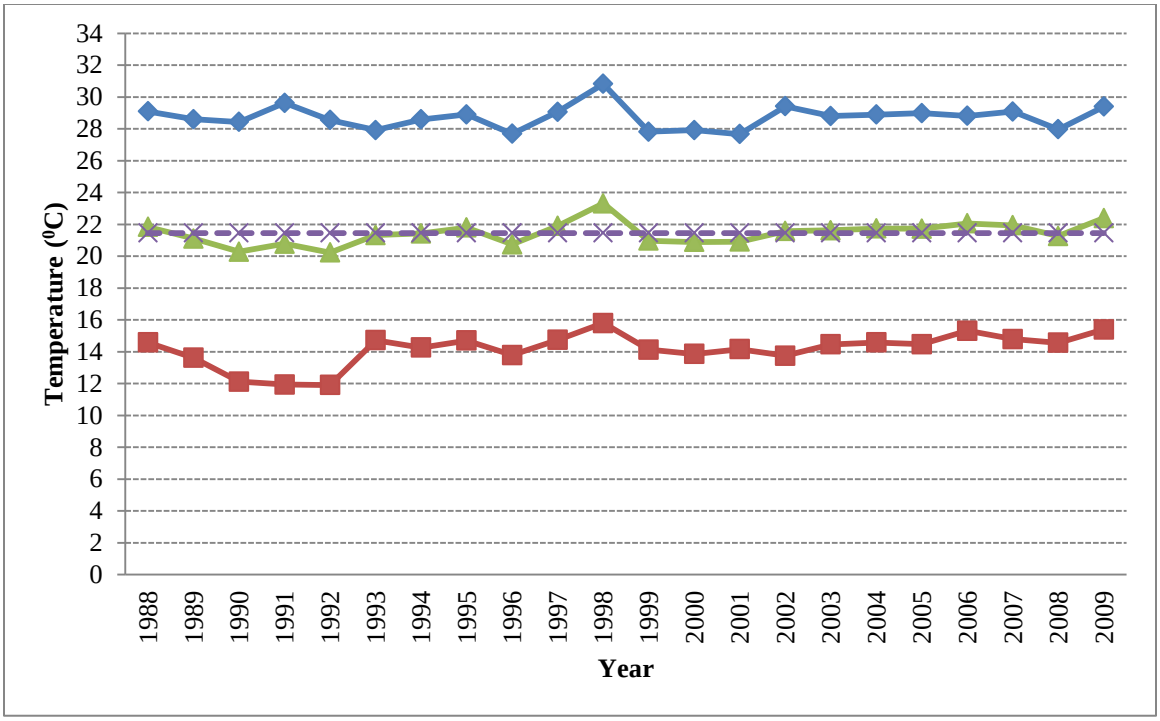

Figure 5 Maximum, minimum and average temperatures in the study area.

The broken line indicates the mean annual temperature over the period 1988-2009.

Source: Data is from NMA; analysis is by the author.

4.4.2. Households' perception of climate change and its impacts

4.4.2.1. Precipitation

A large majority (97.6%) of households interviewed perceived changes in the amount of long-term precipitation over the last 30 years (Table 7). Two households (0.5%) did not perceive changes in precipitation, while another eight (1.9%) were unsure of whether the amount of long-term precipitation had changed or not. Among those who perceived changes in rainfall, 87.2% felt that it had decreased, while 11.1% perceived that it had increased (Figure 6). Moreover, 97.8% of the households witnessed a change in the pattern of rainfall distribution that it had become low and erratic. The unpredictability of rainfall was also partly reflected by the diverse responses of households that 46.3%, 21.8%, 21.5%, and 7.2% of them said rain starts early and stops soon, it starts late and stops soon, it starts early and stops late, and it starts late and stops longer, respectively.

The rest (3.2%) just said that it was erratic. These mixed responses and the high response rate for rainfall pattern change suggest that rainfall had become increasingly variable and unpredictable.

Table 7 Changes in climatic elements perceived by households

Perceived change	Perceived		Not perceived		Not sure	
	Number	%	Number	%	Number	%
Temperature	407	98.5	2	0.5	4	1
Amount of annual rainfall	403	97.6	2	0.5	8	1.9
Pattern of rainfall distribution	404	97.8	3	0.7	6	1.5
Occurrence of drought	392	94.9	17	4.1	4	1
Overall climate	405	98.1	5	1.2	3	0.7

Source: Household survey

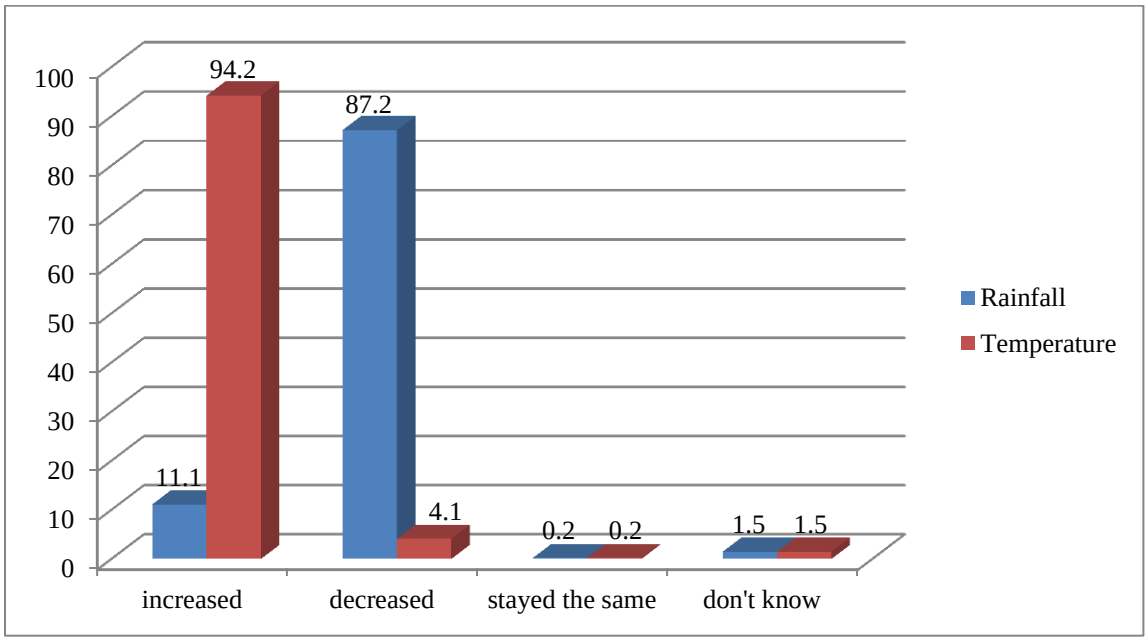

Figure 6 Households' perception of changes in pattern of rainfall and temperature

Source: Household survey

Although the majority of households perceived reductions in the amount of rainfall over the last 30 years the observed precipitation trend does not justify that notion. Such views

of households might have emanated out of discontent that precipitation was so erratic and unreliable that it had become increasingly unsuitable for crop production and livestock raising. It might also be that they compared it with the rainfall pattern of the distant past where they felt that the rainfall was better. A similar view also emerged during the focus group discussions that "rainfall in the past [i.e., in years before the analysis period] was so abundant that there were few months without rain". However, the discrepancies between the perceptions of households and the actual climate data certainly show that local residents lack concrete and up to date climate information.

Both the discussants of the FGD and the interviewed households generally concurred that rainfall in the past was more regular and predictable than it has been in recent years. The FGD members further qualified that rainfall seasons in the past were more distinct than the current ones. This perception of the households and the FGD members that rainfall has become more variable and unpredictable than it had been in the past was supported by the increased variability of rainfall observed between 1981 and 2009. Belay et al. (2017), in a study conducted in the CRV of Ethiopia, also reported a similar finding that rainfall before 20 years was more predictable and regular in the pattern than it had been during the last 20 years. Moreover, Belay et al. (2017) mentioned that rainfall in the past was generally sufficient for crop and livestock production in all seasons and years.

There are also studies which reported similar findings that farmers' perception of rainfall contradicts in some cases with the actual climate data (Meze-Hausken, 2004; Bryan et al., 2009; Moyo et al., 2012; Boissiere et al., 2013; Debela et al., 2015). Despite rainfall measurements showing no downward trend, Meze-Hausken (2004), for instance, reported that the local authorities, farmers, and pastoralists in northern Ethiopia perceived that rainfall was declining. Reasons for divergence were associated with changes in peoples' need for rain or to some other environmental changes that caused water availability to diminish. Similarly, based on meteorological evidence, Debela et al. (2015) refuted households' claim that rainfall in Borena, southern Ethiopia, had declined. Bryan et al. (2009) also reported that farmers in Ethiopia perceived declining rainfall trends while

statistical analysis of long-term rainfall data provides no evidence of a significant reduction.

On the other hand, Gbetibouo (2009), Devkota (2014), and Onubuogu & Esiobu (2014) reported that the perception of farmers on climate variables corresponds with the climate data records. Mengistu (2011) also reported that about 20% of the informants perceived a change in the timing of rainfall, with rains coming either sooner or later than expected rather than a reduction in the amount of total annual rainfall.

4.4.2.2. Temperature

Akin to precipitation, the vast majority (98.5%) of households interviewed perceived changes in long-term temperature (Table 7). The rest were either unsure of the change (1%) or did not perceive changes in temperature (0.5%). Among those who perceived a change in temperature, 94.2% felt that the temperature had increased, while 4.1% felt that it had decreased and a single household (0.2%) felt it had remained the same (Figure 6). The rest (1.5%) were unable to decide on the pattern of increase or decrease in long-term temperature. The views of the majority, which was an increase in temperature, were in line with the observed temperature trend. In general, the views of the people in this study and other similar studies on temperature are more consistent than their views on rainfall (McSweeney et al., 2008; Conway & Schipper, 2011; Tessema et al., 2013; Moyo et al., 2014; Onubuogu & Esiobu, 2014).

4.4.2.3. Drought

Households perceived drought as a persistent problem of the area and about ninety-five percent (94.9%) of the interviewed households responded that they have encountered drought over the last 30 years (Table 7). The FGD participants also identified 1971/1972, 1980/81, 1984/85, 1987/88, 1990/91, 1996/97, 2002/2003, 2009/10, and 2011/12 as drought years. They also explained that the impact of drought in recent years had been softened because of better information, awareness, and government assistance mainly

through productive safety net programs. This, in turn, means that actions were taken before or after the incidence. The drought years identified by the FGD members also coincided well with low rainfall records in the study area (Figure 4).

4.4.2.4. Overall climate

Households were also asked whether they do believe that the overall climate condition of the area has changed over the last 30 years. Almost all the respondents (98.1% of the 413 interviewed households) believed that the climate of the area, in general, had changed and is no longer as it was in the past (Table 7). Only five households (1.2%) failed to see the changes in the overall condition of the climate, while three households (0.7%) were not able to tell about any of the changes in climatic elements. In general, the percentage of respondents for the main climate parameters considered in this study (i.e., changes in precipitation, temperature, and drought) was over 95 percent. This indicates a high level of perception among households in the study area.

The high perception of households to climate change could largely be associated to the agro-ecological setting of the area they are living in (Diggs, 1991; Deressa et al., 2009, 2011; Debela et al., 2015). Diggs (1991), for example, stated that farmers living in areas with more frequent droughts are more likely to perceive a changing climate and its impacts than farmers living in relatively better areas with less frequent droughts. Debela et al. (2015) also reported a high level of perception of climate change (96%) by smallholders living in pastoral/agro-pastoral systems of Borena, which is one of the driest and drought-affected areas in Ethiopia. In general, lowland areas in Ethiopia are drier and experience more frequent drought than other areas (Belay et al., 2005). Therefore, the semi-arid parts of the CRV, where this study is conducted, characterized by the frequent occurrence of drought could have contributed to the high perception rate.

Many studies on assessing farmers' perception on climate change have reported similar findings that farmers had perceived climate change (Meze-Hausken, 2004; Maddison, 2007; Bryan et al., 2009; Mengistu, 2011; Deressa et al., 2011; Maharjan et al., 2011;

Tessema et al., 2013; Boissiere et al., 2013; Devkota, 2014; Egbe et al., 2014; Moyo et al., 2014; Debela et al., 2015; Addisu et al., 2016).

4.4.2.5. Perceived impacts of climate change

Households were first asked whether they have been affected by a serious climate-related hazard over the last 30 years and 92.7% answered that they have been affected. Then, a list of climate-related hazards perceived to have affected them were identified (Table 8) and ranked according to their degree of impact (Table 9).

Table 8 Climate-related hazards perceived to have affected the household during the last 30 years

Type of climate-related hazards	Respondents	Percentage
Shortage of rain	378	98.7
Drought	350	91.4
Change in rainfall timing	340	88.8
Increased temperature	273	71.3
Change in rainfall distribution pattern	250	65.3
Animal disease outbreak	133	34.7
Flooding	94	24.5
Crop pest outbreak	92	24
Human disease outbreak	92	24
Erosion	69	18

Source: Household survey

The survey indicated that the shortage of rain affected many of the households (98.7%), while drought (91.4%), change in rainfall timing (88.8%), increased temperature (71.3%), and change in the pattern of rainfall distribution (65.3%) took the next four positions, respectively. However, in terms of the degree of impact, drought was ranked first and the shortage of rain second. Changes in rainfall timing, increased temperature and change in rainfall distribution pattern took the third, fourth, and fifth positions, respectively.

Table 9 Rank of the top five climate-related hazards by respondents in terms of degree of impact (1-5), with 1 being the most influential hazard

Climate-related hazard	Number	Min.	Max.	Mean	Std. Dev.	Rank
Drought	370	1	5	1.44	.89	1
Shortage of rain	364	1	6	2.26	.81	2
Change in rainfall timing	314	1	8	3.66	1.76	3
Increased temperature	262	1	8	4.08	1.32	4
Change in rainfall distribution pattern	299	1	9	4.49	1.54	5

Source: Household survey

The perceived impacts of the top two climatic factors (i.e., drought and shortage of rain) on the livelihood of the households were also assessed. More than three-quarters (75.5%) of the interviewed households perceived that drought had resulted in a loss of income, loss of assets, a death of livestock, reduced crop yield, reduced consumption, and a shortage of food/food insecurity. The rest (24.5%) of the households perceived a combination of two or more of the impacts listed above.

Likewise, 56.5% of the households perceived that shortage of rainfall had resulted in a similar impact to that of drought, while 43.5% of them perceived a combination of two or more impacts, with the relatively more serious impacts such as loss of assets and death of livestock receiving lower frequencies in the combinations. Much of the similarities in the impacts of the two climatic factors (drought and shortage of rain) could possibly be because of the fact that most of the years with low rainfall records ended up as drought, as explained in the previous section.

4.4.3. Households' adaptation practices and barriers to adaptation

Households' adaptation practices were ascertained by asking them about their perceptions to climate change and then the actions they take to counteract the adverse impacts of climate change. Indeed, a perception of climate change and its ensuing effects is the first step for undertaking adaptation measures (Maddison, 2007) although such practices could

also be undertaken without consciously recognizing that climate change exists or for a different reason (Gbetibouo, 2009; Mertz et al., 2009; Deressa et al., 2009; Onyeneke & Madukule, 2010). Such response measures may also vary depending on the nature of the interaction between social, economic, institutional, and environmental factors (Maddison, 2007; Hassan & Nhemachena 2008; Bryan et al., 2009; Deressa et al., 2011; Maharjan et al., 2011, Piya et al., 2012; Belay et al., 2017). Despite such arguments, however, we assumed that the actions of households are driven by climatic factors, as reported by the households themselves (Maddison, 2007; Nhemachena & Hassan, 2007).

Therefore, households were asked whether they have changed their livelihood strategies/have undertaken adaptation measures as a result of any of the observed climate-related changes. Most of the households (97.6%) responded that they have adapted their livelihood strategies and undertaken different adaptation practices in response to a changing climate. Consequently, a wide range of adaptation practices were found in the study area (Table 10). Adaptation measures practiced by more than three-quarters of the interviewed households include maintaining trees, changing planting dates, using social interconnectedness (social capital), soil conservation, storing livestock feed, changing crop variety, changing crop types, feeding livestock tree parts (leaves, shoots, pods, & barks), temporary sending of livestock to relatives for feed, restoring woodlands, and diversifying crop types.

Most of the adaptation measures mentioned by households are similar to other findings in the climate change adaptation literature (Meze-Hausken, 2004; Maddison, 2007; Hassan & Nhemachena, 2008; Osman-Elasha et al., 2008; Mertz et al., 2009; Onyeneke & Madukule, 2010; Deressa et al., 2011; Mengistu, 2011; Piya et al., 2012; Tessema et al., 2013; Onubuogu & Esiobu, 2014; Ifeanyi-Obi & Nnadi, 2014; Egbe et al., 2014). For example, Bryan et al. (2009) and Deressa et al. (2009) reported tree planting, soil conservation, use of different crops or crop varieties, changing planting dates, and irrigation as the most common adaptation strategies in Ethiopia. Belay et al. (2017) also reported similar adaptation practices of households in the CRV that include changing planting dates, crop diversification, intensive use of agricultural inputs, crop and

livestock integration, supplementary irrigation, soil and water conservation, and tree planting. Irrigation was also mentioned in this study but with a much lower frequency (13.6%), not because of lack of need, which in fact is high, but because of mainly lack of access to water for irrigation.

Table 10 Adaptation practices of households in the CRV

Adaptation Practices	Respondents	%
Maintaining trees for different uses	387	93.7
Changing planting/sowing dates	386	93.5
Using social interconnectedness (social capital) for help	377	91.3
Implementing soil conservation techniques	371	89.8
Storing feed for livestock (grasses, crop residues, etc.)	360	87.2
Changing crop variety	358	86.7
Changing crop types	338	81.8
Feeding livestock the leaves, shoots, pods, & barks of trees	337	81.6
Temporary sending of livestock to relatives for feed	330	79.9
Restoring woodlands	324	78.5
Diversifying crop types	322	78.0
Using more forest products (both for domestic use & sale)	306	74.1
Moving livestock from place to place (pastoralist way)	306	74.1
Reducing meals per day and overall food intake	294	71.2
Storing grains	282	68.3
Receiving aid	251	60.8
Growing trees	250	60.5
Selling livestock	218	52.8
Using inputs such as fertilizer, pesticide, insecticide, etc.	188	45.5
Participating in safety net programs	171	41.4
Changing livestock herd composition	163	39.5
Saving money	161	39.0
Selling wood	138	33.4
Building water harvesting scheme	138	33.4
Reducing number of livestock	128	31.0
Selling charcoal	128	31.0
Borrowing money from relatives	104	25.2
Borrowing money from bank and other institutions	67	16.2
Finding off-farm and non-farm jobs	62	15.0
Using irrigation	56	13.6
Temporarily migrating to urban area	21	5.1

Source: Household survey

However, all these efforts were not enough to attenuate the negative impacts of climate change in the study area and there were barriers to adaptation. Households who did not adapt and those who think that their adaptations were not sufficient and would like to take more efficient adaptation measures mentioned many reasons as barriers to adaptation. These included lack of knowledge about adaptation options, lack of concrete information about climate, lack of water, particularly for irrigation, lack of money for investing on adaptation practices, shortage of land, and a shortage of labor (Figure 7). Figure 7 indicates that lack of knowledge (72.9%) and lack of information (60.5%) were the most important factors hindering adaptation. Maddison (2007), Bryan et al. (2009), Deressa et al. (2009), Onyeneke and Madukule (2010), Tessema et al. (2013), and Onubuogu and Esiobu (2014) also reported similar reasons for farmers who did not undertake effective adaptation measures.

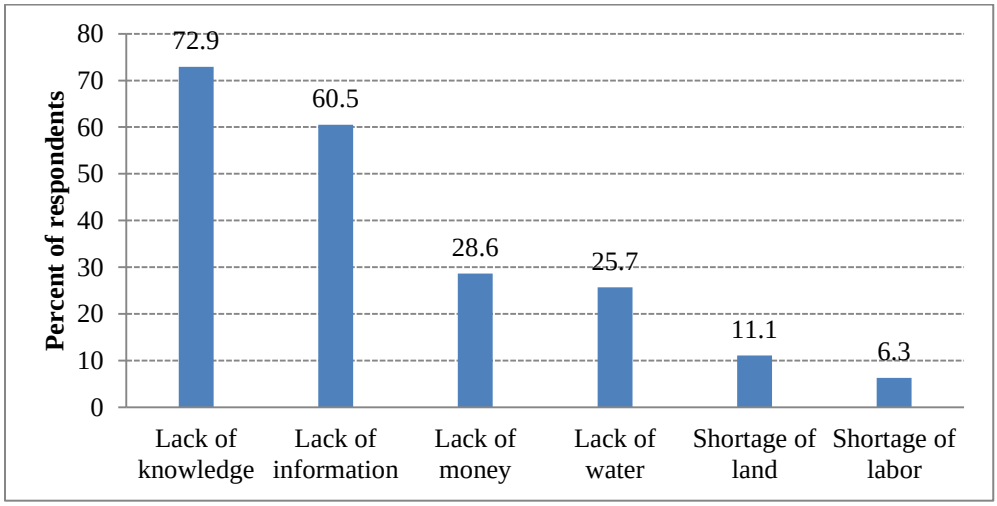

Figure 7 Barriers to climate change adaptation

Source: Household Survey

4.5. Conclusion

The overwhelming majority of the interviewed households had perceived a change in climate and its associated impacts. In response to these changes, an array of adaptation practices is also being practiced. Households perceived reduced precipitation, increased temperature, drought and their impacts. On top of that, they had observed an increase in

the variability and unpredictability of rainfall over the past 30 years. Drought, shortage of rain, and change in rainfall timing were the top three climate-related hazards affecting livelihood. Drought years identified by FGD members coincided well with low annual rainfall records. Moreover, barriers to effective adaptation measures were identified, the most important of which were lack of knowledge about adaptation options and lack of information about climate. Overall, the interviewed households and the focus group discussants believe that the local climate is changing for the worse and that the current adaptation measures are not adequate to thwart its negative impacts.

However, there were also discrepancies between households' perception of certain climate parameters and long-term climate records. While households' perceptions for most of the climate parameters were in line with the long-term climate data records, their perceptions regarding the amount of rainfall were not. They perceived that mean annual rainfall over the past 30 years had reduced but these perceptions were not supported either by the long-term climate trend analysis or by the findings of the focus group discussions.

With regard to rainfall, there seems to be a misconception between reduced rainfall and increased variability and erratic distribution of rainfall. The effect of untimely and erratic rainfall could have made households to think that rainfall had reduced. While different explanations could be given for these differences, households' lack of access to concrete and up to date climate information was, however, clearly evident.

The views of households suggest that people's perceptions of climate change and their adaptation practices provide insights into what they really need to be improved to enhance adaptive capacity and adapt to a changing climate. They could also serve as a useful entry point for development actors and policy analysts to learn how and where to enhance local adaptive capacity and to develop appropriate policies and adaptation strategies. The analysis also shows the importance of combining scientific facts with local people's experiences and opinions so that a more relevant assessment of climate change and adaptation decisions can be made.

Therefore, this study suggests a number of specific interventions that include:

- delivering timely and accurate climate information to the local people,
- raising the awareness (knowledge and skill) level of rural households as well as development agents about climate change and appropriate adaptation practices,
- facilitating availability of credit to be used for investment in adaptation practices,
- investing in yield-improving technologies, both for crop and livestock production,
- investing in irrigation and water harvesting schemes as water is a serious problem constraining crop production in the area,
- creating better opportunities for off-farm and non-farm employment, and
- supporting social networks.

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Chapter Five: Adaptive Capacity of Rural Households to Climate Change

Abstract

The Central Rift Valley (CRV) is one of the most environmentally vulnerable areas in Ethiopia where climate risks seriously threaten the livelihood of smallholders. The ability of smallholders to adapt to the impacts of climate change falls mainly on their adaptive capacity. This paper explores the different components of adaptive capacity of rural households in the CRV and the role of natural assets particularly woodlands in their quest for adaptation. The data were derived from a survey of 413 households selected in four Kebeles – the smallest administrative units– in the CRV. Adaptive capacity of households was assessed using the Local Adaptive Capacity (LAC) framework and measured in terms of both aggregate and composite indices. Normal PCA, Polychoric PCA, and Factorial Analysis for Mixed Data (FAMD) were used to assign weights to the different components of adaptive capacity. The result shows that intangible variables such as institutions and entitlements, knowledge and information, and innovation contributed to adaptive capacity better than decision making and governance, and asset-bases (natural, financial, physical, human and social) combined together. The results also revealed that the adaptive capacity of households in the CRV is generally low with only one of the four study sites, Keraru, scoring a positive adaptive capacity index. Moreover, the composite indices for sub-components indicated that the contribution of woodlands to adaptive capacity was positive and superior to other natural assets. Grazing land was the next best contributor, while farmland and water resources made a much lower contribution. Woodlands form part of the livelihood diversification portfolio and integral source of income and play vital role in the lives of the local people in the CRV. Thus, the findings of this study are useful to better understand the nature of adaptive capacity and its components at household level and guide efforts aimed at enhancing the capacity to adapt to the impacts of climate change. This study suggests the need for an integrated assessment of adaptive capacity with all its components rather than focusing only on asset possessions.

Key words: Adaptive capacity, components of adaptive capacity, woodlands, smallholders, Central Rift Valley.

5.1. Introduction

The ability to adapt to social and environmental changes is central to human wellbeing. Indeed, adaptation to environmental changes has been part of human experience throughout history (DeMenocal, 2001; UNFCCC, 2007; Boko et al., 2007; Wilbanks & Kates, 2010; Munroe et al., 2012). Nevertheless, the scope of challenges posed by environmental disturbances are now unprecedented that additional measures will be required to reduce the adverse impacts of the changes in the near and long-term (Adger & Vincent, 2005; World Bank, 2009; IPCC, 2014a).

Nowadays, it is increasingly accepted that climate change is one of the greatest global environmental challenges likely to have deleterious effects on natural and human systems (Parry et al., 2007; Vincent, 2007). The adverse effects of climate change will be most severely felt by societies in developing countries (Boko et al., 2007; Nkem et al., 2008; Niang et al., 2014). An increasing awareness and a growing concern about the impacts of climate change on human and natural systems has led to a proliferation of scholarly interest in climate change issues particularly since the first IPCC report was published in 1990. The Earth Summit in Rio de Janeiro in 1992 was a landmark international response that subsequently led to the establishment of the UNFCCC in the same year and the adoption of the Kyoto Protocol five years later. The focus of these responses to climate change was on mitigation (reducing the accumulation of greenhouse gases) rather than adaptation (reducing the vulnerability of societies and ecosystems) (Locatelli et al., 2008; Munroe et al., 2012; IPCC, 2014a).

Despite the growing awareness that many regions and groups are increasingly vulnerable, scientific research necessary for encouraging climate change adaptation has been largely disregarded (Burton et al., 2002). However, with some degree of climate change now recognized as inevitable even under the most stringent mitigation scenarios, research and policy debate on adaptation have emerged rapidly in recent years (Smit et al., 2000; Parry et al., 2005; Adger & Vincent 2005; Adger & Barnett, 2009; Swart et al., 2009; Jones & Preston, 2011; IPCC, 2014a). Adaptation research in the context of climate change emerged concurrently with the growing awareness of climate change itself (Smit & Wandel, 2006) although it is still in its infancy (Wilbanks & Kates, 2010). Adaptation is closely associated with the concepts of vulnerability and adaptive capacity (Brooks et al., 2005; Smit & Wandel, 2006; Simane et al., 2016). It is a manifestation of adaptive capacity that is inherent in a system and represents ways of reducing vulnerability (Brooks, 2003; Brooks et al., 2005; Smit & Wandel, 2006; Engle, 2011).

Consequently, the success or failure of adaptation is determined by the system's adaptive capacity, for it describes the ability of a system to mobilize resources to prepare for and respond to current or perceived stresses. The capacity to adapt is, therefore, a critical

element of adaptation (Adger & Vincent, 2005; Smit & Wandel, 2006, Wall & Marzall, 2006; Engle, 2011). Thus, adaptive capacity constitutes the underlying conditions and processes that enable adaptation (Nelson et al., 2007; Newman, 2013).

Conversely, adaptive capacity is a latent property of an individual, community, or social-ecological system, which is activated in response to a crisis or opportunity (Engle, 2011). It is, therefore, necessary to understand, assess, and increase the individual or community's adaptive capacity in order to facilitate adaptive action and moderate the effects of climate change (Brooks & Adger, 2005; Jones et al., 2010; Nantui et al., 2012).

However, despite a number of recent attempts to both conceptualize and evaluate adaptive capacity at various levels, efforts to assess adaptive capacity are in their relative infancy (Vincent, 2007; Jones et al., 2010; Engle, 2011). Little research and analysis has been done on adaptive capacity particularly at household level, despite influential decisions affecting local and system vulnerability being made at this scale (Jones et al., 2010; Elrick-Barr et al., 2014). There is a little understanding of adaptive capacity (Magnan, 2010) and scientific knowledge especially on the dimensions of adaptive capacity is not sufficiently developed (Mendis et al., 2003; Vincent, 2007; Magnan, 2010; Elrick-Barr et al., 2014; Lockwood et al., 2015). Likewise, there are only a few frameworks currently for studying the processes and determinants of adaptive capacity in detail at local level (Jones et al., 2010; Magnan, 2010).

Woodland is also one of the natural assets whose crucial role in adaptation has gained significant momentum only recently (Locatelli et al., 2008; Pramova et al., 2012; Hargarten, 2013). Thus, very few studies exist across the globe (Pramova et al., 2012) and in Ethiopia that measures household level adaptive capacity and assesses empirically the role that woodlands play in the process of adaptation. Most of these studies are either macro in scope or regional level and hence they cannot capture the unique nature of local level adaptations as well as hindrances to adaptation. This study fills this gap by focusing on the understanding of adaptive capacity at the household level and by assessing the contributing factors.

Therefore, the aims of this paper were to identify the different components of adaptive capacity, to assess the adaptive capacity of rural households, and to quantify the role of natural assets, particularly woodlands, to adaptive capacity in four selected sites of the CRV of Ethiopia, which is one of the most environmentally vulnerable areas in Ethiopia.

5.2. Data collection

This study is based on the primary data collected by household survey conducted from October 2013 to February 2014. A total of 413 households (17.4% of the total households) from four selected *Kebeles* (Dakka Hore Qello, Gale Qello, Shalla Billa, and Keraru) were involved in the survey. All *Kebeles* used to be covered by woodlands. Moreover, according to the Livelihood Atlas of Ethiopia, these *Kebeles* fall in three different livelihood zones (MOARD, 2011). Dakka Hore Qello and Keraru fall under the Rift Valley Maize and Horse Bean zone, while Gale Qello and Shalla Billa fall under Siraro Kofele Potato and Vegetable zone, and the Abjata-Shalla-Jido Agropastoral zone, respectively.

A questionnaire was developed in such a way that addresses the different components of adaptive capacity and administered through face-to-face interviews. Accordingly, a total of sixty representative indicators distributed across five major components and subcomponents were used.

5.3. Data Analysis

5.3.1. Analysis of dimensions and indicators of adaptive capacity

Adaptive capacity has been considered as an emergent property of the five livelihood assets in many literatures (Adger & Vincent, 2005; Vincent, 2007; Daze et al., 2009; Dulal et al., 2010; Elrick-Barr et al., 2014). However, assessments based only on livelihood assets have been criticized for their failure to consider important contextual

information (Park et al., 2012) and the underlying social and institutional processes that create capacity (Elrick-Barr et al., 2014). This study included four other dimensions in addition to the livelihood assets, as described in the conceptual framework.

Therefore, the major dimensions considered in this study are asset base (natural, physical, financial, human and social assets), institutions and entitlements, knowledge and information, innovation, and flexible and forward-looking decision-making and governance. Relevant indicators have been included to assess each dimension and provide a more complete picture of adaptive capacity at the local level. The components and sub-components of adaptive capacity and their respective indicators are presented in Table 11.

The indicators are not necessarily specific to climate-related hazards only but are also relevant in addressing other challenges such as food shortages. In a nutshell, they do assist households to build their capacity and overcome the impacts of climate-related hazards through risk pooling, risk distribution, or as a buffer during extreme climatic conditions. A detailed explanation of how each of the components was interpreted against the framework and the relevance of each indicator in enhancing the adaptive capacity of households in the face of a changing climate is provided in the sections below.

5.3.1.1. Asset base

The capacity of households to cope with and respond to changes in climate depends heavily on access to, and control over key assets (Daze et al., 2009). Asset base in this study is considered as one of the five major dimensions of adaptive capacity which itself is represented by a combination of five key assets: natural, physical, financial, human and social assets. Availability and access to these assets will allow the system to respond to evolving circumstances. The indicators used to measure each asset type and their descriptions are presented.

5.3.1.1.1. Natural Assets

The natural asset is represented by four sub-components: farmland, grazing land, woodland and water resources. The productivity of farmland possessed by households rather than mere size is taken as an indicator of farmland asset as it implies to crop productivity. A higher share of more productive farmland means the production of more food and ultimately better adaptive capacity. Thus, households having a higher share of productive farmland compared to those possessing a higher share of less productive farmland will suffer less from climate-related hazards.

Livestock is another important asset in the area. Availability and access to grazing land are therefore important aspects considered in the analysis. Grassland and wooded grassland are considered as grazing lands although savannah woodlands are also used for grazing. This is intentionally done to avoid duplication of assets considered as woodlands are treated separately. Similarly, access to woodlands and size of woodland owned were considered in the analysis as the lives of the local people are intimately associated with woodlands. Lastly, water is a critical resource in the study area both for domestic consumption and agriculture. Hence, access to water resources and quality of water for domestic use is assessed as one of the important natural assets.

5.3.1.1.2. Physical Assets

Indictors for the physical asset are the type of house, ownership of mobile phone and radio, access to electricity, agricultural tools, walking distance to the nearest road and irrigated land. Possession of better quality house, besides being used as an indicator of socioeconomic status, will improve the capacity of households to withstand the risks from extreme climate conditions. Ownership of mobile phone and radio will increase adaptive capacity by creating access to the market, weather, and climate-related information. Access to electricity, among many other benefits, will allow better functioning of radios and mobile phones thereby improving access to information relevant to the livelihood of households. Better information will enable households to

make informed decisions particularly on their farming activities and to take proactive adaptation measures against climate-related risks.

Distance to the nearest road is associated with many other services such as extension service and market for livestock, crops, and other commodities. For example, households living far from the main road or from market centers will find it difficult to sell livestock and they often compromise the price because of the distance factor. They also have less chance of generating income from alternative sources such as non-farm labor which is important in securing livelihood particularly during periods of crop failure or drought. Moreover, it means poor access to extension service and agricultural inputs such as fertilizer and improved seed as the service centers are often located at the road-sides. Greater distance from main roads also means limited travel and hence limited access to information as marketplaces are also informal gathering places for information exchange. Hence, walking distance from the main road is assumed to be inversely related to the adaptive capacity of households as far distances will put them in a disadvantageous position.

Higher possession of agricultural tools is associated with more secured and higher agricultural production. Likewise, more share of irrigated land means more secured production and lesser dependence on natural rain which is becoming more unreliable with climate change.

5.3.1.1.3. Financial Assets

Indicators of financial assets include gross annual income per capita, livelihood diversification index, remunerative income sources, household savings, loans received and ownership of livestock.

Gross annual income is derived from both cash and non-cash income sources. Higher gross annual income per capita implies greater availability of resources at disposal to overcome adversities and make a better living. Along with the amount of annual income,

it is imperative to consider the sources from which these incomes are derived as some economic activities are more sensitive to climate-related events such as drought or shortage of rain. For example, if much of the income is derived from only farming activities, then annual income will be adversely affected during bad years. Conversely, if income is derived from many sources, then the risk will be distributed among the sources and allows households to switch among the economic activities when needed. This aspect of income is captured by constructing Livelihood Diversification Index (LDI). Higher LDI means more options to switch from one activity to another and adapt better to the challenges posed by climate change. Herfindahl index of diversification is used to calculate the LDI of households using the following formulae (Kimenju & Tshirley, 2009).

$$D_k = 1 - \sum_{i=1}^{N} \left(S_{i,k}\right)^2$$

Where D_k is the diversification index, i is the specific livelihood activity, N is the total number of activities being considered, k is the particular household, and $S_{i,k}$ is the share of i^{th} activity to the household income for the k^{th} household.

LDI provides an indication of how diversified the livelihood sources are. However, it does not elucidate the nature of diversification, i.e., whether the diversification is within farming activities or goes far beyond farming (non-farming activities). For example, households whose income sources depend more on natural resource-related activities such as agriculture and livestock will bear greater risk to climate vagaries compared to those who depend on salaried jobs as one of their income sources.

Therefore, remunerative income sources that include salaried job, skilled non-farm job, remittance and safety net transfers were considered as one of the indicators of financial asset. Incomes from these sources are less affected by climate and hence improve the capacity to adapt to climate risks. Besides income at disposal, savings and loans obtained from various sources can be used to make productive investments that in turn are important to build their capacity in the long run and to use it as a buffer during times of

need. For households in the CRV, livestock is an important source of cash income. They keep them as a buffer to sell during times of stress, to generate income to make productive investments or to pay back loans. Thus, available livestock is converted into Tropical Livestock Unit (TLU) and considered as one of the financial assets.

5.3.1.1.4. Human Assets

Highest qualification in the household, number of training attended by household members, the health status of the household, and dependency ratio represented the human asset. While health status directly influences the productivity of households, formal education and training sharpen up their thinking and skill to be more creative and get involved in different activities including non-farming activities, which are less sensitive to climate risks. This will enable them to diversify their livelihood portfolios and increase their income, which in turn are important to buffer and avert climate risks. Dependency ratio implies to the available productive labor force in the household, higher ratio implying more burdens on the earning members thereby reducing the capacity to adapt to the impacts of climate change and vice versa.

5.3.1.1.5. Social assets

Indicators for the social asset are identified to represent both structural (organizational density, networks and mutual support organizations, exclusion, and previous collective action) and cognitive (solidarity, trust and cooperation, and conflict resolution) social assets. As a result, a total of ten indicators were identified. These are number of memberships in community-based organizations (CBO's), presence of networks and mutual support organizations that organize work together in dealing with problems affecting their village, access to credit through social contacts, presence of exclusion, if any, number of collective actions taken to address a common issue during the past year, getting support from the community when needed (when suffering from shocks or stresses), trust among one another in matters of borrowing and lending, looking out for

the welfare of one another, tradition of cooperation in farming activities, and the presence of people or institutions resolving dispute.

An overall positive outcome from these indicators will improve the adaptive capacity of households. For example, the number of membership in CBO's will improve the households' social networks and access to information through their contacts with different stakeholders during meetings. There are also public wells, public stand-pipe waters and communal woodlands managed jointly by the members of the CBO's which can pool risks across the households in the community. Access to credit through social contacts helps households cope with seasonal food shortages or to make some productive investments. The credit could be either in kind or in cash or both. It is often repaid by selling livestock, woodland products or agricultural produce. It is important in rural areas where formal credit and saving institutions are not easily accessible. So, better access to credit implies better adaptive capacity. Other indictors of the social asset will also have a similar impact on adaptive capacity.

In the aggregate, as Woolcock and Narayan (2000) stated, the common aphorism that "it's not what you know, it's who you know" sums up much of the conventional wisdom regarding social capital and its role in adaptive capacity. It is wisdom born of experience that when people fall on hard times, they know it is people whom they know well and are close to them (friends, families, neighbors, associates etc.) that constitute the final safety net to rescue them. Intuitively, then, social capital constitutes an important asset that can be called on during adversities, enjoyed for its own sake, and leveraged for material gain (Woolcock & Narayan, 2000).

5.3.1.2. Institutions and entitlements

The existence of an appropriate and evolving institutional environment that ensures fair and equitable access and entitlement to key resources and assets is a fundamental feature of adaptive capacity. Access to and control of assets is mediated mainly through local institutions and entitlements, or claims (Jones et al., 2010). Therefore, the presence of

local institutions and informal organizations that ensure equitable access and entitlement to key resources, active participation in the decision-making process and empowerment and voice to generate opportunities as a basis for adaptation are key elements of the characteristic. In order to capture these aspects of the dimension, number of the most important formal and informal local organizations that the livelihood of the household depends on, the number of local institutions relied upon during times of climate hazard, equitability of access provided by local institutions in times of climate hazard, regulation of access to key resources, fairness of access to key resources, dependence on outside support from local institutions, and existence of restraining local rules and norms from undergoing adaptation strategies were considered in the analysis.

5.3.1.3. Knowledge and information

For households to properly respond to climate-related changes, they need to have the necessary knowledge and information. The ability of a system to collect, analyze and disseminate knowledge and information in support of adaptation activities is, therefore, an important feature of adaptive capacity. Thus, knowledge and information on adaptation strategies, adequacy of knowledge and information, and availability of systems for data gathering, information analysis, and dissemination in relation to climate-related hazards relevant for the area were assessed.

5.3.1.4. Innovation

The system's ability to foster innovation, support new practices and take risks is a key characteristic of adaptive capacity. An enabling environment that fosters innovations, experimentation, and the ability to explore niche solutions in order to take advantage of new opportunities is essential to enhance adaptive capacity. Therefore, adoption of new practices, taking risks and exploiting new opportunities, ability and willingness to adapt, and access to new and improved technology were pulled together to assess the innovative ideas and practices of households.

5.3.1.5. Flexible and forward-looking decision-making and governance

The anticipation of, incorporation, and response to changes with regards to governance structures and future planning are important aspects of adaptive capacity. Accordingly, informed decision-making, transparency, and prioritization each form key elements of adaptive capacity at the local level. Ten indicators are identified in order to capture all these aspects of decision-making and governance. These include formal organization's access to relevant climate-related information in guiding policy and decision-making, their capacity to deal with climate-related challenges, provision of support to households to adapting to any observed changes in climate, developing plans to help households deal with the changes, learning from past experience in making decisions, taking the right measure, flexibility in decision-making processes in responding to new threats posed by climate-related changes, systems for reviewing and adjusting priorities, transparency in decision-making, and availability and implementation of regulations to protect natural resources and enhance their contributions to the livelihood of households.

Table 11 Dimensions and indicators of adaptive capacity

Component indicators		Description of the indicators	Measure	Hypothesized relation
Asset Base	**Natural assets**			
	- Farmland	Share of more productive land possessed	% of total	+
		Share of less productive land possessed	% of total	-
	- Grazing land	Access to grazing (yes/no)	Categorical	+
		Size of grazing land	Number	+
	- Woodland	Ownership of woodland (yes/no)	Categorical	+
		Size of woodland	Number	+
	- Water	Access to water resources (1. Very scarce 2. Inadequate 3. Adequate 4. Very adequate 5. Plenty)	Ordinal	+
		Quality of water (1. Very poor 2. Poor 3. Medium 4. Good 5. Very good)	Ordinal	+
	Physical asset	Type of house (1=rent/no house; 2=thatch roof; 3=tin roof; 4= both thatch roof and tin roof	Ordinal	+
		Have radio (yes/no)	Categorical	+
		Have mobile phone (yes/no)	Categorical	+
		Have access to electricity (yes/no)	Categorical	+
		Walking distance to the nearest road	Hours	-
		Agricultural tools	Birr	+
		Irrigated land	% of total	+
	Financial asset	Gross annual income per capita	Birr	+
		Livelihood Diversification Index	Number	+
		Remunerative income sources	Birr	+
		Total household savings	Birr	+
		Total loan received by the household	Birr	+
		Ownership of livestock	TLU	+
	Human asset	Highest qualification in the household	Years	+
		Trainings attended by household members	Number	+
		Health status of the household (1. Very poor 2. Poor 3. Fair 4. Good 5. Excellent)	Ordinal	+
		Dependency ratio	Number	-
	Social asset	Memberships in CBO's	Number	+
		Network & mutual support organizations (yes/no)	Categorical	+
		Access to credit through social contacts (1. I need but no access, 2. I do not need credit, 3. I use credit)	Categorical	+
		Exclusion (1. Not at all 2. Somewhat 3. Very much)	Ordinal	-
		Collective action (1. Never, 2. Once, 3. Twice, 4. Frequently)	Ordinal	+
		Support from the community (yes/no)	Categorical	+

		Trust in matters of borrowing and lending (1. Do trust 2. Do not trust)	Categorical	+
		Looking out for the welfare of one another (Strongly disagree 2. Disagree 3. Neither agree nor disagree 4. Agree 5. Strongly agree)	Ordinal	+
		Cooperation in farming activities (yes/no)	Categorical	+
		Resolving dispute (1. No one; people work it out between themselves, 2. Partly with the help other people 3. With the help of other people	Categorical	+
Institutions and entitlements		Formal local organizations	Number	+
		Informal local organizations	Number	+
		Local institutions relied upon for support during times of climate hazard	Number	+
		Equitability of access to the support provided by local institutions (yes/no)	Categorical	+
		Regulating access to key resources during times of climate hazard (yes/no)	Categorical	+
		Equitability of access to key resources (yes/no)	Categorical	+
		Dependence on outside support from local institutions (yes/no)	Categorical	-
		Restraining local rules and norms (yes/no)	Categorical	-
Knowledge and information		Knowledge and information on adaptation strategies (yes/no)	Categorical	+
		Adequacy of knowledge and information (yes/no)	Categorical	+
		Systems for data gathering, information analysis, and dissemination (yes/no)	Categorical	+
Innovation		Adoption of new practices (yes/no)	Categorical	+
		Taking risks and exploiting new opportunities (yes/no)	Categorical	+
		Ability and willingness to adjust (yes/no)	Categorical	+
		Access to new and improved technology (yes/no)	Categorical	+
Flexible and forward-looking Decision-making		Access to climate information (yes/no)	Categorical	+
		Capacity to deal with hazards (yes/no)	Categorical	+
		Provision of support (yes/no)	Categorical	+
		Developing plans (yes/no)	Categorical	+
		Learning from past experience (yes/no)	Categorical	+
		Taking the right measures (yes/no)	Categorical	+
		Flexibility in decision making (yes/no)	Categorical	+
		Systems for reviewing and adjusting priorities (yes/no)	Categorical	+
		Transparency in decision making (yes/no)	Categorical	+
		Regulations to protect natural resources (yes/no)	Categorical	+

Source: Author

5.3.2. Analytical tools used to measure adaptive capacity

Once the dimensions and suitable indicators of adaptive capacity are identified, they need to be measured and compared across the study sites. However, assessing adaptive capacity presents a big challenge (WRI, 2009; Jones et al., 2010; Engle, 2011; Elrick-Barr et al., 2014; Lockwood et al., 2015). Adaptive capacity has begun to be explored only recently (Vincent, 2007) and has yet to receive a sustained empirical examination (Brooks & Adger, 2005). Scientific knowledge on the determinants of adaptive capacity is not sufficiently developed (Magnan, 2010) and hence there exists no universal agreement over its features and determinants at a nation, community or household level (Smit & Wandel, 2006; Jones et al., 2010). Consequently, the methods for measuring and characterizing adaptive capacity vary greatly (Engle, 2011).

While identifying the resources underlying adaptive capacity is relatively straightforward, devising measurements or indicators for their variables is a major challenge (Wall & Marzall, 2006; Vincent, 2007). Indeed, adaptive capacity, because of its latent nature, is not amenable to direct measurement (Smit & Pilifosova, 2001; Brooks & Adger, 2005; Jones et al., 2010; Engle, 2011; Lockwood et al., 2015). Yohe & Tol (2002), for example, stated that ‘‘many of the variables cannot be quantified, and many of the component functions can only be qualitatively described’’ (p. 27). The problem is further exacerbated by the fact that our understanding of adaptive capacity and the process that govern it are not fully understood (Vincent, 2007) and that it is location and context specific (Smit & Wandel 2006; Daze et al., 2009; Magnan, 2010; Engle, 2011; Elrick-Barr et al., 2014; Field et al., 2014).

Although controversial, one popular tool for empirically assessing adaptive capacity is the construction of indices (Vincent, 2007). Indicators and indices are useful for encapsulating a complex reality into simple terms and allowing comparisons across space and/or time (Vincent, 2004). Doing so requires that the individual indicators for each determinant be aggregated to a determinant value and then the determinant values are

aggregated into an overall index of adaptive capacity. The main hurdle in this exercise, however, is that each individual indicator that makes up the determinant has disparate units. These values need to be normalized in order to make valid comparisons (Vincent, 2004; Swanson et al., 2007; Gbetibouo & Ringler, 2009; Nelson et al., 2010). Nevertheless, there are myriad ways for normalizing values of disparate units including the one used by the United Nations Development Program (UNDP) to annually report the Human Development Index (Vincent, 2004; Swanson et al., 2007) albeit normalization is often done by subtracting the mean from the observed value and dividing by standard deviation for each indicator.

$$Normalized\ value = \frac{Observed\ Value - Mean}{Standard\ Deviation}$$

Constructing the adaptive capacity index requires that weights be assigned to each indicator. Assigning weights to indicators is often done in three different ways: equal weighting, expert judgment and Principal Component Analysis (PCA) (Vincent, 2007; Piya et al., 2012). Some researchers follow equal weighting (Vincent, 2004; Nelson et al., 2005; Swanson et al., 2009), i.e., each indicator within a determinant is considered to be of equal importance. However, this method of assigning weights may be too arbitrary and lead to either overweighting of some less important indicators or underweighting of the more important ones.

Assigning weights can also be done based on expert judgment (Adger & Vincent, 2005; Vincent, 2007) though this approach is often criticized for being too subjective. It is also constrained by the availability of subject matter specialists or lack of consensus among the experts conducting the analysis (Gbetibouo & Ringler, 2009). Lately, following Filmer and Pritchett (2001), many researchers preferred to use PCA to assign weights (Cutter et al. 2003; Gbetibouo & Ringler, 2009; Nelson et al., 2010; Piya et al., 2012). However, this approach is not also free of critiques the primary one being that it breaks down every category into dummy variables and the use of these dummy variables in the PCA is not justified, as PCA "as is" is only suitable for continuous data (Kolenikov &

Angeles, 2004). Moreover, it is found to be inferior to other methods for analyzing discrete data.

Hence, the study, in addition to the normal PCA, which was used whenever it was found appropriate, used a variant of PCA techniques such as Polychoric PCA and Factor Analysis for Mixed Data (FAMD) to handle the vexing problem of assigning appropriate weights to the indicators of adaptive capacity, as described below.

PCA is one of the oldest and popular statistical methods in multivariate data analysis used to aggregate several indicators into a single measure (Kolenikov & Angeles, 2004). It was introduced in the early 20^{th} century for the purpose of aggregating data (Pearson, 1901; Hotelling, 1933). Initially, it was designed to reduce the dimension of multivariate continuous data which follow a multivariate normal probability distribution. However, since its application in social science in recent years (such as generating the index and assigning weights for different variables which are often designed to measure latent variables) different approaches have been proposed, as most of the social science data are mixed, i.e., they are composed of both categorical and continuous variables.

One of the approaches is changing the categorical variables into dummy variables and treating the data as normal data and run PCA as used by Filmer and Pritchett (2001). The method was quickly accepted and used by World Bank as a vital means of assessing the socio-economic status of a household based on household assets such as electricity, radio, television, telephone, refrigerator, bicycle, motorcycle, car, and facilities such as source of drinking water, source of heat for cooking, toilet type, materials used for flooring, walls, and roofing (Gwatkin et al., 2003).

However, Filmer and Pritchett's (2001) method has got challenges regarding the technicality behind PCA when the variable has more than two factors, i.e., more than one dummy variable per categorical factor is created. This introduces a lot of spurious correlations, i.e., the dummy variables created from the same variable are negatively correlated although the strength of the dependency declines with the number of

categories. When PCA is fit on this kind of data, PCA is getting confused as to whether the main source of common variation is due to the correlation with the variables or due to the correlation among the variables that are created based on the same categorical variable. Moreover, it loses all of the ordinal information, if there were any (Kolenikov & Angeles 2004).

The second approach is to use either polychoric correlation coefficients or the specific scaling of Factorial Analysis for Mixed data (FAMD) to assign weights. The polychoric correlation coefficient is a measure of association for ordinal variables which rests upon an assumption of an underlying joint continuous distribution. It was first proposed by Karl Pearson in 1900. Although its computation was complicated (Pearson, 1900), with the application of software programs, it is gaining importance in recent years.

This study, therefore, used a polychoric correlation coefficient to assign weights when all variables are ordinal. The correlation matrix is then used to fit the PCA. When the data is mixed (quantitative and qualitative) there are two cases. The first one is when the categorical variables in the mixed dataset are dummy variables, the usual PCA is fitted. The second one is when the categorical variables in the mixed dataset are not dummy variables, the categorical variables are transformed into a disjunctive data table through a system called crisp coding and then scaled using the specific scaling of Factorial Analysis for Mixed Data (FAMD). The analysis was done using psych, FactoMineR and missMDA packages of R-programming language. The first principal component always explains much of the variation and hence the first principal component is used for index generation.

5.3.3. Steps for generating adaptive capacity index

The first PCA was performed for the innermost components to produce indices for farmland, grazing land, woodland and water resource. The loadings from these four categories were used in the second PCA to generate an index for the natural asset. Similarly, indices for financial, physical, human and social assets were generated

independently. As a third step, the results of the five assets were used to generate an index for one of the five principal components, the asset base, i.e., the index of the asset base is computed by using the loadings of the five sub-components (natural, financial, physical, human and social assets). In the fourth round of analysis, PCA was used to generate an index for the other four principal components, namely, entitlement and institution, knowledge and information, innovation, and flexible and forward-looking decision-making and governance. Once indices for the five principal components, i.e., asset base, entitlement and institution, knowledge and information, innovation, and flexible and forward-looking decision making and governance are generated, the final PCA (outer most PCA) was run to generate an index for the overall adaptive capacity. The entire process is shown in the diagram below (Figure 8).

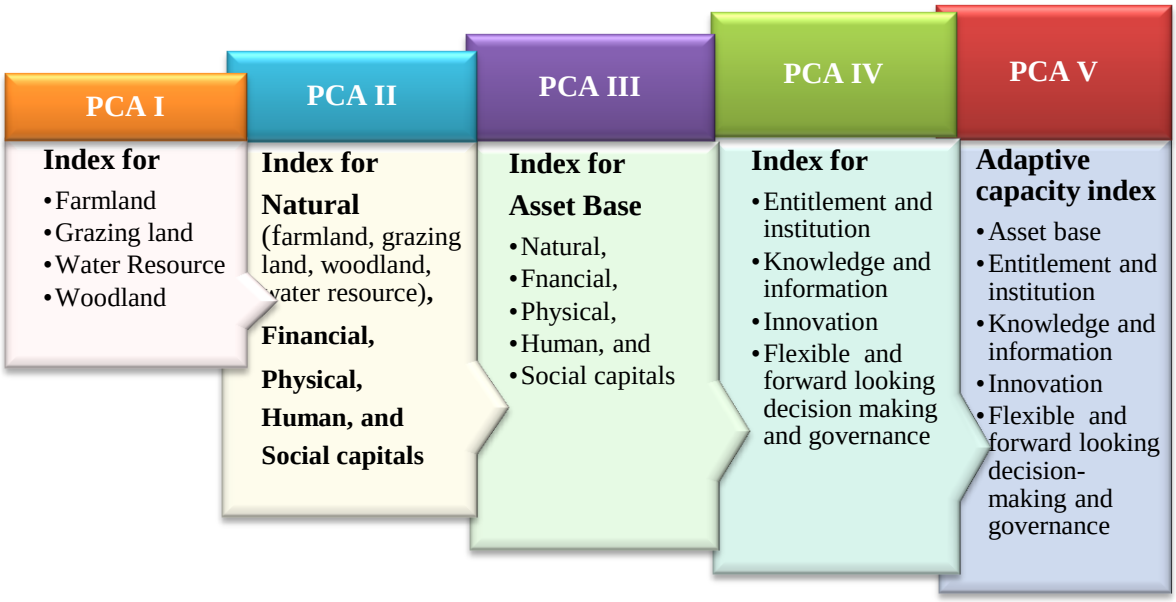

Figure 8 PCA steps for generating index

The loadings from the first principal component are used as weights for the respective indicators. The weights obtained from the first round of PCA are used to generate the index for the next round of indicators and the process continues until the overall index is constructed. The loadings for each indicator varies between -1 and +1 and the sign denotes the direction of relationship with other indicators used to construct the index. The

magnitude of the loadings describes the relative contribution of each indicator to the value of the index. Index for overall adaptive capacity was calculated using the weights (loadings) obtained from the previous PCA run for the five major components (asset base, institutions and entitlements, knowledge and information, innovation, flexible and forward-looking decision-making). The normalized values of the indicators with quantitative dataset are multiplied with the assigned weights to construct the index using the following index formulae:

$$I_j = \sum_{i=1}^{k} b_i \left[\frac{a_{ji} - x_i}{s_i}\right]$$

Where 'I' is the Index Score, 'b' is the loading from first principal component to be taken as weights for respective indicators, 'a' is the indicator value, 'x' is the mean indicator value, and 's' is the standard deviation of the indicators. A higher value of the index indicates higher adaptive capacity and vice versa. However, a negative value of the index does not mean that the household has no adaptive capacity at all, as the index does not give the absolute measurement of adaptive capacity (Piya et al., 2012). It is a relative measure and hence it gives rather a comparative ranking of adaptive capacity among the sampled households. Indices for indicators with only qualitative or mixed datasets are taken care of by the appropriate technique itself, as described in the following section.

5.3.4. Index construction

The aggregate adaptive capacity index of households was generated based on the respective indices of the five principal components: asset base, institution and entitlements, knowledge and information, innovation, flexible and forward-looking decision making of governance. The weight of each component, in turn, is a result of the value of the respective indicators.

The index for asset base was produced based on the respective weights of natural, financial, physical, human, and social assets. The index for the natural asset was generated from four indicators, namely, farmland, grazing land, woodland and water

resource. As indicated in Table 1, the value of farmland was estimated using two variables which are quantitative in nature. The usual PCA is then used to generate the index for farmland. Grazing land and woodland used quantitative and categorical measures. Hence, FAMD is used to estimate their respective indices. The availability and quality of water resources were assessed using ordinal measures. PCA was then run by calculating the polychoric correlation coefficients of the respective variables.

The dataset used to generate the index for the physical asset is mixed (categorical and quantitative) and hence FAMD function of FactoMineR package is used to generate the index. The dataset used for the financial asset, on the other hand, was all quantitative. Hence, the default PCA was run to generate the index. FAMD was also employed to calculate the index for human and social assets, as they used a mixed dataset.

Indicators used to measure the index for institutions and entitlements were both quantitative and qualitative (categorical). FAMD function was then used to generate the index. The rest of the components (knowledge and information, innovation, and flexible and forward-looking decision-making) used categorical variables and hence polychoric PCA is used to generate their respective indices.

5.4. Results and Discussion

5.4.1. Adaptive capacity of households

The structure in which adaptive capacity of households has been measured is presented in Table 12. The five major components, sub-components and indicators, as described in Table 12, were populated with scores obtained from the household data using various PCA techniques. The figures in parenthesis represent weights for the respective components or indicators and signify their relative contribution to aggregate adaptive capacity index. Positive (negative) weights indicate positive (negative) relationships with the other variables used to represent each component or sub-component. The index developed in this study used both aggregate and composite indices. Thus, based on the

loadings of the five major components, an aggregate value of the adaptive capacity index was found while maintaining the transparency in the composite make-up of that value. Composite indices showed the relative contribution of sub-components or indicators.

The analysis reflects that three major components have positive contributions to adaptive capacity, while the rest two have negative contributions. Institutions and entitlements (0.61) have the highest influence on adaptive capacity followed by knowledge and information (0.50) and innovation (0.43). On the other hand, flexible and forward-looking decision-making and governance and asset base made the least contributions with a weight of -0.17 and -0.40, respectively. The proportion of variation explained by the first principal components of all the five components collectively for the overall adaptive capacity index is 42 percent.

Two important lessons can be drawn from this result. The first one is that attention has to be paid to improve the contribution of the low-scoring components such as asset base and decision-making. The second one is that dimensions other than asset base need to get enough recognition in local level adaptive capacity assessments, as demonstrated by components that made positive contributions. Moreover, it is helpful to identify dimensions that are contributing better as well as those that are hampering adaptive capacity.

This study paves the way for a wider and more comprehensive analysis that stretches far beyond analyzing adaptive capacity based only on the five livelihood assets. Including dimensions other than the commonly used asset base sounds more logical as adaptive capacity is multidimensional and determined by complex inter-relationships of a number of factors at different scales as reported by Vincent (2007). Such considerations will open up more rooms for making improvements in overall adaptive capacity.

However, care must be taken not to underestimate the role of assets as they represent the sine qua non of adaptive capacity (Wall & Marzall, 2006). Adaptive capacity is basically dependent on access to resources (Easterling et al., 2004; Adger et al., 2004) and their

availability forms a fundamental platform on which to pursue further understanding of the process of adaptation (Wall & Marzall, 2006). Indeed, a number of studies have adopted assets as direct indicators of adaptive capacity at local levels (Osman-Elasha et al., 2005; Wall & Marzall, 2006; Vincent, 2007; Deressa, 2008; Swanson et al., 2009; Nelson et al., 2010; Piya et al., 2012). They are useful in helping us to understand the resources at the disposal of a system to cope with and adapt to changing environments.

Nevertheless, studies based only on assets mask the role of intangible processes and functions in supporting adaptive capacity (Jones et al., 2010; Elrick-Barr et al., 2014). Assets are so essential that they must not only exist in adequate quantities but the system requiring assets must also be able to mobilize them effectively in the pursuit of adaptation (Brooks & Adger, 2005; Wall & Marzall, 2006). Thus, solely looking at the household's asset base is unlikely to give a complete picture of a system's adaptive capacity. For example, access to and control of assets is mediated through institutions and entitlement (Jones et al., 2010). It is therefore apparent that asset base assessments need to be supplemented with the assessment of the often intangible processes that play an integral part in determining the ability of a system to adapt to shocks and stresses. The findings of this study demonstrate exactly that.

The analysis also highlights the importance of multiple perspectives in assessing adaptive capacity. It provides a new perspective both in terms of the scope of analysis and information regarding adaptive capacity at the local level. While the results of this comprehensive analysis support the arguments of WRI (2009), Jones et al. (2010), Ludi et al. (2012), Elrick-Barr et al. (2014), and Noble et al. (2014), it is difficult to make a direct comparison with the findings of asset-based assessments which has been virtually the norm in previous studies. In this study, asset base, which itself includes the five livelihood assets, is just one of the five principal components used to analyze adaptive capacity. Thus, it can still be possible to make a comparison of the results of other studies with the results of only one of the components of this study, but not directly with the adaptive capacity scores of this study that includes four other major components.

Looking into the PCA results, as is, the first and foremost policy focus for households in the CRV should be to improve further the contribution of components with positive contributions as they are the ones contributing better to the adaptive capacity of households than other components. However, this does not imply that the remaining components are not that important. It rather means that their contributions at the moment are lower and that they can be improved by taking the right measures. Components such as asset base and decision-making and governance are even influencing adaptive capacity negatively. This calls for massive efforts to turn them into positive contributors.

Therefore, the analysis also tells that actions should be taken to improve the contribution of components that are not contributing as much as the households like. It is the system as a whole in an integrated manner that it should function properly to improve adaptive capacity and not one or certain components in isolation. It is, therefore, critical that all components and indicators form an integrated and systematic part of the adaptive capacity of households. Moreover, the adaptive capacity index is showing only the current potential to adapt and it changes with time. Thus, a proactive and flexible position should be envisaged to improve the overall adaptive capacity of households in the CRV.

Table 12 Structure of aggregate adaptive capacity index, composite sub-indices and component indicators

AC	Asset Base (-0.40)	Natural Asset (0.32)	Farm land (-0.43)	More productive land (0.70)
				Less productive land (-0.70)
			Grazing land (0.49)	Access to grazing (0.03)
				Size of grazing land (1.00)
			Woodland (0.70)	Woodland ownership (0.56)
				Size of woodland (0.56)
			Water resource (-0.30)	Access to water (-0.80)
				Quality of water (0.80)
		Physical Asset (0.42)	House type (0.49)	Distance to road (0.06)
			Mobile phone (0.40)	Irrigated land (0.02)
			Radio (0.35)	Agricultural tools (0.29)
			Electricity (0.23)	
		Financial Asset (0.35)	Ann. income/capita (0.68)	Remunerative income (0.59)
			LDI (-0.12)	Loan (-0.13)
			Saving (0.05)	Livestock in TLUs (0.39)
		Human Asset (-0.37)	Education (0.48)	Health status (0.34)
			Training (0.56)	Dependency Ratio (0.00)
		Social Asset (-0.68)	Membership in CBOs (0.49)	Trust in borrowing & lending (0.43)
			Networks (0.07)	Trust in welfare (0.02)
			Access to credit (0.51)	Cooperation (0.05)
			Exclusion (0.11)	Solidarity (0.05)
			Collective action (0.09)	Conflict resolution (0.01)
	Inst. & Ent. (0.61)	Formal organizations (0.65)	Informal organizations (0.51)	Reliable local institutions during hazards (0.04)
		Equitability of support (0.30)	Regulation of resources (0.73)	Equitability of access to key resources (0.12)
		Dependence on outside support (0.03)	Restraining rules & norms (0.34)	
	K&I (0.50)	Knowledge & information provision (0.28)	Adequacy of information and knowledge (0.90)	Systems for data gathering, analysis & dissemination (0.95)
	Innovation (0.43)	Adoption of new practices (0.83)	Taking risks & exploiting new opportunities (0.62)	Ability & willingness to adapt (0.80)
		Access to new and improved technologies (-0.16)		
	Decision-making (- 0.17)	Access to information (0.72)	Capacity to deal with the challenges (0.84)	Provision of support (0.50)
		Developing plans (0.84)	Learning from past experience (0.76)	Taking the right measures (0.82)
		Flexibility in decision-making (0.72)	Systems for adjusting priorities (0.80)	Transparency in decision-making (0.70)
		Regulations to protect natural resources (0.58)		

Source: Author's analysis based on the household survey

5.4.2. Role of woodlands in the adaptive capacity of households

In order to discern the role of woodlands in the adaptive capacity of households it is necessary to look into the make-up of the adaptive capacity index itself. Adaptive capacity index in this study is constructed based on the five principal components in which the asset base is one of them. The score of the asset base, in turn, is constructed based on the loadings of the five assets: natural, physical, financial, human and social assets. The weight of natural asset is also derived from the respective weights of farmland, grazing land, woodland and water resources. Hence, it is in here that we see the contribution of woodland to adaptive capacity via natural asset and asset base in general.

The composite indices derived from the PCA show that the relative contribution of woodlands to natural asset was the highest with a weight of 0.70. It was followed by a positive contribution from grazing land (0.49). However, farmland and water resources have made a negative contribution to the natural asset with a weight of -0.43 and -0.30, respectively.

Ownership of the more productive land has a higher impact in determining the contribution of farmland, while a higher share of less productive land decreases the contribution of farmland to the natural asset. Likewise, the score of water resources is affected by lack of water resources both for agricultural production and domestic use rather than the quality of water already available. This response is a reflection of the fact that water is a critical resource in the CRV as it is semi-arid and natural rain is unreliable. The positive response for the quality of water is largely associated with the water being supplied through the recently installed public stand-pipes that covered most of the study area.

With regard to grazing land, it appears that its productivity in terms of providing the required services rather than its size is a constraint as the size of grazing land receives the highest weight. For woodlands, both indicators, i.e., ownership of woodland and size of woodland, have equal positive weights and contributes better than any of the other three

resources to the natural asset. This, in turn, means that woodlands have a higher impact in determining the contribution of the natural asset to the overall asset base and ultimately to the adaptive capacity of households. Moreover, it implies that woodlands are providing the goods and services expected of them better than the other natural resources considered.

In the analysis, it is reflected that woodlands can play important roles in enhancing the adaptive capacity of households. The high rating of woodland's contribution to adaptive capacity can be associated with the multitude of benefits it provides to the households. Woodlands provide goods and services to the local communities facing climate threats. Almost all households (99%) use woodland products for various purposes. Indeed, the lives of the local people are highly associated with the existence of woodlands. Considering only the main direct roles of woodlands, they provide important safety nets, livelihood diversification, and integral income sources for households.

The safety net function of woodlands is linked with the role they play during periods of hardship such as crop failure due to drought or temporary need for extra income, i.e., when households face unexpected income shortfalls or extraordinary cash need. While their safety net role is considered as part of coping strategies (i.e., in reaction to stress), their role in the diversification of livelihoods constitutes part of the adaptation strategies of households (i.e., in an anticipation of stress) (Vedeld et al., 2004; 2007; Pramova et al., 2012).

The role of woodlands in livelihood diversification has already been accounted in the calculation of adaptive capacity in the form of LDI. It is achieved mainly through the collection of firewood, construction wood, charcoal, timber, fodder, fruits and traditional medicines. Only the first three major woodland products (firewood, construction wood, and charcoal) were considered for the LDI calculation though all were mentioned by the households. For instance, the leaves, twigs, and seed pods of acacia trees are an important source of feed for livestock particularly during long dry spells where grasses are either less or no more available (Figure 9). Similarly, the income contribution of woodlands

was accounted for with the calculation of gross annual income per capita. These functions of woodlands make them relevant for building the adaptive capacity of households.

Figure 9 A farmer shaking acacia trees with a hooked long stick to drop seed pods and feed cattle

Source: Author

5.4.3. Comparison of adaptive capacity

Adaptive capacity index for households was created for cross-household comparison in a rural semiarid setting in the CRV of Ethiopia. Comparison of adaptive capacity across the study areas required the aggregation of indicators into an overall index of adaptive capacity although the composite make-up of index construction is also maintained to display the relative contribution of each indicator. It deemed essential as Ethiopia is promoting a Climate Resilient Green Economy (CRGE) and there remains a policy need for empirical assessment. As Flora (1999, p. 401) stated, “What we measure reflects what we subsequently do”. Moreover, it is apparent that indicators within the national adaptive

capacity index setting do not allow enough sensitivity for differentiation at local levels. The index values for adaptive capacity and its five major components across the four study sites are shown in Figure 10.

The index scores provide the relative position or ranking of the households in their respective *Kebeles* in the study area. Such ranking helps in identifying which *Kebele* is weaker or stronger with respect to a specific adaptive capacity indicator or all indicators in the aggregate. The low index score on a particular indicator suggests the need for specific interventions to improve the adaptive capacity of households. Likewise, the low overall adaptive capacity index indicates that households living in that *Kebele* have on average relatively low adaptive capacity. Accordingly, Keraru is the only one with a positive adaptive capacity index value. The rest have low adaptive capacities. Shalla Billa is the second best in terms of adaptive capacity index, though it is still negative. Gale Qello and Dakka Hore Qello stand as third and fourth in the adaptive capacity index order, respectively (Figure 10).

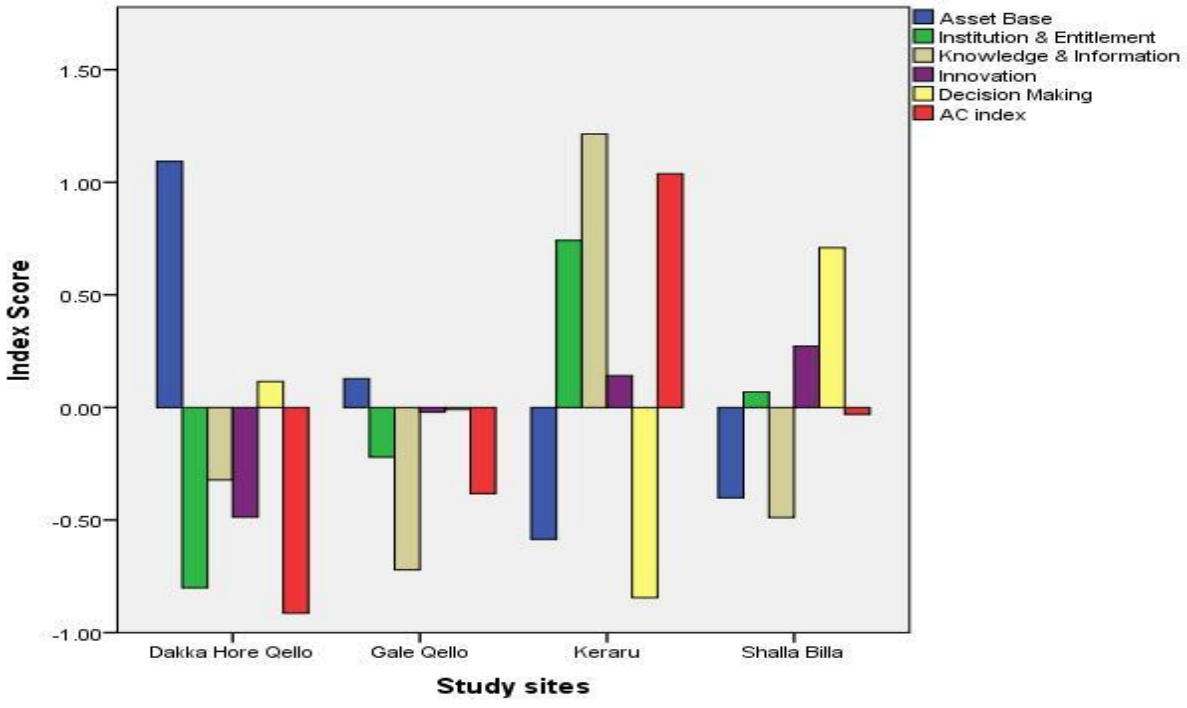

Figure 10 Index scores across the four study *Kebeles.*

Source: Author's analysis based on the household survey

Dakka Hore Qello has positive contributions from two components (asset base and decision-making and governance) and negative contributions from all other components that make it last in the standings. All except one component in Gale Qello scored negative values although it stands third in the adaptive capacity index standings. Although the aggregate adaptive capacity index for Shalla Billa is negative, it has positive scores for three of the components, namely, flexible and forward-looking decision-making, innovation, and institutions and entitlements. Akin to Shalla Billa, Keraru has positive contributions from three components and negative contributions from the remaining two. It fares the best in two of the five components (institutions and entitlements and knowledge and information), second in one (innovation) and last in two components (asset base and flexible and forward-looking decision-making and governance). The highest contributions for Keraru are made by knowledge and information and institutions and entitlements, respectively.

Overall, of all the study sites, Keraru has not only the highest adaptive capacity index but also a positive one. The higher the adaptive capacity of households, the greater is their potential to moderate adverse effects of climate change, and the lower their vulnerability. Therefore, households living in Keraru appear to be in a relatively strong position in terms of the capacity to adapt to climate-related hazards.

The different weights obtained from PCA for the five major components used to assess adaptive capacity of households in four study sites in the CRV indicate that decision-making and policy measures need to be location and context specific even at local levels. For example, according to the National Atlas of Ethiopia, Dakka Hore Qello and Keraru are classified in the same livelihood zone, while adjacent *Kebeles* Shalla Billa and Gale Qello are classified in two different livelihood zones. However, Dakka Hore Qello and Keraru are in the opposite end of the adaptive capacity index ladder while Shalla Billa and Gale Qello are close in terms of adaptive capacity index though Shalla Billa is marginally better. This implies that location and contextual factors can influence adaptive capacity. Keraru is far better than Dakka Hore Qello in three components except two. For

instance, Knowledge and information in Keraru has a weight of 1.21, while it is -0.32 in Dakka Hore Qello. On the other hand, the main difference between Shalla Billa and Gale Qello appears to be because of flexible and forward-looking decision-making which is the highest of all *Kebeles* in the case of Shalla Billa with a weight of 0.71.

Differences in adaptive capacity among the study sites can, therefore, be explained in terms of the specific situations of each site. In Keraru, for example, the relatively easy access to the main road, electrification of some areas and the presence of strong local institutions could have contributed to the highest score of both knowledge and information and institutions and entitlements. Moreover, irrigation is practiced in the area. Had it not been for poor decision-making and governance and asset base, as reflected by their high negative contributions, households in Keraru could have been found in an even better position.

Shalla Billa, on the other hand, has the highest livestock number with an average Tropical Livestock Unit of 9.8 and the highest woodland cover (77%), is second in terms of adaptive capacity. This could be attributed mainly to the higher share of less productive land because of less fertile soils and unreliable rainfall and poor access to market, particularly for livestock. Even though Shalla Billa is considered as one of the most difficult areas for grain production, it seems that decision making and governance has contributed positively for households to overcome the adverse effects of climate change. Among the *Kebeles* selected for the study, Shalla Billa is the highest beneficiary of the Productive Safety Net Program (PSNP) and Keraru is the last.

PSNP beneficiaries are selected by the local administration based on the degree of vulnerability to climate vagaries and rightly so. This is perhaps one of the reasons why the contribution of decision-making and governance is rated as the lowest in Keraru (-0.84) and the highest in Shalla Billa (0.71) albeit it needs further investigation. It also provides further evidence to the one reported by Adger and Vincent (2005) that government policies and local level adaptations are not independent of each other. Indeed, adaptive capacity at the local level is influenced by processes operating at the

higher level (Adger et al., 2004; Daze et al., 2009). The last two *Kebeles*, Gale Qello and Dakka Hore Qello, have no marked differences in terms of the contribution of the different components to adaptive capacity apart from some differences in magnitude.

5.5. Conclusion

This paper began by noting that, despite the need for progress, little research and analysis has been done on adaptive capacity at the local level, community or household level. Many researchers have adopted the 'five capitals' enumerated in the sustainable livelihood framework to asses adaptive capacity. While the availability of assets represents the sine qua non of adaptive capacity and is proven to be a useful starting point, it does not provide enough recognition for processes and functions that are important in mobilizing resources effectively. Thus, in order to capture these elements of adaptive capacity, this study adopted the Local Adaptive Capacity (LAC) framework developed by ACCRA.

Analysis of adaptive capacity of households using the LAC framework has confirmed that adaptive capacity is not only determined by the availability of assets, but also by the processes and functions needed to mobilize these resources. The analysis shows not only components that are contributing better than the others but also those that hamper adaptive capacity. Availability of strong institutions and entitlements to key resources has contributed better than knowledge and information on climate-related issues and adaptation strategies, and innovation. On the other hand, decision-making and governance and asset base have shown negative influences on adaptive capacity.

This analysis of adaptive capacity at the household level based on the selected components sheds some important insights of policy relevance. In the first place, it promotes the need for a wider and more comprehensive analysis of adaptive capacity. Secondly, it helps to guide efforts aimed at enhancing adaptive capacity by providing clues about the relative contribution of components and by indicating where adaptive capacity might be strong or lagging. In this regard, the immediate policy focus should be

geared towards improving the contribution of institutions and entitlements as well as household's knowledge and information to climate-related matters, and innovation, as they are currently making positive contributions.

However, in the long-run, there is a need to put in place concerted efforts to improve the contribution of the low-scoring components since overall adaptive capacity is influenced by the proper functioning of all the components as a system rather than each individual component as a separate unit. Striking the right balance between the components is very crucial. The capacity to adapt is also dynamic and influenced by a range of factors. Ultimately, emphasis should be placed on consistently improving the ability of the system as a whole to overcome the impacts of climate change and to exploit the opportunities presented by the same. Carrying out continuous assessments would also help monitor a household's progress in terms of their ability to adapt to climate-related changes.

Moreover, the results of the composite indices provide further information to stakeholders including policy-makers, researchers, and development actors on which sub-component(s) to focus on and make improvements by unveiling their relative importance to the respective principal components. Each component or sub-component plays its own role in adaptive capacity. Physical, financial assets and natural assets made a positive contribution to the asset base, while human and social assets made a negative one. Furthermore, woodlands made the highest contribution to natural asset followed by grazing land. This indicates the important role that woodlands play to the adaptive capacity of households living in and around the CRV of Ethiopia by improving the contribution of natural asset and then asset base in the aggregate.

The high rating of woodlands is a reflection of their role in providing important safety nets, livelihood diversification and integral income sources for households. These roles are by considering only the direct and main provisioning services and does not include regulatory and mitigation roles. Thus, policy and development interventions should take into consideration the invaluable roles that woodlands play in the CRV and take the

necessary measures to ensure that they are sustainably managed and continue providing vital products and services to the local community.

In addition, comparison of adaptive capacity across the four study sites within the CRV provides another important lesson that adaptive capacity is location and context specific even at local level. Among the four study sites, only Keraru has a positive adaptive capacity and that was mainly because of strong local institutions and entitlements to key resources and better knowledge and information on climate issues including adaptation strategies. This implies that the CRV, in general, has a low adaptive capacity and that attention has to be paid to improve the adaptive capacity of households. Along with measures that need to be taken to improve the contribution of the different components of adaptive capacity addressed in this study, it is suggested that the existing Productive Safety Net program be kept until the adaptive capacity of households is built to the extent that they can absorb any potential climate-related shocks and stresses. Overall, the findings of this paper help stakeholders to better understand the nature of adaptive capacity and its determinants at the household level and consequently to address the various dimensions of adaptation to climate change and design appropriate adaptation strategies.

Finally, it is also believed that this study will provide inputs to the methodological aspects of assessing adaptive capacity at the local level particularly with regard to indicator selection and method of analysis. Although a wide range of variables and indicators are addressed, there are no limits to the number of variables and indicators that can be included in a given study. Researchers can select a suite of variables and indicators depending on the context of the locality under investigation since it is not possible to provide a list of off-the-shelf indicators to capture universal determinants of adaptive capacity at local level. Thus, the indicators listed in this study may not be replicated exactly for other rural households, albeit the logic behind their selection can. A variant of PCA techniques employed in this study such as assigning weights through polychoric correlation coefficient and FAMD can be useful tools particularly for social

science studies where mostly the data is of mixed nature, i.e., both qualitative and quantitative.

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Chapter Six: Woodland Cover Change and Its Impacts on the livelihood of the households and the environment

Abstract

Woodlands, which have been part of the landscape and important source of livelihood for smallholders living in the environmentally vulnerable Central Rift Valley (CRV) of Ethiopia, are experiencing rapid changes. Detecting and monitoring these changes is essential for better management of the resources and the benefits they provide to people. The study used a combination of both quantitative and qualitative methods to analyze the extent and pattern of woodland cover changes from 1973 – 2013, and the impact of the changes on livelihood and natural resources. A pixel-based supervised image classification with maximum likelihood classification algorithm was used for land cover classification and change detection analyses. Accuracy assessment was made for the latest satellite image (2013). Local peoples' perceptions were used to explain the impact of the changes. Four major land cover classes were identified with an overall accuracy of 88.3% and Kappa statistic of 0.81 for the latest image. The analysis revealed a major land cover reversal that woodland (92.4%) was the dominant land cover in 1973, while it is agriculture (44.7%) in 2013. A rapid reduction in woodland (54%) and forest (99%) covers took place between 1973 and 2013, with the majority of the conversions made during the government transition period (1973 to 1986). Agriculture (3,878%) and grassland (11,117%) increased tremendously during the 40-years period at the expense of woodlands and forests. Bare land increased moderately (40%). The local people perceived the impacts of these changes on their livelihood, such as reduced availability and increased price of woodland products as well as on the environment. Thus, woodlands are under threat and their impacts are already being felt. If the current trends of land cover change remains unhalted peoples' livelihoods will be highly affected. Hence, better management modalities need to be in place for woodlands to continue providing vital ecosystem goods and services.

Key words: *Woodland, land cover change, pattern of land cover change, impacts, Central Rift Valley.*

6.1. Introduction

Woodland is land spanning more than 0.5 hectares with trees higher than 5 meters and a canopy cover of 5–10 percent, or trees able to reach these thresholds in situ; or with a combined cover of shrubs, bushes and trees above 10 percent (FAO, 2010). They provide a wide range of economic, social, and ecological benefits, ranging from cultural to tangible economic values (Hergarten, 2013; FAO, 2012). Under proper stewardship, this important capital asset can play a critical role in human livelihood, as well as in ecosystem functioning and health (FAO & JRC, 2012). They are also important to help people adapt to the impacts of climate change (MEA, 2005; IPCC, 2007; Locatelli et al.,

2008). These wide-ranging roles of woodlands have received renewed recognition in recent times (Pramova et al. 2012).

One of the most important changes that the world is experiencing today is land cover change (Lambin et al., 2001, 2003; Hansen et al., 2003; Mayaux et al., 2004; FAO, 2012). Of all land cover changes, forest/woodland cover change or deforestation is one of the oldest and most important changes that people have made to the surface of the earth (Geist & Lambin, 2001, 2002; FAO, 2012). Woodlands are still under threat by various extractive human activities that result in degradation of habitat, land fragmentation, and land use change (e.g., from forestry to agriculture) (Hergarten, 2013). Climate change can also exacerbate these pressures and exert significant negative impacts on the capacity of woodlands to provide vital ecosystem services (Seppälä et al., 2009).

As a result of immense human pressure, the world's forest and woodland covers have been greatly reduced. They used to have once covered about six billion hectares of the earth's land surface several years ago, while they are currently estimated at just over four billion hectares, about 31% of the land surface (FAO, 2010). The same report indicates that net deforestation at the global level occurred at the rate of 0.14 percent per year between 2005 and 2010. During the same period Africa lost 3.4 million hectares of forest annually. This makes Africa one of the largest net losers of forests in the world next to South America which has an estimated loss of around 4 million hectares per year. Forest clearance in Africa is driven mainly by the demand for land for cultivating crops and grazing, and for fuel (FAO, 2012). The heaviest forest losses in sub-Saharan Africa happens in areas where wood is needed for fuel or where forestland is needed for growing crops (FAO, 2010; Chidumayo et al., 2011; FAO 2012). Ethiopia is one of the countries in sub-Saharan Africa experiencing such challenges.

Ethiopia, with a land area of over 1.12 million km^2 and a population of over 100 million people is experiencing huge deforestation rate (Yirdaw, 1996; Zewdu & Hogbeg, 2000; WBISPP, 2004; Dessie & Kleman, 2007; Tefera, 2011) and land cover change (Gete & Hurni, 2001; Garedew et al., 2009; Amanuel & Mulugeta, 2014). For example, the rate of

deforestation in Ethiopia between 2005 and 2010 was reported to be 1.11% per year, which is considerably high as compared to the world's 0.14% and Africa's 0.5% during the same period (FAO, 2010).

Currently, Ethiopia's forest cover is reported to be 11.4% by FAO (2015) and 15% by MEFCC (2016). The FAO (2010) figure (11%) was also very close to the current estimate and it was basically derived from the report of Woody Biomass Inventory and Strategic Planning Project (WBISPP, 2004). In the FAO (2010) report, high forests (i.e. natural forests with tall trees), plantations, and high woodlands were reclassified as 'forest', while low woodlands and shrub-lands were reclassified as 'other wooded land'. In the recent reports of both MEFCC (2016) and FAO (2015), Bamboo forests and dense high woodlands are included as forests.

According to WBISPP (2004), Ethiopia has just over 4 million hectares of high forest (3.56 % of the area of the country), 29.24 million hectare of woodland (25.5%), and 26.4 million hectares of shrub-land (23.1%). Acacia woodlands cover about 55% of the total woodland area, i.e., more than the other types of woodlands altogether (Eshete, 1999). Acacia woodlands are mainly concentrated in the lowlands of the Rift Valley (Eshete, 1999; Gebrekirstos et al., 2008) and are the climax vegetation of the area (WBISPP, 2004).

Indeed, Acacia woodlands have been one of the characteristic features of the landscape of particularly the CRV and important source of livelihood for the people living in and around the area. They provide a wide range of goods and services for the local people and the nation at large. For example, the majority of charcoal that is being used by the citizens of Addis Ababa, Ziway and Adama towns is coming from the CRV woodland (Eshete, 1999; Alem et al., 2010). For the rural people living in the CRV, the Acacia woodlands are used to obtain alternative means of livelihood (Ayele & Gemechu, 2009). They are also a major source of income and a contingency food particularly during crop failures which are not uncommon due to shortage and uneven distribution of rainfall, drought, high rate of evapotranspiration and shortage of rivers and streams which can be

used for irrigation (Garedew et al., 2009; Biazen, 2012). Moreover, woodlands can play an important role in improving the adaptive capacity of the people (Chidumayo et al., 2011). These socio-economic contributions of woodlands are in addition to their ecological roles in safeguarding the fragile ecosystem of the CRV area (Eshete, 1999; Jansen et al., 2007).

Several studies have been conducted in Ethiopia to examine forest decline and land-use and land-cover changes. However, very few have attempted to address land-use and land-cover issues in the center of the Main Ethiopian Rift (MER) (Muzein, 2006; Dessie & Kleman, 2007; Garedew et al., 2009; Tsegaye et al., 2010; Meshesha, 2012; Biazen, 2012). Most of these studies were carried out either far away from the main CRV or focused on overall land rather than woodland cover changes. The later entails the need to have woodlands at least in the past.

For example, Garedew et al. (2009) reported an 85% and 100% reduction in woodland cover of Keraru and Gubeta-Arjo *Kebeles* between 1973 and 2000, respectively. Biazen (2012), on the other hand, reported that the total land area cover by both dense and scattered Acacia stands decreased from 77% in 1965 to 40% in 2010. However, their datasets for woodland assessment in the main CRV area were relatively small and all the sites they studied were found close to the main road that extends from Addis Ababa to Hawassa and Moyale towns. Garedew et al. (2009) covered 4.4 km^2, while Biazen (2012) covered 6.3 km^2 areas in their respective study sites and the western part of their study sites where it is relatively far from the main road and supposed to have better woodland cover was not included. Moreover, parts of Gubeta-Arjo fall in the Midlands were woodlands cannot grow. Hence, in order to get a better view of woodland changes in the main CRV area this study included all areas between the three Lakes (Langano, Abijata, and Shalla). Continuous monitoring of changes in woodland resources even in areas covered by previous studies is also important for better management and decision-making.

This paper tries to answer the following questions: (1) how have the woodland resources changed over time? and (2) what impacts do woodland changes pose on the livelihood of the local people and the surrounding natural resources?

6.2. Data Collection

Remote sensing and GIS techniques and field observations were used in order to analyze the extent and pattern of woodland cover change over the last forty years (1973 – 2013). Socioeconomic survey at household level was conducted to examine people's perception towards woodland changes, the impact of these changes and their drivers. Focus group discussions and key informant interviews were conducted in order to elaborate and supplement the results of the household survey.

6.2.1. Land use/land cover data acquisition and analysis

Landsat images of different time series were used for analyzing the land use/cover change in the study area. A total of six images representing six different time points were used to study the changes over the last forty years (1973 – 2013) and they were obtained from three different Landsat imagery data sources: Landsat MSS (Multi-Spectral Scanner), Landsat TM (Thematic Mapper), and Landsat ETM+ (Enhanced Thematic Mapper plus). This time points were mainly selected to reflect the changes that the acacia woodlands in the central rift valley have experienced over the three different regimes of Ethiopia, namely, the Imperial period pre-1974, the Derg or 'socialist' period between 1974 and 1991, and the current regime since 1991. Due to the limited availability and quality of satellite images, one satellite image was analyzed both for the imperial and socialist periods each, while it was possible to analyze four images for the current government. Accordingly, the land-use/cover changes between the six periods (i.e., 1973, 1986, 2000, 2005, 2011 and 2013) were quantified and a change detection matrix for all periods was derived. The detail of the data sources is given in Table 13.

Table 13 Spatial datasets used for land cover analysis in the study area.

No.	Data type (path & row)	Acquisition data	Type of sensor	Spatial resolution
1	Landsat MSS (p168r55)	January 01, 1973	MSS	57m * 79m
2	Landsat TM (p168r55)	January 21, 1986	TM	30m reflective, 120m thermal
3	Landsat ETM+ (p168r55)	February 05, 2000	ETM+	15m panchromatic, 30m reflective, 60m thermal
4	Landsat ETM+ (p168r55)	December 12, 2005	ETM+	15m panchromatic, 30m reflective, 60m thermal
5	Landsat ETM+ (p168r55)	January 01, 2011	ETM+	15m panchromatic, 30m reflective, 60m thermal
6	Landsat ETM+ (p168r55)	January 12, 2013	ETM+	15m panchromatic, 30m reflective, 60m thermal

These images were corrected for geometric and atmospheric errors using ERDAS imagine 9.1 software. The geospatial data used in this study have spatial reference systems defined within WGS84, Zone 37N grid of the Universal Transverse Mercator (UTM) projection. A pixel-based supervised image classification with maximum likelihood classification algorithm was employed for land cover classification and change detection analyses. A total of 179 ground truthing points collected from the field were used for 2013 image validation. ArcGIS 9.3 software was used for mapping purposes.

6.2.2. Household survey

A cross-sectional survey was conducted from October 2013 to February 2014 engaging 413 mixed crop-livestock farming households from four *Kebeles* providing a sampling intensity of 17.4%. The survey was conducted to assess the perception of households towards the impact of land cover change on their livelihood and the surrounding natural resources. The households were listed and classified into three wealth categories (poor, medium, and better-off) based on a locally set criteria (Table 5). The classification was made based on the assumption that wealth status may influence the dependence of the people on woodlands and their consequent perception about the state of the woodlands

and their impacts. The interview results were analyzed using a statistical software SPSS version 20.

6.2.3. Focus Group Discussion

Four Focus Group Discussions (FGDs) representing each selected *Kebele* were held in order to supplement the findings of the household survey and to generate data about the views of the people on the impacts of woodland changes on the livelihood and the environment. The group participants were people who know better about the overall condition of the area. The group mainly consists of elderly people albeit women and youth were also represented. The group size was limited to 6 to 10 people and the total number of people participated in the discussion was 31. The discussions were held under a tree canopy in their vicinities, which they are comfortable with, and facilitated by a moderator, the researcher himself, a translator and a note taker. Points were noted when the consensus among group members was reached. In addition, the development agents were always around the group for any assistance needed including making prior communications and appointments with the local people.

6.2.4. Key Informant Interview

Key informant interviews (KII) were conducted for specialized information particularly with regard to the condition of the woodland in the area. The key informants include district experts, Abijata-Shalla Lakes National Park chief warder and experts, development agents, and *Kebele* council members. A total of 13 key informants were interviewed. These individuals were selected because they are supposed to have special information and knowledge which others do not possess (e.g. forest policies, institutional changes, ownership issues, forest practices, and actions taken on culprits regarding woodland use). A semi-structured checklist with interactive conversions was made with the informants. This interview was conducted in order to enrich and substantiate the outcomes of the FGDs and household interviews.

6.3. Results and Discussion

6.3.1. Characteristics of the land cover units

Six different land categories were identified as a primary unit for characterizing the land cover of the study area. The descriptions used in the classification of the land cover types are presented in Table 14. The secondary units identified and quantified include the surface area of each land cover type in hectares (Table 16), land cover change in hectares and change trajectories (Table 17), and observational products such as the satellite image products and the radar chart output (Figure 11 and 12).

The overall classification accuracy for the latest image was 88.3% with the Kappa statistic of 0.81 (Table 15). The Kappa statistic result shows a high level of agreement for the classified image. User's and producer's accuracies of individual classes ranged from 81.8% (for grassland) to 91.7% (for bare land), and 73.3% (for bare land) to 95.6% (for woodland), respectively. As confirmed by the ground-truthing work, there were errors during the classification of the image into different land cover classes. However, the error between the classes was low. The relatively higher confusions occurred between woodlands and agriculture and agriculture and bare land. For example, ten out of the 75 randomly generated samples of woodlands were incorrectly classified as agricultural land, while two out of 81 agricultural lands were incorrectly classified as woodlands. Similarly, four out of 81 agricultural lands were incorrectly classified as bare land, while there was no bare land incorrectly classified as agricultural land. These errors are acceptable as the overall accuracy for effective land use and land cover change analysis is higher than the 85% minimum threshold level (Anderson et al., 1976; Thomlinson et al., 1999).

Table 14 Description of land use/land cover types identified in the CRV of Ethiopia.

No.	Land cover type	Description
1	Forest	Land covered by vegetative communities comprised principally of trees of same or different species. This class represents woodlots around home gardens, patches of remnant natural forests on slope sides and stretches of riverine forests, forests found near rivers and lakes. Woodlots around homesteads are mainly used as source of wood, windbreaks and live fences, whereas the remnant natural forest is mainly used for livestock grazing and browsing just like woodlands.
2	Woodland	Land covered predominantly by Acacia trees. Some species of trees, shrubs and bushes may also be found mixed with the Acacia trees. Different species of grasses can normally be found under the canopies of the acacia woodland and in open spaces. This cover type dominates the area between the three lakes (Shalla, Langano and Abijata) where Acacia is the dominant species. This land cover class is mainly used for grazing and browsing by both domestic and wild animals and is also the source of wood for households.
3	Grassland	This is a landscape largely dominated by grasses and other occasional herbaceous plant communities separated by intervening bare space. Very small proportion of trees and shrubs may exist in this category. This cover type prevails around the lakes, particularly Lake Abijata, marking the continuous lake secession process in which the transition from bare land when the lake retreats is followed by a succession of grass communities. They are predominantly used for grazing.
4	Cropland	Land allotted to cultivation of mainly annual food crops. This land cover is found across all parts of the study area and is predominantly a rain-fed type of production system.
5	Bare land	A cover class represented by rock outcropping, roads, eroded surface, settlement areas, silt deposition and lake secession sites that are largely devoid of above-ground vegetation.
6	Others	This category represents small areas that are difficult to classify as one of the above land cover/land use classes. They may refer to shadowed areas, infrastructures and a mixture of two or more land cover categories per pixel.

Source: Author

Table 15 Error matrix of classification accuracies for 2013

Classification	Woodland	Agriculture	Grassland	Bare land	Ground truth points	User's Accuracy, %
Woodland	65	10	0	0	75	86.7
Agriculture	2	73	2	4	81	90.1
Grass land	1	1	9	0	11	81.8
Bare land	0	1	0	11	12	91.7
Total	68	85	11	15	**179**	
Producer's Accuracy, %	95.6	85.9	81.8	73.3		

Overall accuracy = 88.3%; Kappa statistic = 0.81

Source: Author

6.3.2. State of woodland cover during 1973 – 2013

The woodland cover change and the rate of change between the reference periods in the study area over the last forty years (1973 – 2013) are presented in Table 16 and 17, respectively. Figure 11 shows the spatial distribution of the different land cover types in the reference years chosen, i.e. in 1973, 1986, 2000, 2005, 2011, and 2013 and Figure 12 displays shifts in the pattern of land cover types over the course of the entire study period (1973 – 2013). The Radar chart shows a unidirectional change mainly from woodland to agriculture and grassland.

Ninety-five percent of the total land area in 1973 was covered by tree-dominated vegetation, like woodlands (92.4%) and forests (2.7%), while bare land and agriculture accounted for less than 5% of the area (Table 16). However, this pattern of land cover has dramatically changed over the course of the study period. Woodland cover dropped from 92.4% in 1973 to 69.7%, 56.1%, 50.1%, 50.5%, and 42.4% in 1986, 2000, 2005, 2011, and 2013, respectively (Table 16). In 2013, in just forty years' time, a major reversal in land cover has occurred; agriculture being the dominating land cover type (44.7 %). Grassland also expanded from almost nothing to 8%. Hence, agriculture and grassland have significantly expanded at the expense of woodlands and forests.

Besides the land cover changes that the area has experienced the rate of change between the periods is even more worrisome. For example, agriculture increased by 3,878.2 % over the last forty years, i.e. it increased from only 467 ha in 1973 to 18,578 ha in 2013. Likewise, grassland increased by 11,116.7%, i.e. from almost nothing to 3,365 ha over the same time period. On the other hand, there was a loss of 54.1% and 99.1% of woodland and forest cover between 1973 and 2013, respectively. This indicates that there have been drastic changes in land use and land cover of the area during the study period.

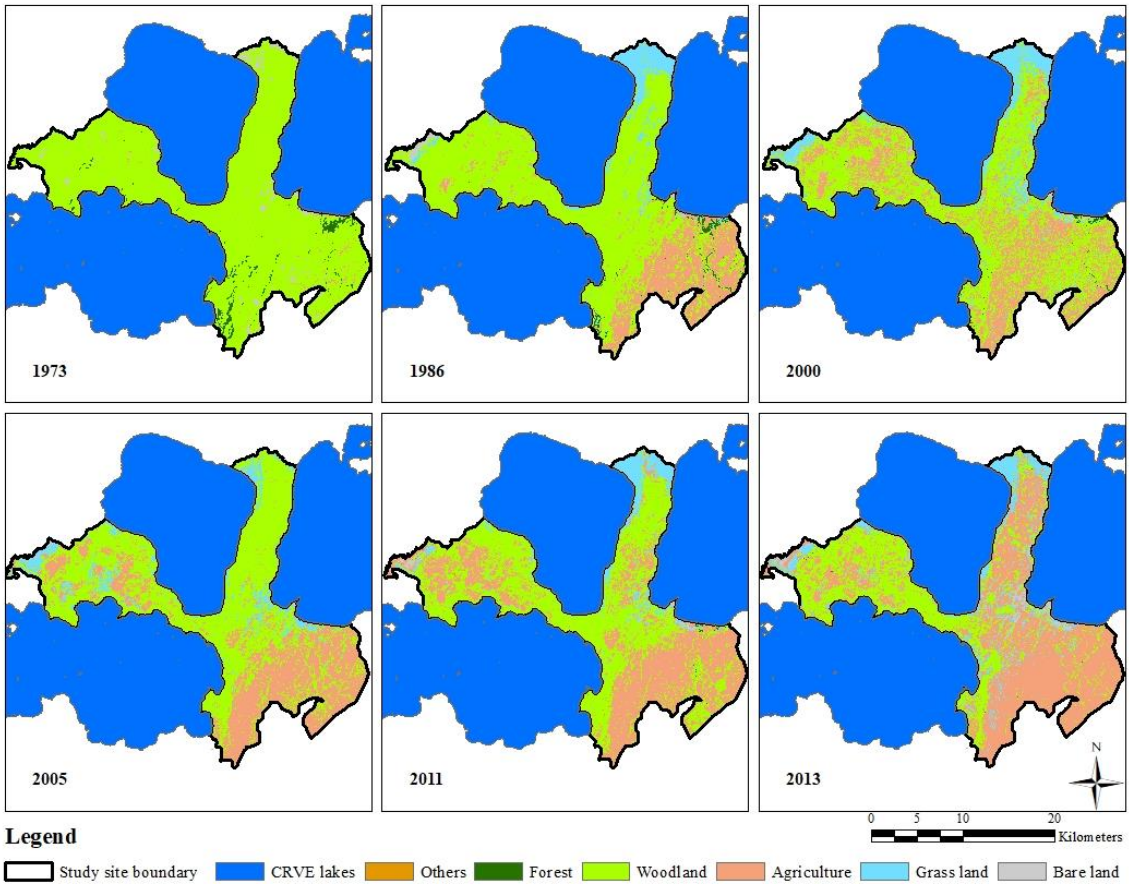

Figure 11 Land cover of the study area in a) 1973, b) 1986, c) 2000, d) 2005, e) 2011 and f) 2013

Table 16 Area in hectare and percentage of the land cover of each class in each reference year.

Cover types	1973		1986		2000		2005		2011		2013	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Woodland	38417	92.4	28022	67.4	23328	56.1	20842	50.1	21002	50.5	17633	42.4
Forest	1141	2.7	562	1.4	221	0.5	10	0.0	79	0.2	10	0.0
Agriculture	467	1.1	8790	21.1	12181	29.3	16792	40.4	16323	39.2	18578	44.7
Grassland	30	0.1	3555	8.5	5077	12.2	3747	9.0	3463	8.3	3365	8.1
Bare land	1351	3.2	600	1.4	659	1.6	122	0.3	529	1.3	1891	4.5
Others	191	0.5	68	0.2	131	0.3	84	0.2	200	0.5	120	0.3

Table 17 Land cover change in hectare and percentages of the change for each land cover class between the periods indicated.

LC types	1973-1986		1986-2000		2000-2005		2005-2011		2011-2013		1973-2013	
	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%	Ha	%
Woodland	-10395	-27.1	-4694	-16.8	-2486	-10.7	160	0.8	-3369	-16.0	-20784	-54.1
Forest	-579	-50.7	-341	-60.7	-211	-95.5	69	690.0	-69	-87.3	-1131	-99.1
Agriculture	8323	1782.0	3391	38.6	4611	37.9	-469	-2.8	2255	13.8	18111	3878.2
Grassland	3525	11750.0	1522	42.8	-1330	-26.2	-284	-7.6	-98	-2.8	3335	11116.7
Bare land	-751	-55.6	59	9.8	-537	-81.5	407	333.6	1362	257.5	540	40.0
Others	-123	-64.4	63	92.6	-47	-35.9	116	138.1	-80	-40.0	-71	-37.2

Source: Author

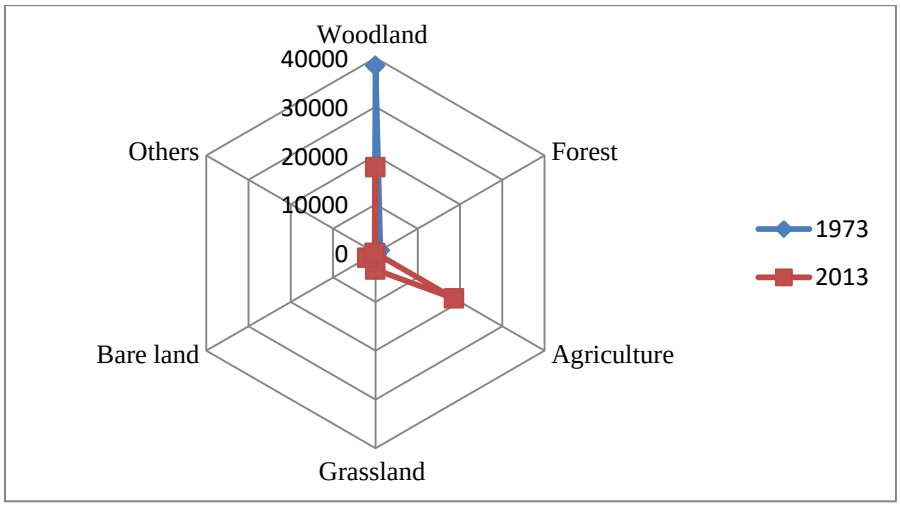

Figure 12 Radar Chart displaying shifts in the pattern of land cover change in hectares between 1973 and 2013

6.3.3. Land use/Land Cover changes in the Central Rift Valley area

6.3.3.1. General trends of land use and land cover change

The findings of this study demonstrates the dynamics of land use and land cover changes in the CRV of Ethiopia over the last four decades on both spatial and temporal scales. These changes were mainly associated with woodland cover change. Up until 1973, the study area was predominantly covered by woodland. However, it has experienced substantial land use and land cover changes since then and these changes have led to marked differences in vegetation cover and land use patterns over the study period (1973 to 2013). Currently, four major land cover types are found, namely, woodland, agriculture, grassland, and bare land. Forests have virtually disappeared. The major transition in land cover change took place between woodland and agriculture and grassland. As a result, woodland cover has substantially declined, while agriculture and grassland covers have enormously increased.

Few studies conducted in the CRV area also reported similar results that there is a loss of woodland cover and that it is converted mainly to agriculture and grassland (Muzein,

2006; Garedew et al., 2009; Biazen, 2012; Meshesha, 2012). Biazen (2012) reported a reduction in woodland cover (both dense and scattered trees) from 77% in 1965 to 40% in 2010. This result is close to the current finding. Garedew et al. (2009), on the other hand, reported a decline in woodland cover from 40% to 9% for Keraru and from 54% to nothing for Gubeta Arjo *Kebeles* between 1973 and 2000. Keraru was also part of this study, whereas Gubeta Arjo was not included as it is a bit far from the Acacia covered lowlands of the CRV and most parts of the *Kebele* are also classified under Midlands with different vegetation types.

According to Muzein (2006), more than 37% of the total Abjata-Shalla Lakes National Park area lost its vegetation cover and agriculture was responsible for the loss of 80% of the total terrestrial productive ecosystem. Meshesha (2012) also reported a 69% woodland loss in the CRV. Although the trend of land cover change was similar, the rate of change reported by these studies seems to vary as their studies covered different sites and sizes of areas and slightly different time periods as well. For example, Meshesha et al. (2012) covered 26 districts including adjacent highlands where agriculture is intensively practiced. Moreover, the definitions given to the different land cover types might have contributed its share.

Several results indicating forest decline outside the main CRV of Ethiopia were reported. For example, Dessie and Kleman (2007), Kindu et al. (2013), and Amanuel and Mulugeta (2014) studied land use and land cover changes in the southern parts of the country and reported a total natural forest cover loss of 82%, 24.4%, and 22.64% between 1972 and 2000, 1973 and 2012, and 1973 and 2004, respectively. Kindu et al. also reported a 36% and 24.8% woodland cover and plantation forest losses, respectively. Studies of forest cover change in the eastern and western parts of the country are limited.

However, Tsegaye et al. (2010) reported a 97% reduction in woodland cover in the northern Afar rangelands in eastern Ethiopia between 1972 and 2007. Similarly, Emiru and Taye (2012) reported almost a complete disappearance of natural forests and a massive reduction in woodland cover in the western part of Ethiopia between 1957 and

2006. Alemu et al. (2015) also reported an annual loss of 2834 hectares of woodland in the western lowlands of Ethiopia for the past 25 years (1985 – 2010).

Relatively many studies were conducted in the highlands of the central and northern parts of the country where land degradation and deforestation have been a serious problem already many years ago (Phjonen & Pukkala, 1990; EFAP, 1994; Reusing, 1998; Bishaw, 2001; WBISPP, 2004). These areas experienced either complete removal or massive reduction in forest cover (Kebrom & Hedlund, 2000; Gete & Hurni, 2001; Belay, 2002; Kidanu, 2004; Amsalu et al., 2007; Minale, 2013; Yeshaneh et al., 2013). For instance, Gete and Hurni (2001) reported that 99% of the forest cover in Dembecha area in the Northwestern highlands of Ethiopia was converted to agricultural land between 1957 and 1995. Likewise, Amsalu et al. (2007) reported an 83% reduction in natural vegetation in Beressa watershed in the central highlands of Ethiopian from 1957 to 2000.

Contrary to all these reports and the findings of this report, however, Bewket (2002) reported an increase in forest cover for the last four decades in Chemoga Watershed in the Blue Nile Basin of Ethiopia. The increase was ascribed to households' tree planting practices of mainly Eucalyptus species dictated by the growing scarcity of wood for fuel in the area.

6.3.3.2. Patterns of land cover change in the different periods of analysis

The pattern and rate of woodland cover change in the study area slightly vary from place to place and across the different time periods considered in this study. Based on the results of the image analysis (Figure 11) and the change analysis made for the five sub-periods (1973-86, 1986-2000, 2000-2005, 2005-2011, and 2011-2013) (Table 17), it appears that changes in woodland cover did not occur at the same time in all places within the study site. The eastern and southeastern, and the northern part of the study area were the first to experience woodland cover change mainly to agriculture and grassland, respectively. Then, the conversion of woodlands to agriculture and grassland advanced into the remaining parts with the western and southwestern part being the last destination.

Consequently, the pattern of woodland cover change was explained in terms of the relative suitability of the area for living and crop cultivation as well as access to the road to sell wood and agricultural products. It was explained by key informants and FGD participants that the western and southwestern parts of the study area were considered to be the most hostile environment for living and women who get married to a person living in these areas were considered to be unlucky. According to the same sources of information, the soil and rainfall condition in these areas are considered to be worse than even the adjacent areas and makes crop production in particular and life in general a challenge.

In addition, most of these areas are found far from the main road connecting the capital, Addis Ababa, to the southern provinces including Hawassa town or are rugged in topography making transportation of especially wood products to market outlets a problem. It is worthwhile to mention here that most charcoal and firewood used to be sold along the roadside. Thus, a relatively better woodland cover is currently found in these areas. Conversely, less woodland cover is found in areas where the fertility of the soil is relatively good and sedentary agriculture is intensively practiced and where access to the main road is easy. These views of key informants and FGD participants are consistent with the reports of Eshete (1999) and Bekele (2003).

Across time scales, most of the land cover changes took place in the first period of analysis, i.e. between 1973 and 1986. This period was also a transitional period where the socialist (Derg) regime ended the reign of the Imperial regime in 1974. Following the transition, a new land reform proclamation that declares “land for the tiller” was articulated and announced in 1975, which is a radical change in terms of property relations as land in the previous regime was owned by the state and at the hands of the landlords. All lands including forestlands were nationalized and put under public ownership. The feudal system and landlords were abolished and the land was distributed to the then tenants and the public through the newly organized peasant associations. By this time, peasant associations in the study area claimed large tracts of woodlands without

having clear regulatory provisions as to what rights and duties are vested in the individuals and communities over woodland management and use. This sudden policy and institutional change that destroyed the old without properly entrenching the new turned the woodland into an open-access resource as properly explained by Bekele (2003).

According to key informants and FGD members, therefore, this change was one of the main reasons for the massive destruction of woodlands as the local people were in a rush to own and expand agricultural lands. Indeed, it was explained that visible clearing of woodlands for agriculture started earlier than this period when the royal family started to establish and run small-scale modern farms in the late 1950s and 1960s. Bekele (2003), Garedew et al. (2009) and (Biazen, 2012) also reported similar cases in their study sites.

Moreover, this policy and institutional change were made in the aftermath of one of the severe droughts that Ethiopia has experienced during the turn of the Imperial period (from 1971 to 1973). Hence, the informants added that this drought incidence was another catalyst to exacerbate the destruction of woodlands during this period as the affected people learned to generate income from the sale of charcoal and firewood to buy food and overcome its impacts. According to the same sources, the 1984/85 drought has also marked its own impact albeit the people, the poor in particular, have already continued selling charcoal and firewood since they have learned to make them and generate additional income for the households even in the absence of drought.

Some studies reported similar findings during the same period (1973 – 1986), while others reported either generic change trends or changes that are not disaggregated into smaller and similar periods which in this case are difficult to make a comparative analysis. In the CRV area Muzein (2006), Garedew et al. (2009), and Biazen (2012) reported similar results. Muzein (2006) reported that there were more active LULC change processes in the area during1973 and 1986 than the rest of his study periods. In the same way, Garedew et al. (2009) stated that major deforestation and forest degradation took place during 1973 and 1986. He also added that the severe drought of

1984/85 has contributed to this change. Biazen (2012), on the other hand, reported a massive increase in cultivated land (110%) between 1965 and 1986 at the expense of woodlands. He further added that severe forest loss took place during and in the aftermath of government transitions.

Outside of the CRV area, there are relatively many reports with consistent findings. For example, Amanuel and Mulugeta (2014) reported that most of the forest cover conversions in Nadda Asendabo watershed in Southwestern Ethiopia took place between 1973 and 1986. Similarly, Kindu et al. (2013) reported a reduction in woodland cover of 81.8%, 52.3%, and 36.1% in Munnesa area during 1973 and 1986, 1986 and 2000, and 2000 and 2012, respectively, indicating that the major change happened during the 1973 to 1986 period. Shiferaw (2011) also reported a major land cover change between 1972 and 1985 in Borena, Northeastern Ethiopia.

On the other hand, Yeshaneh et al. (2013) with a slight time difference reported that most of the deforestation in the Koga catchment, Northwestern Ethiopia, took place between 1970 and 1980. Likewise, in a study conducted in the Ethiopian central highlands, Beressa watershed, Amsalu et al. (2007) reported that the major deforestation in the central highlands of Ethiopia was carried out between 1957 and 1984. He also stated that the major land reform that took place in 1975 has led to the clearing of extensive protected forest areas. Dessie and Christiansson (2008) too reported that large areas of forest were cleared during periods of political transitions. Congruently, Belay (2002) reported that a significant conversion in Derekolli catchment, Northeastern Ethiopia, occurred between 1957 and 1986.

However, contrasting findings have also been reported by Tsegaye et al. (2010), Tefera (2011) and Meshesha et al. (2012). Tefera (2011), although his study period was between 1984 and 2007, reported that the major change in woodland cover took place between 2002 and 2007. The causes of change described include removal of plants for farmland preparation, fuel wood, construction wood, charcoal and traditional farm implement making.

Tsegaye et al. (2010), on the other hand, reported a major woodland cover change between 1986 and 2007 (90% reduction) rather than between 1972 and 1986 (67%) in the Northern Afar rangelands. The major reasons given were increased sedentarization of the Afar pastoralists during the period (1986 and 2007) and high influx of migrants from the Tigray highlands, particularly after the 1984/85 drought, which resulted in a huge destruction of woodlands and expansion of cultivation. Similarly, Meshesha et al. (2012) reported a higher woodland cover loss between 1985 and 2006 (55.6%) than the change observed between 1973 and 1985 (30.7%). The major causes mentioned were population and livestock growth, unsustainable farming techniques, poverty, and the land tenure system. Such contrasting findings signify that land use/land cover changes are influenced not only by policy and institutional changes but also local socioeconomic contexts.

Although major changes in the study area took place between 1973 and 1986, conversion of woodlands to other land uses continued persistently throughout the study periods except one (2005 to 2011). In this period (2005 – 2011) there was an indication of a reversal from agriculture and grassland to woodlands and forests. There was no particular reason given by the informants for the slight temporary increase in woodlands and forests, and reduction in cultivated land and grassland during this period. However, it appears that the government has put more effort to stop further degradation and protect the woodlands.

The current government, after taking over from the socialist regime in 1991, observed the intensified destruction of woodlands, as did the community, and the gap between policy and practice on the ground. After the takeover, the new government did not reinstitute the necessary tools and organizations quick enough to stop tree felling and protect forests as explained by the informants and also Bekele (2003). Hence, it was during this period that the government enacted the forest proclamation of the country in 2007 that addresses the development, conservation, and utilization of forests. The implementation of this proclamation and the associated efforts might have contributed to the temporary reversal of land covers between 2005 and 2011. However, the reversal does not last long and

massive woodland and forest areas were converted back to agriculture and grassland after 2011, as observed from the results of the 2013 satellite image (Figure 11) and the figures extracted from the analysis (Table 16).

The last analysis period (2011 to 2013) was conducted in order to detect active changes in land cover and remarkable changes were observed in this short time span. The recent satellite image analyzed indicated that deforestation is still actively progressing and that there was massive destruction of woodlands.

6.3.4. Smallholder farmers' view on the impact of woodland cover change

6.3.4.1. *Perceived impact of woodland cover change on livelihood*

The life of smallholder farmers living in the central rift valley is highly intertwined with woodlands. According to the responses of interviewed households, FGD participants, and key informants, it is impossible for the local people to think life without woodlands. Following the survey results, for example, all of the interviewed households (100%) agreed that woodlands are an important source of livelihood. According to the peoples' account, woodlands have been providing them with a range of goods and services. They have been the source firewood, construction wood, charcoal, food, fodder, medicine, farm implements, and income.

Moreover, smallholder farmers recognize that woodlands are important to protect the watershed and maintain and improve soil fertility, which in turn improve crop productivity. Shade is also an important service for both humans and animals living in the CRV area to attenuate the effect of temperature, particularly during warmer days and periods. The survey result shows that shade is the second most valued service of woodlands (98.1%) next to firewood (98.8%). Subsequently, they experience that changes in this important resource have affected their life. They witness the fact that most of the goods and services that the woodlands used to render have diminished as a result of the changes they have experienced over the years.

According to the informants, for example, edible fruits which were abundant while there were dense woodlands are no more available now. Traditional medicines which used to be extracted from the different parts of plants found in the woodlands have now significantly reduced. Similarly, cash income which used to be generated from the sale of firewood and charcoal to supplement the livelihood of particularly poor households has significantly reduced. They also stated that woodlands have been providing a variety of fodder to livestock and harbor grasses. However, both the quantity and quality of fodder has greatly reduced recently to the extent that people are forced to reduce the number of livestock, which in turn can be interpreted in terms of lost income and reduced means of livelihood.

Furthermore, according to the same sources, woodlands were the resources people turn into and depend on when faced with the challenges of drought and crop failure. They have been used as a source of immediate income to buy food and overcome the impacts of drought and crop failure. They also added that even if there is no drought and crop failure the production and sale of charcoal increases during the rainy season (June to September) where there is normally a temporary gap in the food supply as the stored grains nears completion and harvesting of the next crop is not done yet. The price of charcoal during this period also reduces significantly as many people had to sell charcoal in order to buy food items. This, in turn, diminishes their ability to buy more food.

In addition, loss of woodlands has resulted in the overall reduction of the availability of woodland products and an increase in their respective prices. According to the survey results, ninety-eight percent (98.1%) of households said that the availability of firewood and charcoal is decreasing and about ninety-one percent (90.8%) of the households responded that the price of firewood and charcoal is increasing.

As a result, unlike the previous times where a shortage of wood was not envisaged, currently wood even for domestic use has already become a scarce commodity. This has led to the use of crop residues (99%) and cow dung (51.3%) as a source of energy. This,

in turn, has a negative implication to soil fertility and crop productivity because they could have been used to ameliorate the fertility of the soil had they been allowed to stay on the crop field. The informants further associate the decline in crop productivity with the destruction of woodlands describing erosion as a reason for the loss of soil fertility. As an example to demonstrate the association of woodlands with crop productivity, they mentioned that in the past rented combiners where not interested to harvest crops found near woodlands and in between trees. However, now they prefer to harvest crops found near trees as they can harvest more in those fields than plain cultivated lands (the rent is agreed per quintals harvested). They also added that decreased availability of woodland products has increased the burden of particularly women who travel long distances to collect firewood for domestic consumption.

6.3.4.2. Perceived impact of woodland cover change on the environment

According to the survey results, the change in the woodland cover is well understood by the large majority of households (99%). Moreover, key informants and discussants of the FGDs witnessed that the CRV area, where woodlands and forests have been their green blankets for years, are now loosing not only their spectacular scenery but also wild animals. They stated that the area was known for harboring a variety of wildlife, including large mammals such as Buffalos, Giraffes, and Lions. They have also realized that woodlands did not only suffer from area change but also lack of continuity and quality. As explained by key informants and can be observed physically or on satellite images (Figure 11), the existing woodlands, except few patches, are so disturbed and fragmented that some wild animals have extirpated from the area because of loss of habitat. Yohannes et al. (2017) also reported similar results that wild animals such as Oryx, Swayne's hartebeest, Lion, Buffalo, Water buck, and Giraffe have been exterminated from the area and replaced by a small number of other species that include Grant's gazelle, Greater kudu, Anubis baboon, Colobus monkey, Grivet, Oribi, Klipspringer, black-backed and common Jackal, and Warthog.

The density of trees in the woodlands is also low and both the quantity and quality of grass that used to be found in the underneath of woodlands has reduced. Likewise, they explained that some economically important tree species such as *Acacia tortilis* are threatened because of heavy exploitation, especially for charcoal production. This implies that it is more likely that there is a decline in biodiversity though not quantified. Yohannes et al. (2017) also reported that biodiversity has declined in the area.

In addition, key informants believe that changes in woodland resources aggravate soil erosion and degradation. Their views are supported by the fact that soil loss in the study area has increased from 235,619 tonnes per year in 1973 to 519,114 tonnes per year in 2013 as a result of a change in land use and land cover types (Table 18). This, in turn, means that the land use/land cover change has resulted in a net soil loss of 283, 495 tonnes per year, which yields a 120% increase in soil loss over the forty years period.

It is also observed that deep gullies are developing, river banks are expanding, severely degraded soils and exposed rocks are prevailing, and lakes are shrinking (Figure 13). According to the views of key informants and the reports of Ayenew (2004), Muzein (2006), Temesgen et al. (2013), and Yohannes et al. (2017), Lake Abijata, in particular, is on the verge of dying. Water abstraction by the Abijata Soda Ash factory, which draws 5 million m^3 of water from the Lake annually and significant reduction in the amount of water flowing from Bulbula River to the Lake due to intensive use of water by the floriculture industries and irrigation projects were the main reasons mentioned in addition to siltation and high evaporation.

The expansion of bare land from 1351 ha in 1973 to 1891 ha in 2013, as revealed by the satellite image analysis (Table 16), also indicates the extent of land degradation that has occurred in the area over the last forty years. Some of the interviewees also associate the shortage and erratic nature of rainfall and the occurrence of recurrent drought with the destruction of woodlands.

Table 18 Estimate of soil loss from land use/land cover types

Land use/land cover types	Rate of soil loss (t/ha/yr)	**1973**		**2013**		**Net Soil Loss**	
		Area (ha)	Soil loss (t/yr)	Area (ha)	Soil loss (t/yr)	Tons	%
Woodland	5	38,417	192,085	17,633	88,165	-103,920	-54
Forest	5	1,141	5,705	10	50	-5,655	-99
Agriculture	20.2	467	9,433	18,578	375,276	365,842	3,878
Grassland	5	30	150	3,365	16,825	16,675	11,117
Bare land	20.2	1,351	27,290	1,891	38,198	10,908	40
Others	5	191	955	120	600	-355	-37
Total		**41,597**	**235,619**	**41,597**	**519,114**	**283,495**	**120**

Source: Area estimates are by the author (Table 16); soil loss estimates are based on the soil loss rate estimates of Hurni et al. (2015)

Figure 13 River bank expansion, gully erosion, and wind erosion (dust storm)

Source: Author

6.4. Conclusion

The results revealed that major land cover changes have occurred over the last forty years. The landscape of the area has dramatically changed from a forested landscape to a predominantly agricultural landscape. Forty years ago almost all the area was covered by woodlands and forests and agriculture was insignificant. Bare land by then was very small. So, basically, it was a forested landscape. However, over the course of the study period, agriculture and grassland expanded significantly at the expense of woodlands and forests. Forests have almost disappeared from the landscape of the study area. The highest woodland cover change occurred between 1973 and 1986 albeit the conversion continued during the other periods as well except the 2011 – 2013 period where there was a temporary gain in the area. The latest analysis period (2011 – 2013) indicated that woodland conversion is still actively progressing. It should, however, be noted that despite most popular beliefs and some research reports that all is gone, there are still some woodlands and all are not lost yet particularly in remote areas.

Along the way, woodlands have been playing a crucial role for the livelihood of smallholder farmers living in the CRV in particular during times of drought and crop failure and their degradation have diminished their contributions to the society and the environment. Smallholder farmers perceived that the availability of wood products has reduced, their prices increased, income from woodlands declined and crop productivity dropped. Moreover, the conversion of woodlands to other land uses has contributed to the degradation of the soil through erosion and loss of fertility, landscape fragmentation and loss of habitat, and a decline in biodiversity including wildlife and medicinal plants.

The effect of these changes will be more pronounced given the fact that it is taking place in one of the most environmentally vulnerable areas of Ethiopia where small changes in natural resources can have far-reaching consequences on the provision of ecosystem goods and services. Unless actions are taken to halt woodland cover change there is no reason why woodlands will experience the same fate as forests which have almost

disappeared from the landscape of the study area. Urgent attention must, therefore, be paid by relevant stakeholders in order to arrest woodland degradation and safeguard the fragile ecosystem before it reaches the irreversible stage. Hence, better management modalities need to be in place for woodlands to continue providing vital ecosystem goods and services that can improve the livelihood and adaptive capacity of the smallholders in the area as well as the society at large.

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Chapter Seven: Proximate and Underlying Causes of Woodland Decline

Abstract

Despite the multiple benefits they are providing, woodlands in the Central Rift Valley (CRV) of Ethiopia are under increasing human pressure. This study explored the proximate pressure factors and the driving forces of woodland decline in the CRV. A combination of qualitative and quantitative datasets was used to identify and explain the factors. Descriptive statistics, regression analysis, narratives, and GIS and remote sensing techniques were used to analyze the data. It was found that woodland decline was triggered by the interplay of seven proximate and ten underlying causes. Cropland expansion, charcoal production, firewood collection, and harvesting for construction and industrial uses were the top five ranked proximate causes perceived by respondents in descending order of influence. The driving forces fall into six fundamental forces that include economic, policy and institutional, demographic, cultural, technological, and natural factors. Population increase, poverty, drought, lack of alternative energy sources, and lack of awareness represent the top five positions of the driving forces in descending order of importance. An evidence of an association between household's perception of some proximate and underlying causes and their respective Kebeles was also found. Moreover, household size and wealth status had significantly and positively affected the perception of households towards lack of forest policy as a driving force. Poor households were more likely to perceive the impact of lack of forest policy on woodlands than better-off households. Because of the combined effect of the underlying and proximate causes, woodlands are declining. Hence, urgent attention is needed from all relevant stakeholders to mitigate these factors and rescue the ever-shrinking resources that have been offering valuable goods and services to the society and the environment. Further studies that analyze the linkages between the different factors and their likely impacts on the woodland resources and the local people are suggested.

Key words: *Proximate causes, underlying causes, woodland decline, smallholders, Central Rift Valley.*

7.1. Introduction

Woodlands are the largest remnant forest and land-cover types in Ethiopia covering about 26% of the land surface (WBISPP, 2004; Tefera, 2011). Acacia woodlands constitute about 55% of the total woodland area and are mainly concentrated in the lowlands of the Rift Valley (Eshete, 1999; WBISPP, 2004; Gebrekirstos et al., 2008). They have been the characteristic feature of particularly the Central Rift Valley (CRV) area and have been playing important socioeconomic and environmental roles (Jansen et al., 2007; Garedew et al., 2009; Garedew, 2010; Reaugh-Flower, 2011; Biazen, 2012). They provide wood, fodder, traditional medicine, and charcoal, among others. For example, the majority of charcoal being used by the citizens of the nearby towns including Addis Ababa is coming

from the CRV woodlands (Alem et al., 2010). They are also an important source of income for the local people particularly during times of crop failure and drought (Garedew et al., 2009; Garedew, 2010; Biazen, 2012). These direct contributions are in addition to their ecological roles in safeguarding the fragile ecosystem including soil retention and soil quality enhancement, habitat provision, biodiversity conservation, and local climate regulation (Jansen et al., 2007; Reaugh-Flower, 2011; Yimer & Abdelkadir, 2011; Meshesha et al., 2012).

However, these important resources are under heavy pressure because of human activities and declining over time (Muzein, 2006; Garedew et al. 2009; Reaugh-Flower, 2011; Biazen, 2012). Despite a number of efforts to stop the woodland decline, studies indicate that the CRV continues to lose some hectares of woodlands every year. This trend is threatening the existence of woodlands and the products and services they render to the society and the environment. If this is so, why do woodlands decline and what are the factors creating these pressures on them? Despite differences in terminology, the meaning of proximate causes or direct drivers is pretty much the same as that of most uses of pressures in different literatures (Maxim et al., 2009; Atkins et al., 2011). Underlying causes are also referred to as indirect drivers or driving forces.

Globally, the causes of land change are more contested than any other facet of land change research (Turner et al., 2007). Investigations into the causes of land change commonly involve the more proximate factors (Serneels & Lambin, 2001; Lambin et al., 2001), which are human activities or immediate actions at the local level that originate from intended land use and directly impact forest cover (Geist & Lambin, 2002). Focusing on proximate causes alone increases the chance of committing errors such as ‘‘blaming the victim’’ in cases of deforestation by impoverished farmers (Turner, et al., 2007). The distal factors that shape the proximate causes, though they tend to be difficult to connect them empirically to land outcomes, are also vital to better understand the reasons for forest decline (Contreras-Hermosilla, 2000; Geist et al., 2006; Turner et al, 2007). They are the fundamental social processes that underpin the more proximate causes and either operate at the local level or makes an indirect impact from the national

or global level (Geist & Lambin, 2002). However, the distinction between proximate (or direct) and underlying (or root, or indirect) causes is not as neat as most would like it to be as some underlying causes can be viewed as the effect of still higher causes depending on the perspective of analysis (Dale, 1997; Contreras-Hermosilla, 2000).

A broad range of factors has been identified worldwide to explain the causative pattern of particularly tropical deforestation since the 1980s (Geist & Lambin, 2002; Lambin et al., 2003; Campbell et al., 2005). Earlier studies have given too much emphasis on single-factor causation (Geist & Lambin, 2002) such as population (Allen & Barnes, 1985; Cropper & Griffiths, 1994; Mather & Needle, 2000) and shifting cultivation (Myers, 1993; Rerkasem, 1996; Ranjan & Upadhyay, 1999). Recent studies have moved from simplistic representations of one or two factors to a much more profound understanding that involves context-specific interactions among a large number of factors at different spatial and temporal scales (Lambin et al., 2003). Although causative factors are many and varied, about half a dozen broad fundamental forces and three major proximate causes are consistently used in global environment change research (Geist et al., 2006). The broad underlying causes include technological, economic, political, institutional, demographic, and sociocultural factors, while the major direct causes are agricultural expansion, infrastructure expansion, and wood extraction. Lately, natural factors such as drought, flood, fire, and pests are gaining importance as direct drivers of land cover change (Contreras-Hermosilla, 2000; Geist & Lmbin, 2002; Yang et al., 2008; Román-Cuesta et al., 2014; Kicklighter et al., 2014).

In Ethiopia, a number of attempts have been made to identify the causative factors of forest decline. Until recently, the focus of most of these studies was in the forests of the highly populated highlands of Ethiopia where serious deforestation has taken place for years (Teketay, 1992; Amsalu et al., 2007; Shiferaw, 2011; Minale, 2013; Girma & Hassan, 2014; Kindu et al., 2015; Wubie et al., 2016). Woodlands came into the picture after deforestation on the highlands slowed down because very little is left for further extraction and after it is gradually shifting to the lowlands where woodlands are still found (Emiru & Taye, 2012, Alemu et al., 2015). Even then, only Garedew et al. (2009)

and Biazen (2012) attempted to address the causative factors of land cover change in the main CRV of Ethiopia. Biazen (2012) reported on the interplay of recurrent drought, socioeconomic changes, institutional dynamics, improved agricultural technologies, and access to markets as the drivers of land cover change. Garedew et al. (2009), on the other hand, identified population increase, crop productivity decline, and drought as the main driving forces. Garedew et al. (2009) also cited unclear property rights and poor administration as contributing factors to woodland loss.

Nevertheless, the continued rate of deforestation in the CRV meant that more effort is needed to better understand the human-environment relationships. Thus, this study explored the proximate causes and underlying driving forces that create pressures on the remaining woodlands of the CRV of Ethiopia. We analyzed the frequency of the perceived proximate causes and underlying driving forces of deforestation and ranked them according to their relative impacts.

Addressing both aspects is important because decision-making is influenced by factors at the local and higher levels (Lambin et al., 2003). Identifying the physical actions that create pressures on woodlands is essential to understand the current state of woodlands and the extent of the problem. Yet, information on the underlying causes of woodland change is crucial for policymakers as policies focus more on the fundamental processes that require remedial action than the actual signs on the field. Tersely, a better understanding of proximate and underlying causes is useful to predict changes that are likely to occur, to design policies, management strategies, and interventions that can rescue woodlands while still providing valuable goods and services, and to foresee potential impacts on the environment and the livelihood of the local people.

7.2. Data Collection

A combination of household survey, Focus Group Discussion (FGD), Key Informant interview (KII), and field observations were used in order to assess the proximate and underlying causes of woodland decline. Moreover, part of the data generated through GIS

and remote sensing techniques so as to analyze land-use/cover change in the study area over the last forty years were used to demonstrate the effect of the pressures that human activities are exerting on woodland resources.

The household survey was used to identify the proximate or direct causes and driving forces (underlying causes) of woodland change as perceived by smallholding farmers in the four selected *Kebeles*. On the other hand, FGDs were used to supplement the findings of the household survey and find explanations for perceived proximate and underlying causes. KIIs were also used to enrich and substantiate the outcomes of the FGDs and household interviews with regard to the proximate and underlying causes of woodland cover change in the study area. In addition, field observations were conducted in order to get a broader view of the woodland resources and associated pressures and to observe the activities being practiced in the area including the collection, use, and marketing of firewood and charcoal as well as the techniques used to produce charcoal.

7.3. Data Analysis

Descriptive statistics, narratives, regression analysis, and GIS and remote sensing techniques were used to analyze the data. Descriptive statistics was used to describe the socioeconomic characteristics of households (Table 19) and to analyze the frequency of respondents and their rankings to perceived proximate and underlying causes of woodland change. The frequency of respondents was needed to gauge the popularity of the factors, while the ranking is important to screen the relative impact of each perceived factor on woodland resources. The land-use/cover data was processed through GIS and remote sensing techniques to elucidate the effect of the proximate pressure factors on woodland resources. Data collected through FGD, KII, and observation were narrated qualitatively. The existence of associations in perceptions among respondents in different *Kebeles* regarding proximate and underlying causes were tested using a non-parametric test named the Chi-Square test. Both Pearson's Chi-Square values and Likelihood ratios were used to test the relationships.

Table 19 Sample household's characteristics in the study area (n=413)

Household attributes	Value
Gender (male, %)	83.3
Average age of household heads (years)	40.9
Education (literate, %)	63.4
Major occupation of household head (farming, %)	96.6
Ethnicity (Oromo, %)	98.8
Religion (Muslim, %)	95.2
Marital status (currently married, %)	85.5
Type of marriage (Monogamy, %)	74.5
Average number of wives for polygamous marriage type	2.2
Average household size (number)	7.37
Average land holding size (ha)	2.5
Average number of livestock in TLU	7.7
Average household income (Birr[a]/year)	30,310

Ethiopian currency: at the time of the study period, 1USD=18.9789

Regression analysis was employed to identify the socioeconomic determinants of household's perception to some driving forces of woodland decline. Lack of forest policy was specifically picked for this analysis after no clear pattern was observed in the perception of households for the driving force, unlike others where either the majority perceived or did not perceive them. In this case, the outcome was shared between the two group memberships almost equally, i.e., it was almost half (53%) perceived, while the other half (47%) did not perceive the lack of forest policy as a driving force. Thus, the nature of the response prompted the need to discern what determines the outcome, i.e., which socioeconomic variables explain household's perception towards this particular driver. In addition, policy issues have strong implications for future management and use of woodlands.

The independent variables used to explain the perception of households to lack of forest policy as a driving force (the dependent variable) were sex, age, education, occupation, household size, wealth status, land holding size, and household income. The predictor socioeconomic variables were a combination of discrete and continuous variables, while the outcome of the dependent variable was dichotomous. Logistic regression analysis is, therefore, suited to this kind of data (Lesschen et al., 2005) and applied accordingly. The

logistic regression function that estimates the likelihood of the effects of the explanatory variables (independent) on the response variable (perception to lack of forest policy as a driving force) is given as:

$$\text{Logit}(Y) = \alpha + \beta_1 X_1 + \beta_2 X_2 + \beta_3 X_3 + \ldots + \beta_n X_n$$

Where Y is the dependent variable indicating the probability that Y = 1, α is the intercept, $\beta_1 \ldots \beta_n$ are coefficients of the independent variables, and $X_1 \ldots X_n$ are the independent variables.

In order to detect the presence of correlations between the predictor variables and minimize their effects on the regression estimates they were tested for multicollinearity before the regression analysis was run. Tolerance and variance inflation factor (VIF) are commonly used to screen variables for multicollinearity. Despite differences in expressions, they serve the same purpose. VIF is the reciprocal of "tolerance" and are often used to detect multicollinearity. Although there are no agreed cut-off points for tolerance and VIF to detect the existence of multicollinearity the rule of thumb is to use 0.20 for tolerance and 5 for VIF. A tolerance level of below 0.20 and a VIF of above 5 indicate that multicollinearity is a concern.

7.4. Results and Discussion

7.4.1. Proximate causes of woodland decline

The survey revealed that seven proximate causes that put woodlands under pressure were perceived by households in the CRV (Figure 14). Agricultural expansion and cutting trees for firewood, construction wood, and charcoal production were the four most frequently mentioned proximate causes of woodland decline. Whereas clearing for grazing, clearing to keep away pests and harvesting for industrial purposes were mentioned with a much lower frequency. Almost all households (99.8%) recognized agriculture as the main direct cause of woodland decline and it was followed by wood

extraction for firewood (98.3%), construction wood (97.1%), and charcoal production (87.9%). The rest received lower responses: clearing for grazing (26.3%), clearing to keep away pests (13.8%), and harvesting for industrial purposes (11.6%).

The figures indicate that those that received higher frequencies are common problems to all the *Kebeles* regardless of their specific contexts, while those that received lower frequencies are either specific to some *Kebeles* or they are not major problems across all *Kebeles*. For example, harvesting wood for industrial purpose is mentioned only by respondents from one *Kebele*, Dakka Hore Qello. Similarly, out of the respondents that cited clearing to keep away pests as a direct cause of deforestation over eighty percent (81%) were from Dakka Hore Qello indicating that it is more a problem of this *Kebele* than others. On the other hand, none of the respondents from Keraru cited clearing to keep away pests as a direct cause. Clearing woodland for expanding pasture was mentioned by respondents from all *Kebeles* but with a much lower frequency signifying that it is not a major cause for the woodland decline. However, it still harbors the notion that livestock ranching is exerting some pressure on woodlands and needs close attention. Muzein (2006), for example, highlighted that overgrazing in the CRV as a result of high livestock density and unsuitability of the area for productive livestock development is creating pressures on woodlands.

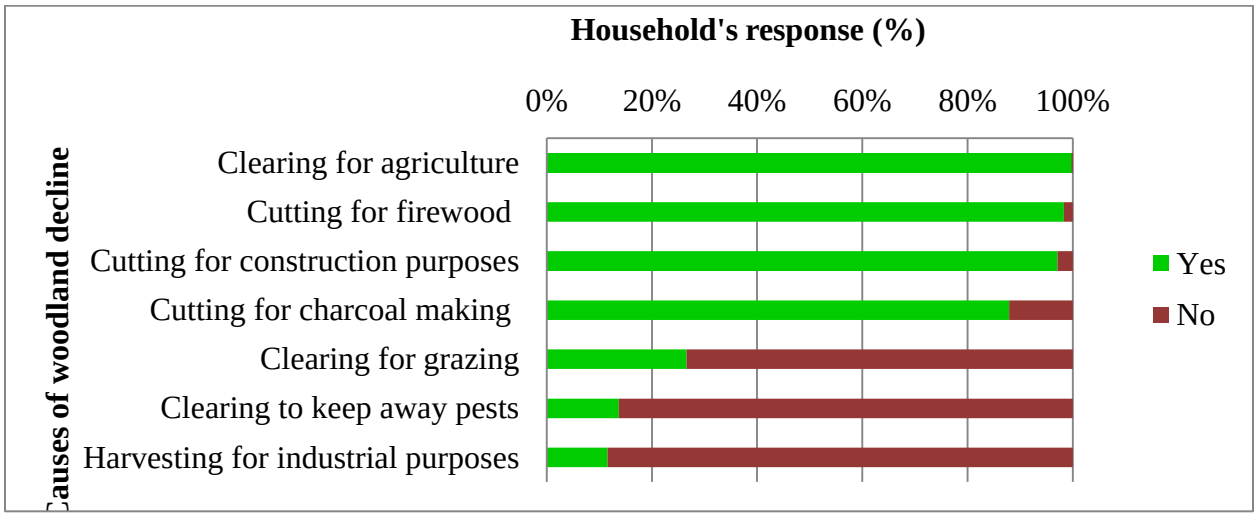

Figure 14 Proximate causes of woodland decline perceived by rural households

Source: Household survey

At the proximate level, woodland decline (deforestation, degradation or both) in the CRV is, therefore, best explained by a combination of multiple causal factors rather than by single variables. Although cropland expansion is still the dominant direct cause of the woodland decline in the CRV it is observed that it is not the only one contributing to the cause. Indeed, agriculture has been the main cause of deforestation globally as much of the planet's forest removal is happening along tropical agricultural frontiers (Geist & Lambin, 2002; Carr, 2004). However, recent studies emphasize that land cover change is a result of multiple interacting variables and processes arising from different coupled human-environment systems (Tegene, 2002, Lambin et al, 2003; Shvidenko et al., 2005; Tefera, 2011). It is also argued that prior studies have given too much emphasis to population growth and shifting cultivation as primary causes of deforestation (Geist & Lambin, 2001, 2002). Population increase is now considered as an underlying cause of deforestation. The findings of this study strengthen the fact that while single factor causes are rare and multiple causes not infinite, as reported by Reid et al. (2006), some specific combination of factors account for a major share of land cover change.

The pressure factors perceived by households in the CRV fall within the first two of the commonly grouped three broad categories of proximate causes of forest decline: agricultural expansion, wood extraction, and infrastructure expansion (Angelsen & Kaimowitz, 1999; Contreras-Hermosilla, 2000; Geist & Lambin, 2001). Although there is an asphalt road that crosses the study area, graveled and dry weather roads that connect the *Kebeles* within the district, and recently installed electric and potable water supply lines in some *Kebeles*, infrastructure development was not mentioned by respondents as a direct cause of woodland loss. The hunger for these basic services might have masked their direct impact on woodlands. However, the indirect effect of roads on woodlands by facilitating transportation and creating market outlets for woodland products was stated. This influence was considered as an underlying cause rather than a direct cause of woodland decline. Thus, it is treated under the policy and institutional aspects of woodland change in the next section.

Despite slight differences in the number of factors reported and their allied effects on forest conditions the type of proximate causes identified in the CRV are not basically different from those reported elsewhere in the world regarding tropical deforestation (Cropper & Griffiths, 1994; Dale, 1997; Abbot & Homewood, 1999; Contreras-Hermosilla, 2000; Geist & Lambin, 2001; Barreto et al., 2006; Geist et al, 2006; Amacher et al., 2009; Odada et al., 2009; Chidumayo et al., 2011; Mmom & Mbee, 2014). The effect of the same factor on the extent and condition of forests also varies with the specific human-environment relations in different places and over time. Eventually, forest loss because of human pressure is more common than forest gain worldwide (Drummond & Loveland, 2010; FAO, 2012). Nevertheless, there are also cases where the reverse of tropical deforestation (i.e., a shift from agricultural land to forest) has been reported in some parts of the world such as Europe and the United States of America mainly because of agricultural land abandonment (Burgi & Turner, 2002; Beilin et al, 2014).

In Ethiopia, proximate causes have often been reported along with driving forces with a generic tag causes or drivers of land cover change (Tsegaye et al., 2010; Tefera, 2011; Lemenih et al., 2014; Kindu et al., 2015; Wubie et al., 2016) and few report them independently or as separate chunks of a report. Among those that addressed the proximate causes of forest decline independently are the works of Teketay (1992), Urgessa (2003), and Dessie and Kleman (2007). This is not enough given the magnitude of the deforestation problem in Ethiopia and the fact that tropical deforestation is one of the best examples where the distinction between proximate and underlying causes can clearly be seen (Walker, 2004). Nonetheless, drawing from both sets of reports, similar results were found particularly with regard to the major proximate causes of deforestation, i.e., agricultural expansion and wood extraction. Clearing of forests to keep away crop pests was also reported by Urgessa (2003).

However, unlike the findings of this study, road construction (Teketay, 1992), settlement or government induced resettlement (Teketay, 1992; Reid et al., 2000; Tefera, 2011; Lemenih et al., 2014; Alemu et al, 2015; Kindu et al., 2015), forest fire (Tefera, 2011; Lemenih et al, 2014), extraction of traditional medicine and condiments (Teketay, 1992),

and recently expansion of commercial agricultural investment especially cultivation of cash crops such as sesame and cotton (Alemu et al., 2015) have been reported in different parts of the country where woodlands are predominantly found.

The different human activities identified in the study area particularly cropland expansion and wood extraction for fuel, construction, and charcoal production are exerting huge pressure on woodlands and threatening its continuity (Figure 15). It is evident that agriculture is expanding at the expense of woodlands from almost nothing to about 45% in just forty years period and the trend is still continuing though at a slower rate of conversion in recent years. The forest resources of the area are massively shrinking from over 95% of the study area forty years ago to a little over 40% at present. The remaining woodland is also open and disturbed mainly because of the continued extraction of wood products for charcoal production and fuel both for domestic consumption and sale. This entails the need for designing appropriate interventions that can address the problems and maintain the woodlands while still providing the necessary products and services to the people and the fragile ecosystem of the CRV.

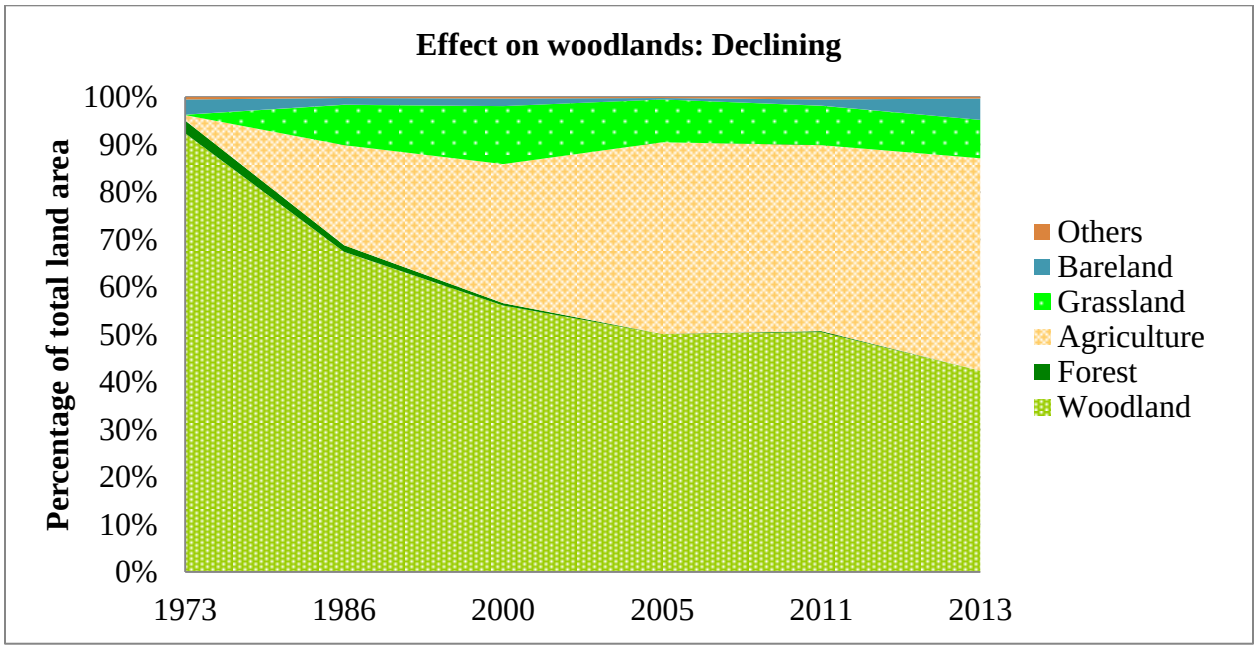

Figure 15 Effect on woodlands depicted as a percentage of the study area from 1973 to 2013.

7.4.2. Underlying causes of woodland decline

Households in the CRV perceived ten driving forces (i.e., underlying causes) of woodland decline (Figure 16). They fall into five fundamental forces of tropical deforestation that include economic, demographic, policy and institutional, cultural, and natural factors (Contreras-Hermosilla, 2000; Geist & Lambin, 2001, 2002; Lambin et al., 2006). Poverty and lack of income and alternative energy sources fall under economic factors; population increase under demographic factors; lack of forest policies, weak institutions, tenure issues, and policy changes along with changes in government and changes to the same regime under policy and institutional factors; lack of awareness about the importance, impact, and management of woodlands under cultural factors; and drought under natural triggering factors. Drought here is considered as an underlying cause because of the socioeconomic activities practiced behind its occurrence rather than its direct impact on the survival, growth, and distribution of woodlands.

However, there were disparities in the perception of the driving forces among respondents. The percentage of respondents who perceived the driving forces varied between 29.5% and 99.5% (Figure 16). The top three driving forces perceived by households were poverty (99.5%), drought (97.8%), and lack of alternative energy sources (97.6%). They were closely followed by another batch of three driving forces that include population increase (89.8%), lack of awareness (88.1%), and lack of income sources (86.7%). Weak institutions (38%), unclear tenure rights (37.5%), and policy changes (29.5%) represent the last three driving forces of woodland change perceived by households. Lack of forest policies, with a response rate of 53%, falls in between a group of top six and last three driving forces.

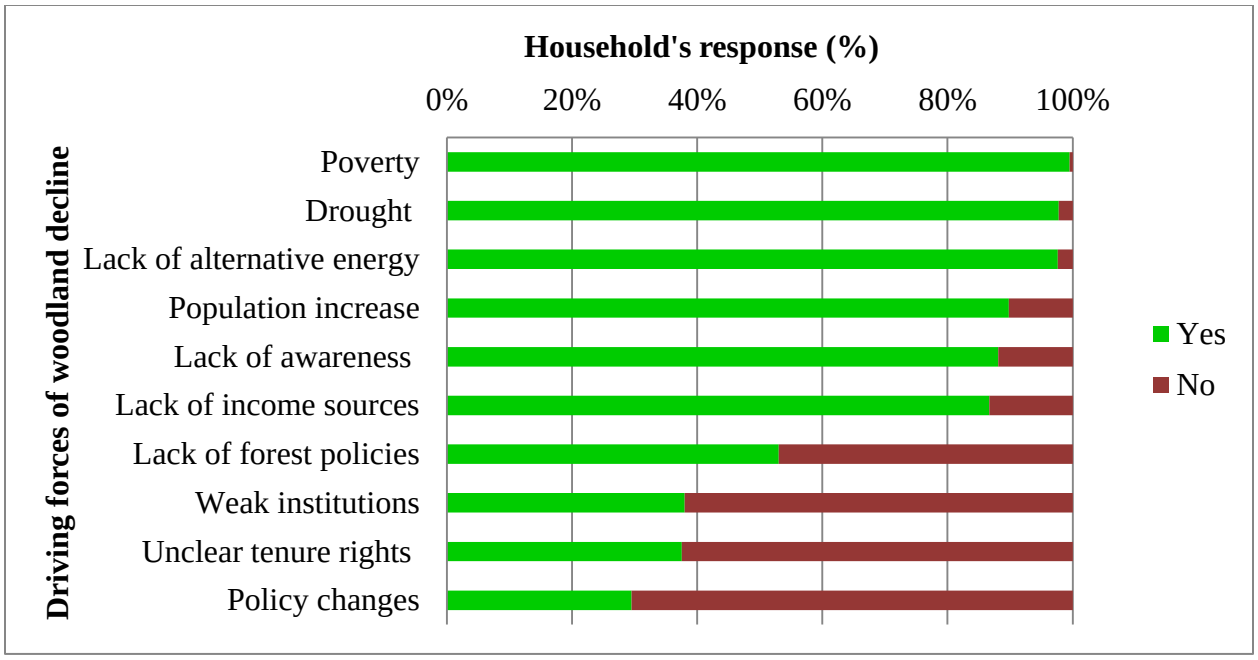

Figure 16 Driving forces of woodland decline perceived by rural households in the CRV

The percentage of respondents signifies the prominence of the particular driving force among the households in influencing the woodland resource. For example, the top three driving forces are well known as a driver of the more proximate causes of woodland decline by almost all households, while the last three are known as a driving force in some households. It has also a bearing on the magnitude of influence exerted by each driving force on the woodland resources of the study area. Eventually, akin to proximate causes, the woodland decline in the CRV at the underlying level is also best explained by the interplay of multiple factors rather than by single-factor causations.

7.4.2.1. Economic factors

Of all the underlying causes perceived by households, economic factors appear to play a strong role in the process of woodland changes in the CRV of Ethiopia. The interview result indicates that poverty is one of the most prominent economic factors driving forest decline. This is understandable because of the fact that agriculture (both crop cultivation and livestock rearing) is not dependable mainly because of low and erratic rainfall distribution and frequent occurrence of drought in the area (Muzein, 2006; Garedew et

al., 2009; Kool, 2010; Biazin, 2012). Households apparently depend on woodlands to support their livelihood and thereby influencing their status. Poverty has also been reported as one of the driving forces of deforestation globally (Gray & Moseley, 2005; FAO, 2012), in Nigeria (Mmom & Mbee, 2014) and in some other parts of Ethiopia (Manale, 2013; Wubie et al., 2016).

According to key informants and FGD participants as well as the reports of Garedew et al. (2009) and Biazen (2012), the local people predominantly poor households with limited income sources turn into woodlands to generate income and buy food during times of crop failure and drought. They also sell woodland products to fill food and income shortfalls encountered at any point in time particularly before major crops are ready for harvest. Moreover, woodland products are used as a means to eke out a living by the poorest households. In the survey, it was found that income derived from woodlands account for 20% of the total income of rural households in the CRV. The figure rises to 27% for poor households. This is a substantial support, particularly because it is generated during times of hardship when no other option seems feasible. While the contribution of the economic activities to support the livelihood of the rural households is most welcome, the pressure they are exerting on woodlands is worrisome.

Lack of alternative energy sources is not also far-off from poverty in its influence on woodlands as it is the third most popular driving force. Literally, households do not have options to cook food and light their houses other than using biomass energy including firewood, charcoal, crop residues and recently even cattle dung. The use of electricity, solar panel, and other similar energy sources, though started, are not expanded. Currently, less than 4% of the households have access to electric power. As a result, households use firewood (100%), crop residues (99%), charcoal (32%), and cattle dung (51%) as a source of domestic energy and the woodlands are the only source of firewood and charcoal in the area. It is, therefore, apparent to see the impact of having less alternative energy sources on woodlands.

7.4.2.2. Demographic and cultural factors

Demographic and cultural factors were the other group of driving forces that played major roles in determining the status of woodlands in the CRV. According to the peoples' account, an increase in human population has exerted too much pressure on woodlands as the demand for agricultural land and wood for both domestic consumption and sale has also increased. Population growth could be partially explained by the polygamy culture practiced in the area, as confirmed by this study as well as the reports of Garedew et al. (2009), Biazen (2012), and Kindu et al. (2015). As stated by key informants, polygamy is decreasing recently both in terms of engagement and number of wives. Likewise, some of the cultural factors such as lack of awareness about the importance, impact, and management of woodlands or generally low level of education of the inhabitants are believed to have upheld frontier mentality to use the nearby woodlands and led to less concern about their sustainability.

Population growth as a driving force of forest/woodland cover change appeared in almost every study made about the drivers of land-use/cover change in Ethiopia (Amsalu et al., 2007; Dessie & Christiansson, 2008; Garedew et al., 2009; Tsegaye et al., 2010; Tefera, 2011; Shiferaw, 2011; Biazen, 2012; Emiru & Taye, 2012; Yeshaneh et al., 2013; Minale, 2013; Lemenih et al., 2014; Girma & Hassan, 2014; Alemu et al., 2015; Kindu et al., 2015; Wubie et al., 2016). This is not surprising since population growth has long been singled out for its role in altering the face of the earth (Mather & Needle, 2000; Carr, 2004) and it is still a major force of tropical deforestation including Ethiopia (Contreras-Hermosilla, 2000; Geist & Lambin, 2001,2002; Whiteman, 2014). Population pressure has been accentuated as a driver of all proximate causes of deforestation (Cropper & Griffiths, 1994; Judith et al., 2011).

However, neither population growth nor poverty alone constitutes the sole and major driving forces of land-cover change globally (Dale, 1997; Lambin et al., 2001; Olson et al., 2004; Shvidenko et al., 2005; Giannecchini et al., 2007; Amacher, 2009). Population factors always act in concert with other variables and cannot fully explain tropical

deforestation (Jarosz, 1993; Lambin et al., 2001; Geist & Lambin, 2001, 2002; Carr, 2004). The findings of this paper also confirm that population increase is not the only driving force contributing to forest decline in the CRV of Ethiopia.

On the other hand, cultural factors appeared sporadically in land-use/cover change studies in Ethiopia. Emiru and Taye (2012), for example, reported a change of customary land tenure system following the intrusion of Highlanders from the neighboring regions that led to some extractive economic activities such as selling charcoal and firewood. It was emphasized that such activities were never practiced in the area before the intrusion of the Highlanders. A quite similar explanation was given by Tsegaye et al. (2010) in a study made in the Afar region, Northeastern Ethiopia. Bekele (2003), quoting the statement of an 80-year-old informant, also reported that cutting big trees was taboo in the past in the community living around Langano area in the CRV as they are their assembly places besides the multiple benefits they provide to them. Similarly, key informants and FGD participants in this study highlighted that elder people in the area rarely cut big trees. Much of the tree cutting practices is accomplished by youngsters and of course poor people who do not have many options to make a living.

7.4.2.3. Policy and institutional factors

Policy and institutional issues were identified by the interviewed households as a contributing factor to the woodland loss in the CRV but this time with a much lower frequency. All policy and institution-related factors (i.e., lack of forest policies, weak institutions to implement policies, unclear tenure rights, and policy changes) appeared in the last four groups of the driving forces perceived by households. Hence, according to the perception of the interviewed households, this implies that policy and institutional issues, though mentioned, were not the major underlying causes of the woodland decline in the CRV.

However, key informants and FGD members underscored the role of policies and institutions in changing the landscape of the area. The difference in perception might

have emerged as a result of differences in knowledge and experience as well as age differences. The average age of the interviewed households was only about 41 years (40.9 years), while key informants and FGD members included elderly and knowledgeable people.

Key informants and FGD participants explained that they have come across through three different regimes: the imperial regime, the socialist regime, and the current government. Akin to the regime changes they have also experienced changes in policy and institutions with serious implications for resource ownership and management. Owing to the irregularities in the ownership and management of the rift valley woodlands and the uncertainty unfolding it across the different regimes, woodlands have been the victim of destruction up until now. Similar narratives about the role of policy and institutional issues as an underlying cause of land-cover change in Ethiopia were also given by different authors with varying degrees of importance (Bekele, 2003; Amsalu et al., 2007; Dessie & Christiansson, 2008; Tefera, 2011; Shiferaw, 2011; Biazen, 2012; Emiru & Taye, 2012; Yeshaneh et al., 2013; Minale, 2013; Lemenih et al., 2014; Wubie et al., 2016).

For example, Dessie and Christiansson (2008) highlighted that large areas of forest were cleared during periods of political transition. He cited the then Munessa-Shashemene Forestry Project near the study area, which lost 71% of its forest area during the government change of 1991, as an example. Bekele (2003) also reported a huge loss of forest and woodland resources in the CRV and other parts of Ethiopia during periods characterized by a combination of violent change and political vacuum created in the course of government transitions. Amsalu et al. (2007), Tefera (2011), Shiferaw (2011), Biazen (2012), Emiru and Taye (2012), Minale (2013), and Yeshaneh et al. (2013), Lemenih et al. (2014) all had similar findings that government changes and the resulting changes in institutions and tenure rights over resources has contributed to the loss of forest resources in Ethiopia. Amsalu et al. (2007), for instance, reported widespread deforestation in protected areas following the 1974 government transition.

Another institutional issue mentioned by both key informants and FGD participants as a driving force of woodland decline was access to road and market. It was explained that the opening up of the asphalt road that crosses the study area and connects the capital city, Addis Ababa, to other major towns such as Bishoftu, Ziway, and Hawassa has facilitated the transportation and marketing of woodland products particularly charcoal to these towns. In doing so, they believe that it has accelerated the rate of woodland loss. The views of key informants and FGD members are consistent with the findings of Eshete (1999), Dessie and Christiansson (2008), Tsegaye et al. (2010), Biazen (2012), and Kindu et al. (2015) who all reported that access to the main road facilitated the sale and transport of wood products to major towns and hence accelerated the rate of deforestation.

7.4.2.4. Natural factors

Drought was one of the natural factors identified by the interviewed households as well as key informants and FGD members as one of the main underlying causes of woodland decline. Although almost all households interviewed (97.8%) perceived drought as an important driver of woodland cover change the narratives were made based on the views of key informants and FGD members. They singled out two major drought incidences, the 1972/73 and the 1984/85 drought periods, because of the impact it created on the lives of the people though there were many drought periods that the local people experienced. They stated that the impact of particularly the 1972/73 drought on woodlands was enormous. This drought incidence not only taught many people how to make income out of the resource and overcome its impacts but also the skill of making charcoal which they sustained it until today to a bitter effect on woodlands. These views of the informants are in agreement with the findings of Garedew et al. (2009), Tsegaye et al. (2010), Biazen (2012), Shiferaw (2013), and Kindu et al. (2015) who all reported drought as a triggering factor to deforestation. Tsegaye et al. (2010) even singled out the severe droughts of 1973/4 and 1984/85 as the main causes of the woodland decline in the Northern Afar rangelands as perceived by the pastoralists.

7.4.2.5. Technological factors

Although technological factors such as the use of traditional charcoal making techniques using earth kilns and the use of open stoves for cooking was not mentioned by the interviewed households it was confirmed through observation, key informant interview and FGD that they have played their own share for the loss of woodland resources in the study area (Figure 17). This sends a strong call for promoting the use of improved stoves that can save energy and efficient technologies that can minimize wastage and improve the conversion of wood to charcoal thereby reducing the number of trees being cut for charcoal production and fuel use.

Figure 17 Traditional charcoal production using earth kiln

Source: Author

7.4.3. Rank of perceived proximate causes and variations among respondents

Ranking of the proximate causes by households indicates the relative influence of each perceived cause on woodland resources, while the frequency of respondents indicates their recognition as the direct cause of woodland decline. Accordingly, agricultural expansion was ranked first meaning that it was the top proximate pressure factor for woodland resource change in the CRV (Table 20). It was followed by wood extraction from woodlands that include charcoal making, firewood collection, and cutting for construction and industrial purposes, respectively. Charcoal production was then the second top factor for woodland destruction next to cultivation. On the other hand, clearing woodland areas for grazing purposes and to keep away crop pests occupied the last two positions with the later taking the last spot. The particular cause was least ranked means that its influence on woodlands was viewed by households as the least.

The consistency of households in ranking the perceived causes was also observed. The least standard deviation of ranking was observed for the cause ranked first (i.e., clearing woodland areas for cultivation) and the highest for the second-ranked cause (i.e., cutting trees for charcoal making). This indicates that the ranking of households for agricultural expansion as a proximate cause of woodland decline was all near to the top and close to each other that the difference between them was so small on average. In contrast, there was a disparity in ranking among households who perceived charcoal production as a direct cause of woodland loss in the CRV.

It was also found that there was a very strong evidence of a relationship between a household's perception of some proximate causes and the *Kebeles* they are living in (Table 21). Significant differences among the perception of respondents were found for cutting trees for charcoal production (Chi-Square = 24.72, df = 3, $p < 0.001$), clearing for grazing (Chi-Square = 19.98, df = 3, $p < 0.001$), clearing to keep away pests (Chi-Square = 114.23, df = 3, $p < 0.001$), and harvesting for industrial uses (Chi-Square = 167.78, df = 3, $p < 0.001$). The difference in perception signifies that some proximate causes were

more important to certain *Kebeles* than others. On the other hand, no association was found between the household's perception of cropland expansion and firewood and construction wood collection as proximate causes of woodland loss and the *Kebeles* they reside. This shows that these problems were common to all the *Kebeles* and household's perception was not influenced by their respective *Kebeles*, i.e., their perceptions of these three proximate causes were not dependent on *Kebeles*.

Table 20 Ranks of proximate causes by respondents in order of importance (1–7), with 1 being the most influential proximate cause

Proximate causes	**Number**	**Min.**	**Max.**	**Mean**	**Std. Dev.**	**Rank**
Clearing for agriculture	412	1	4	1.36	0.61	1
Cutting for charcoal making	363	1	7	2.45	1.19	2
Cutting firewood	406	1	6	2.71	0.70	3
Cutting for construction purposes	401	1	6	3.46	0.97	4
Harvesting for industrial purposes	48	2	8	4.44	1.18	5
Clearing for grazing	110	2	7	4.64	1.02	6
Clearing to keep away pests	57	4	8	5.65	1.03	7

Source: Author's analysis based on the household survey

Table 21 Relationship between household's perceived responses towards proximate causes of woodland decline by *Kebele*

Proximate causes	Response by *Kebele*								
	Dakka Hore Qello (n=101)		Shalla Billa (n=125)		Keraru (n=118)		Gale Qello (n=69)		χ^2
	Yes	No	Yes	No	Yes	No	Yes	No	
Clearing for agriculture	101	0	125	0	118	0	68	1	
Cutting for firewood	101	0	124	1	114	4	67	2	
Cutting for construction	100	1	122	3	113	5	66	3	
Clearing for charcoal	75	26	116	9	111	7	61	8	***
Clearing for grazing	20	81	51	74	21	97	18	51	***
Clearing to keep away pests	46	55	5	120	6	112	0	69	***
Harvesting for industries	48	53	0	125	0	118	0	69	***

*** Significant at $P < 0.001$, indicating that the location of farmers/households had a significant effect on the perception of farmers towards proximate causes

Source: Author's analysis based on the household survey

7.4.4. Rank of perceived driving forces and variations among respondents

Of the ten driving forces perceived by respondents population increase, poverty, drought, lack of alternative energy sources, and lack of income sources constituted the top five ranks, respectively (Table 22). Policy change along with changes in government was the last ranked driving force. This denotes that population growth was viewed by households as the highest influential driving force, while changes in policy were the least. The lowest rank given for policy changes by the interviewed households was against the weight of explanations of the key informants and FGD participants as well as the reports of Bekele (2003), Amsalu et al. (2007), Dessie & Christiansson (2008), and Biazen (2012), who all highlighted the impact of policy changes on the forest resources of Ethiopia albeit no ranking among the driving forces was done. The least and highest standard deviation of ranking was observed for poverty and unclear tenure rights, respectively.

Moreover, significant differences were found in perception among respondents living in different *Kebeles* for all the driving forces except poverty (Table 23). Poverty, though ranked second to population increase in terms of its influence on woodlands, was perceived by all households except two who are living in Keraru *Kebele*. So, literally, there was no difference in perceiving poverty as a driving force of woodland change in the study area. Likelihood ratios rather than Pearson's Chi-Square values were taken for testing the significance of the association between household's perception of drought and alternative energy sources as drivers and their *Kebeles*. The likelihood ratio is preferred when the assumption of Chi-Square for a table bigger than 2*2 is violated, i.e., when the expected counts less than 5 are greater than 20%. The existence of an evidence of an association between the location of respondents and their perceptions towards the driving forces except poverty shows that some driving forces are more important to certain *Kebeles* than others.

Table 22 Ranks of driving forces by respondents in order of importance (1–10), with 1 being the most influential driving force

Underlying causes	**Number**	**Min.**	**Max.**	**Mean**	**Std. Dev.**	**Rank**
Population increase	371	1	10	2.21	2.24	1
Poverty	411	1	9	2.38	1.33	2
Drought	404	1	7	2.96	1.43	3
Lack of alternative energy sources	403	1	10	4.35	1.74	4
Lack of income sources	358	1	10	5.05	1.59	5
Lack of awareness	364	1	10	5.53	1.52	6
Unclear tenure right	155	1	10	5.55	3.03	7
Weak institutions	157	1	10	6.55	2.43	8
Lack of woodland policies	219	1	10	6.67	1.51	9
Policy changes	122	3	10	7.81	1.43	10

Source: Author's analysis based on the household survey

Table 23 Relationship between household's perceived responses towards the driving forces of woodland decline by *Kebele*

Driving Forces	Response by *Kebele*								
	Dakka Qello (n=101)		Hore Shalla Billa (n=125)		Keraru (n=118)		Gale Qello (n=69)		χ^2
	Yes	No	Yes	No	Yes	No	Yes	No	
Poverty	101	0	125	0	116	2	69	0	
Drought	100	1	125	0	116	2	63	6	**
Lack of alternative energy	99	2	125	0	113	5	66	3	*
Population increase	88	13	113	12	118	0	52	17	***
Lack of awareness	94	7	104	21	115	3	51	18	***
Lack of income sources	73	28	122	3	110	8	53	16	***
Lack of woodland policies	90	11	15	110	97	21	17	52	***
Weak institutions	90	11	13	112	36	82	18	51	***
Unclear tenure right	92	9	13	112	32	86	18	51	***
Policy changes	63	38	12	113	40	78	7	62	***

*, **, *** Significant at $P<0.05$, $P<0.01$, $P < 0.001$, signifying that location in which the households are living in had significant effect on their perception towards the driving forces

Source: Author's analysis based on the household survey

7.4.5. Determinants of household's perception for lack of forest policy as a driving force of woodland decline

Lack of forest policy was picked for the analysis as there was no clear pattern of perception for it, i.e., the number of households who perceived it and did not perceive it as a driving force was very close. This means that it was not possible to determine whether households have perceived lack of forest policy as the driving force of woodland decline or not. This discrepancy provokes an analysis of what determines or influences the perception of households towards the cause.

Accordingly, eight explanatory socioeconomic determinants were included in the analysis after they were screened for multicollinearity. There was no multicollinearity problem between the variables considered; the VIF values for all the variables were below 2 which is very good. Of all the variables only household size and wealth status had affected the perception of households for lack of forest policy as a driver of woodland loss positively and significantly (Table 24). Households with bigger household size were more likely to perceive the lack of forest policy as a driving force than those with small household size. The logistic regression analysis suggests that the odds of perceiving lack of forest policy as a driver increase by a factor of 1.08 for an increase in household size. Conversely, it means that for an additional household member, the odds of perceiving lack of forest policy as a driver is increased by 8%.

Likewise, the likelihood of perceiving the lack of forest policy as a driving force by poor households, other factors held constant, is 3.44 times higher than better-off households (better-off households were used as the reference category). Household income was also significant ($p < 0.05$) though it did not meaningfully affect the odds of perceiving lack of forest policy as a driver. The odds ratio of one suggests that there was no change in the odds of perceiving the driver as income increases. The rest of the explanatory variables that include sex, age, education, occupation, and land holding size did not contribute significantly to the perception of households towards the lack of forest policy as a driving force of woodland decline in the CRV area.

Table 24 Binary logistic regression results of household's perception for lack of forest policy as a driving force of woodland decline

Independent variables	*B*	S.E.	Wald	*df*	Sig.	Exp(*B*)	95% C.I. for EXP(B)	
							Lower	Upper
Sex (1)	0.66	0.34	3.76	1	0.05	1.93	0.99	3.75
Age	0.00	0.01	0.05	1	0.83	1.00	0.98	1.02
Literacy (1)	-0.05	0.27	0.03	1	0.86	0.95	0.56	1.63
Occupation (1)	1.01	0.59	2.90	1	0.09	2.74	0.86	8.76
Household size	0.08	0.04	4.93	1	0.03*	1.08	1.01	1.16
Wealth status			22.60	2	0.00***			
Wealth status (1)	1.24	0.41	9.01	1	0.00***	3.44	1.54	7.71
Wealth status (2)	0.14	0.40	0.13	1	0.72	1.15	0.53	2.51
Land size	-0.02	0.01	1.55	1	0.21	0.98	0.96	1.01
Household income	0.00	0.00	6.96	1	0.01*	1.00	1.00	1.00
Constant	-2.41	0.69	12.19	1	0.00***	0.09		

Number of observation = 413; Model $\chi^2(1) = 36.85$, P<0.001; Hosmer and Lemeshow = 0.99 > 0.05; Nagelkerke's $R^2 = 0.114$; * and *** = statistically significant at P < 0.05 and P < 0.001, respectively.

Source: Author's analysis based on the household survey

7.5. Conclusion

This study analyzed the context of woodlands in the CRV and the factors that contribute to their changes. It was found that woodlands are under threat by various human-induced pressures. A combination of seven proximate pressure factors and ten fundamental driving forces were identified as reasons for the decline of woodland resources in the study area. The top five immediate pressure factors perceived by respondents were cropland expansion, charcoal production, firewood collection, and cutting for construction and industrial uses, which are listed in descending order of influence on woodlands. The ten underlying causes identified in the CRV fall into six fundamental forces of tropical deforestation that include economic, policy and institutional, demographic, cultural, technological, and the indirect effects of natural factors. The top five ranked driving forces were population increase, poverty, drought, and lack of alternative energy and income sources in descending order of importance. Although the

number and relative importance vary, these factors are not basically different from those described for tropical deforestation worldwide.

An evidence of a relationship between a household's perception of some proximate and underlying causes and their respective *Kebeles* was also found. Regarding proximate causes, significant differences among the perception of respondents were found for cutting trees for charcoal production and industrial uses and clearing for grazing and to keep away crop pests. There was no significant difference in perception for cropland expansion, firewood collection and construction wood harvesting. Similarly, there were significant differences between all the driving forces perceived by respondents except poverty. An evidence of an association between the location of respondents and their perceptions towards certain factors suggests that there were differences in the relative importance of the factors among the *Kebeles*. Plainly, it means that one factor could be more important to a certain *Kebele* than others implying a different course of action to be taken in the respective *Kebeles* to rectify the problem.

The study further illustrated that among eight explanatory socioeconomic determinants only wealth status and household size had a significant positive effect on household's perception towards lack of forest policy as a driving force of woodland decline in the CRV. It was noted that poor households were more likely to perceive the impact of lack of forest policy on woodlands than better-off households. Household income was also significant although it did not produce a positive impact on their perception as the odds ratio was just one.

Moreover, despite the tendency of many analysts to attribute undesirable forest decline to a single or dominant causative factor such as population growth or agricultural expansion, this study illustrated that it is the result of many factors incorporating different proportions that lead to forest changes. Nevertheless, the number and complexity of the factors vary across spatial and temporal scales. So, it is literally impossible to find uniform causes and drivers and similar interactions associated with them that can be

universally applied. This, in turn, suggests the need to undertake context-specific and detailed studies and to find highly specific remedies.

Regardless of all the restraints, there is, however, enough knowledge to understand that certain causes in most cases are likely to have an influence on forest decline. Therefore, the findings of this study can be useful to other areas in Ethiopia and elsewhere where the socioeconomic and environmental settings are similar. In particular, the lowlands of Ethiopia, where woodlands are the dominant vegetation type and subsistence agriculture is practiced, are likely to experience similar problems. Thus, they can be used to predict changes, to develop policies, to design management strategies and interventions, and to forecast the impacts of the changes on the environment and the livelihood of the local people in the CRV and other areas with similar settings. It should also be underscored that successful policy-making requires fundamental forces as well as proximate causes of changes in forest quantity and quality.

Finally, the study stresses that urgent attention is needed from all relevant stakeholders to rescue the ever-shrinking woodlands that have been providing valuable goods and services to the people as well as the fragile ecosystem of the CRV area. Unless actions are taken to mitigate both the driving forces and the proximate pressure factors there is no reason why woodlands will experience the same fate as forests which have virtually disappeared from the landscape of the study area. Although striking a balance between the human use of the resources and their sustainable management has always been a challenge, appropriate measures need to be in place before the situation reaches an irreversible stage. In addition, further study is needed to analyze the linkages between the different factors and their likely impacts on woodlands.

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Chapter Eight: Summary, Conclusions and Policy Implications

8.1. Summary

Climate change is already happening with many adverse impacts on human societies and the environment. It is one of the main challenges that mankind has faced in this century. Although climate change is a global phenomenon and developing countries have little historical responsibility, they are likely to be most affected by it since they lack the capacity to cope with and adapt to its effects. Of the developing countries, Africa as a whole and Ethiopia, in particular, is among the most vulnerable countries in the world and with the least capacity to adapt to the impacts of climate change.

Ethiopia's vulnerability is largely associated with its strong economic dependence on rain-fed agriculture and its limited capacity to adapt to changes in climate. It is further exacerbated by prevalent stresses, such as widespread poverty, high population growth, environmental degradation, inadequate infrastructure, weak institutions and low levels of awareness on climate change issues. Although the degree varies, all rural livelihood systems in Ethiopia are vulnerable to changes in climate mainly because of their heavy dependence on rainfall. In terms of the environment, dry-lands (arid, semi-arid and dry sub-humid areas) are the most vulnerable and affected parts of the country.

Indeed, exposure to climate variability and its associated impacts are not new in Ethiopia. The country has experienced numerous climatic as well as environmental shocks over the last several thousands of years. Drought, for example, has been a persistent problem for Ethiopia. However, the recent climatic perils such as increased rainfall variability and more intense and frequent drought and flood are associated with anthropogenic climate change. Consequently, despite efforts being made both at national and local levels, the country is suffering from the impacts of these climate-related changes. This highlights the fact that many societies in Ethiopia lack the capacity to withstand the vagaries of climate change and remain poorly adapted even to the current climate. Moreover, climate change

will pose novel risks which are likely to worsen the already distressing situation of many rural households in Ethiopia. Thus, there is a need to make concerted efforts and take timely actions to both mitigate its causes and adapt to its unavoidable effects.

Taking effective adaptation measures, in turn, requires a better understanding of adaptive capacity as adaptations are manifestations of adaptive capacity. Despite this fact, studies to better understand the adaptive capacity of rural households in Ethiopia and in particular in the semi-arid areas of the Central Rift Valley (CRV), which are highly exposed to climate risks such as recurrent drought and rainfall variability, are limited. Most studies focused on assessing vulnerabilities and adaptation strategies rather than the constituents of adaptive capacity which can guide adaptation practices and development interventions with an ultimate end of reducing vulnerability. Most of these studies were also conducted at higher levels, while managing climate risk has traditionally been the responsibility of households, with the exception of large-scale calamities. Moreover, the contributions of natural assets such as woodlands to adaptive capacity are often overlooked in adaptive capacity assessments.

Therefore, the aims of this study were (1) to evaluate climate trends and households' perception of climate change, its impacts, and adaptation practices, (2) to identify the elements of adaptive capacity of households and assess the role of the different components, in particular, woodlands in adaptive capacity, (3) to compare the adaptive capacity of households across the selected *Kebeles*, (4) to assess the changes that the woodland resources of the area have experienced over the years and their impacts on the livelihood of the local people and the environment, and (5) to explore the associated proximate causes and driving forces of woodland cover change.

The study was conducted in the CRV, which is one of the most environmentally fragile and vulnerable areas in Ethiopia experiencing the vagaries of climate change. The researchers took a pragmatist position and followed a convergent parallel mixed methods approach to address the research problem. Thus, quantitative and qualitative data were

generated at roughly the same time and converged to provide a comprehensive analysis of the research problem.

Accordingly, a number of data collection techniques such as remote sensing and GIS, household survey, focus group discussion (FGD), key informant (KI) interview and field observations were employed. A total of 13 key informants, 31 FGD members and 413 households in four selected *Kebeles* were involved in the study. Remote sensing and GIS techniques were used to detect land use/cover change. A household survey was conducted to assess households' perception of climate change, to generate data for assessing adaptive capacity, to identify perceived proximate and underlying causes of woodland cover change, and to assess perceived impacts of woodland cover change on livelihood and the environment. KI interviews and FGDs were basically conducted to tap specialized information and substantiate the outcomes of the household survey. Field observation was also conducted to see the overall condition of the woodland, the impact of woodland cover change on the environment, and related activities such as collection, use, and marketing of wood products, and the techniques used to produce them. Descriptive statistics, Principal Component Analysis (PCA), Factorial Analysis for Mixed Data (FAMD), regression analysis, Chi-Square test, narratives and satellite image analysis using remote sensing and GIS techniques were used to analyze the data.

The study found out that a large majority of the surveyed households (98.1%) perceived a change in climate over the last 30 years. Similarly, 94.2% and 87.2% of the households perceived that temperature had increased and rainfall had decreased, respectively. The climate data analysis also depicted temperature increase and high rainfall variability but not a reduction in the amount of rainfall. Drought, shortage of rain, and change in rainfall timing were ranked as the top three climate-related hazards by households. Over three-quarters (75.5%) of the households perceived that drought had resulted in a loss of assets, loss of income, death of livestock, reduced consumption, a decline in crop yield, and food insecurity. More than half (56.5%) of the households also perceived similar impacts from the shortage of rainfall. In response to these impacts, households adopted a number of adaptation practices. However, there were also barriers to adaptation.

In the adaptive capacity assessment study, we identified five major components of adaptive capacity and developed a total of sixty indicators. Aggregate and composite indices were calculated for the respective indicators. The analysis revealed that, of the five major components, institutions and entitlements (0.61), knowledge and information (0.50), and innovation (0.43) contributed to adaptive capacity positively and better than decision-making and governance (-0.17) and asset-base (-0.40). Within the asset-base, physical asset (0.42), financial asset (0.35) and natural asset (0.32) made positive and better contributions, while human asset (-0.37) and social asset (-0.40) made lower contributions. The natural asset, in turn, was composed of farmland, grazing land, woodland and water resource and the contribution of woodlands (0.70) were positive and superior to others followed by grazing land (0.49). The contributions of farmland (-0.43) and water resource (-0.30) to natural asset were low. These findings are important to understand the constituents of adaptive capacity and their relative contributions and hence to design appropriate interventions.

In addition, the adaptive capacity index created for cross-household comparison across the four *Kebeles* indicated relative differences in their capacity to adapt to climate-related hazards. Adaptive capacity of households in the CRV appears to be generally low with only one *Kebele*, Keraru, showing a positive aggregate adaptive capacity index (1.04). So, households in Keraru seem to be in a relatively better position with respect to their capacity to adapt to the impacts of climate change. The adaptive capacity index scores for Shalla Billa, Gale Qello, and Dakka Hore Qello were -0.03, -0.38, and -0.91, respectively.

The composite index scores for the major components of adaptive capacity also revealed differences across the *Kebeles*. For example, Dakka Hore Qello, which stands last in terms of aggregate adaptive capacity index, received the highest contribution from asset-base, while Keraru, which ranked first in the aggregate adaptive capacity index order, received the least. Likewise, the contribution of decision-making and governance to the adaptive capacity of households in Keraru was the least, while it was positive for Shalla

Billa and Dakka Hore Qello. This signifies not only the role that the different components play in enhancing adaptive capacity but also the fact that they tend to exist and function differently in different contexts even at the local level. This further invokes the idea that interventions aimed at improving adaptive capacity need to be tailored to specific locations and contexts.

On the other hand, the land use/cover change analysis witnessed major changes in land use/cover and substantial impacts on the livelihood of the local people and the surrounding environment. The analysis disclosed that forty years ago the area was basically a forested landscape (95%) and agriculture was just about starting accounting for only 1% of the entire area. Open grassland was also negligible with only 0.1%. However, over the last forty years, agriculture and grassland expanded considerably that they have dramatically changed the landscape to a predominantly agricultural landscape. Now, ninety-five percent of the area is covered by three land use/cover types, namely, agriculture (45%), woodland (42%), and grassland (8%). The remaining 5% is mainly bare land. In the process, woodlands have lost 54% of the area, while agriculture and grassland gained a mammoth 3,878% and 11,117%, respectively.

These changes have huge implications on the society and the environment. While the socioeconomic impact of expanding agriculture is understandable, its continued expansion could also bring grave consequences on the contribution of woodlands and the state of the environment. The local people have already perceived reduced availability of wood products, increased wood prices, reduced income from woodlands, declining crop productivity, lack of traditional medicine, and loss of edible fruits. They have also perceived environmental impacts such as degradation of woodland resources, degradation of soil, fragmentation and loss of habitat, and loss of biodiversity. These changes entail serious attention as they are taking place in one of the most environmentally sensitive areas in Ethiopia. A small change in natural resources in these areas could bring far-reaching consequences on the ecosystem and the provision of goods and services, which are vital in supporting the livelihood and adaptive capacity of the local people.

The factors that contributed to woodland decline were also explored. It was found that woodland changes were triggered by the interplay of seven proximate and ten underlying causes. Cropland expansion and wood extraction for charcoal production, fuel, and construction materials were the main proximate causes perceived by households. On the other hand, population increase, poverty, and socioeconomic drivers triggered by drought, such as the colossal sale of firewood and charcoal following drought and crop failure were the top three ranked driving forces of woodland decline perceived by households in descending order of importance.

Moreover, a test was made to see if there was any association between household's perception of proximate and underlying causes and the *Kebeles* they are living in. The Chi-Square test showed that there was a very strong evidence of a relationship for some proximate causes and all but one driving force. Significant differences in perception of households living in different *Kebeles* were found for four proximate causes that include cutting trees for charcoal production, clearing for grazing, clearing to keep away pests and harvesting for industrial purposes. However, no association was found for the remaining three proximate causes, namely, cropland expansion, firewood collection and cutting for construction purposes. While differences in perception signify differences in the relative importance of the factors in the respective *Kebeles*, the absence of association demonstrates the commonality of the problems across the *Kebeles*.

Similarly, significant differences in perception across the four *Kebeles* were observed for all the driving forces except poverty. This evidence shows that some driving forces except poverty are more important to certain *Kebeles* than others. On the other hand, the absence of differences in perception for poverty indicates that the impact of poverty on woodlands is clear and common to all households across all *Kebeles* that there was no significant difference in perceiving it as a driving force of woodland decline.

Finally, analysis of the determinants of household's perception towards lack of stringent forest policy as a driving force of woodland decline indicated that only household size and wealth status affected the perception of households positively and significantly. Poor

households and households with bigger household size were more likely to perceive the impact of lack of forest policy on woodlands than better-off households and those with small household size, respectively.

8.2. Conclusions

This study began with a premise that, despite the need for progress, little research and analysis has been done on adaptive capacity at the local level, community or household level. Many researchers have adopted the 'five capitals' enumerated in the sustainable livelihood framework to asses adaptive capacity. While the availability of assets represents the sine qua non of adaptive capacity and is proven to be a useful starting point, it does not provide enough recognition for processes and functions that are important in mobilizing resources effectively. Thus, in order to capture the important elements of adaptive capacity at the household level, this study developed a conceptual framework based mainly on Smithers & Smit (1997) and Jones et al. (2010) frameworks.

Analyzing adaptive capacity using the conceptual framework enabled us to identify five major components of adaptive capacity and develop a total of sixty indicators. The analysis confirmed that adaptive capacity is not only a function of available assets but also the processes and functions needed to mobilize them. Analysis of the contribution of the major components to adaptive capacity also revealed that intangible assets such as institutions and entitlements, knowledge and information, and innovation contributed positively and better than governance and asset-base.

It was also unveiled from the composite index analysis for the sub-components of asset-base that there were relative differences in their contribution. The physical, financial, and natural assets contributed positively, while human and social assets made a negative one. The physical asset was the best contributor to asset-base, while social asset was the least. Similarly, woodland and grazing land contributed positively to the natural asset, while water resources and farmland contributed negatively. The contribution of woodlands to

natural asset was superior to others. In the aggregate, the analysis portrays the complexity and multidimensionality of evaluating adaptive capacity at the local level.

Moreover, assessment of the household's adaptive capacity across the four *Kebeles* indicated relative differences. Although the adaptive capacity of households in the CRV, in general, appears to be low households in Keraru seem to be in a relatively better position in terms of their capacity to adapt to climate-related impacts. The adaptive capacity indices for the rest of the *Kebeles* were negative with varying degrees. The composite index analysis for the major components of adaptive capacity also revealed that their contribution varied from *Kebele* to *Kebele*. For example, Keraru benefited more from the availability of strong local institutions and entitlements to key resources and better knowledge and information on climate-related issues. Conversely, they seem to suffer from lack of asset-base and poor decision-making and governance. This indicates that it is the combination and balance of the different components in the respective *Kebeles* that determine the adaptive capacity of households.

On the other hand, based on the results of the land use/cover change analysis, it is now understood that the area has undergone through a major land use/cover change over the last forty years. It is disclosed that the area has changed from a forested landscape forty years ago to a predominantly agricultural landscape today. As a result, woodlands, which have been supporting the livelihood and adaptive capacity of households and the fragile ecosystem, are declining. Thus, according to households, these changes are also exerting substantial impacts on their livelihood and the state of the environment. They have already perceived various socioeconomic and environmental impacts including reduced availability of wood products, increased wood prices, reduced income from woodlands, loss of edible fruits and traditional medicine, degradation of woodland resources, degradation of soil, and loss of habitat and biodiversity.

Therefore, despite the multiple benefits they are providing, woodlands are under increasing human pressure. According to households, this pressure on woodlands was triggered by the interplay of seven proximate and ten underlying causes. The major

proximate pressure factors perceived by households were cropland expansion and wood extraction for fuel, charcoal, construction and industrial uses. The fundamental factors that underpin the more proximate causes perceived by households include economic, demographic, policy and institutional, cultural, and natural factors. However, some proximate factors such as charcoal making, clearing for grazing and to keep away crop pests, and harvesting for industrial use were more important to certain *Kebeles* than others. Akin to proximate factors, the importance of all the driving forces except poverty was different across the *Kebeles*. Moreover, poor households and households with bigger household size were more likely to perceive lack of stringent forest policy as a driving force of woodland decline than better-off households and those with small household size, respectively.

8.3. Policy Implications

This study sheds some important insights into policy relevance. First, the study highlights the complex and multidimensional nature of adaptive capacity at the local level. The elements of adaptive capacity are not only limited to the availability of assets but also to the processes and functions that mobilize them. And these elements are closely linked to development issues such as access to resources (economic, environmental, and human resources), infrastructure development, institutions, and governance. Therefore, policies geared towards enhancing adaptive capacity should be seen in a broader context of sustainable development. The components that determine the adaptive capacity of households should be considered as an integral part of sustainable development and addressed systematically. Indeed, best adaptation is sustainable development as climate change challenges are the result of unsustainable socioeconomic development.

Second, the main policy focus to foster adaptive capacity should be to improve the system as a whole in an integrated manner because all the components form an integrated and systematic part of adaptive capacity. However, more attention is needed to improve the contribution of the low-scoring components such as decision-making and governance and asset-base as they are currently hindering the adaptive capacity of households.

Third, policy and development interventions should be tailored to specific locations and contexts as the adaptive capacity of households living in different *Kebeles* exhibited relative differences. The existence and function of the different components of adaptive capacity were also different across the *Kebeles*. Thus, the findings of this study can be used to direct policy and target issue – and place – specific investments that can boost the capacity of households to adapt to the impacts of climate change. This, in turn, means that this study argues against the idea of designing large, spatially contiguous strategies to improve the adaptive capacity of rural households in Ethiopia.

Fourth, despite playing a vital role in supporting the livelihood and adaptive capacity of households and the fragile ecosystem, the dwindling woodland resources and their impacts on the society and the environment suggest that either the existing policy is not stringent enough or lacks the necessary implementation tools. Hence, this study suggests revisiting the country's forest policy as well as its forest management strategies so that woodland resources will be sustainably managed and continue providing the vital goods and services. The revision should also take into perspective the adaptation of forests to climate change impacts and their role in climate change adaptation and mitigation.

Fifth, successful forest policy development and implementation require knowledge of both the fundamental driving forces and the proximate causes of forest decline. Undoubtedly, urgent action is needed to arrest the factors that are contributing to the loss of woodland resources in the CRV. Hence, the findings of this study could serve as a useful input to improve forest policy, to design forest management strategies and interventions, to predict changes in forest resources, as well as to forecast the likely impacts of the changes on the society and the environment.

Finally, this study suggests a number of specific policy options and interventions that could enhance adaptive capacity at the local level. These include delivering timely and accurate climate information; raising the level of awareness of households and development actors about climate change and appropriate adaptation practices;

facilitating availability of credit for investment in adaptation practices; investing in yield-improving technologies, irrigation and water harvesting schemes, and resource management, including the restoration of woodlands; creating opportunities for off-farm and non-farm employment; supporting social networks; and continuing the existing Productive Safety Net Programs until the adaptive capacity of households is built to the extent that they can handle climate change impacts by themselves.

Annex

1. Household Questionnaire

Questionnaire ID No. _____

Adaptive Capacity of Woodland Dependent Households to Climate Change in the Central Rift Valley of Ethiopia

Rural Household Survey Questionnaire

Dear respondent, this study will be conducted in order to assess the livelihood and adaptation strategies of the communities and the role of woodlands in climate change adaptation. The objective of this questionnaire is, therefore, to collect primary data on socio-economic and development related issues that are helpful to assess the impacts of climate change and the responses being made by the local community in the study area. It is intended for households that have harvested any crop or sold any livestock in the last 12 months of the farming year and your household was selected randomly from a list of households living in this area. This period should approximately cover October 2013 – February 2014. Thus, you are kindly requested to answer the questions honestly and in accordance with the actual situation of your household. Your earnest assistance to the surveyor to successfully complete the questionnaire is of immense value.

We would also like to assure you that we will strictly follow the scientific research ethics and keep any personal information that you provide confidential. Indeed, your response will remain anonymous. Moreover, you should feel confident that this interview and the information that you will provide us works only for this study and has nothing to do with development assistance or any other expectations.

Lastly, I thank you for your cooperation!

Name of Peasant Association (PA) _____ PA Code_____

Name of household head_____ ID number _____

Economic status in his/her own description: 1=Poor, 2 = Medium, 3 = Better-off

Time interview commenced: 2013 year, ___Month___ Day___Hour____ Minute

Time interview concluded: 2013 year, ___Month___ Day___Hour____ Minute

Name of interviewer _____ Signature_____

Name of supervisor _____

Checks

Date Checked	Checker initials	Status		Problem	Comments	Corrected?	
		Ok	Return			Yes	No

1. Household characteristics

1.1. Household size _____

1.2. Household characteristics (*fill the table below*)

No.	Name of household members *(List household head first & use first names only)*	1.1. Relationship to head of household	1.2. Sex	1.3. Age	1.4. Religion	1.5. Ethnic group	1.6. Educational status *(for all ≥5 years old)*		1.7. Marital status *(For household head only)*			1.8. Major Occupation
		1. Head 2. Spouse 3. Daughter/ Son 4. Sister/ Brother 5. Parent 6. Adopted child 7. Other relative 8. Non-relative	1. Male 2. Female	Age of ___in completed years	1. Muslim 2. Orthodox 3. Protestant 4. Catholic 5. Waqifeta 6. Non-religious 7. Other, specify _____	1. Oromo 2. Amara 3. Kembata 4. Wolaita 5. Other, specify _____	1.6.1. Can ___ read and write? 1. Yes 2. No (skip to 1.7)	1.6.2. The highest grade completed	1.7.1. 1. Currently married 2. Divorced 3. Widowed 4. Separated 5. Never married 6. Other, specify _____	1.7.2. If married, type of marriage? 1. Monogamy 2. Polygamy	1.7.3. If polygamy, number of wives__	1. Farmer 2. Livestock Herder 3. Domestic work 4. Trader 5. Farm laborer 6. Shepherd 7. Student 8. Civil Servant 9. Artisan 10. Driver/Mechanic 11. Skilled worker (factory) 12. Not in labor force 13. Unemployed 14. Other, specify_____
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												
11												
12												
13												
14												
15												

2. Livelihood strategies

2.1. What are the means of livelihood for the household? (*you can tick more than one alternative given in the table below and rank the top five in order of importance*)

Code	Means of livelihood	Tick	Rank *(only for the top five)*
1	Crop production		
2	Livestock production		
3	Vegetable production		
4	Firewood collection		
5	Construction wood collection		
6	Charcoal making		
7	Fishing		
8	Beekeeping		
9	Safety net transfer		
10	Remittance		
11	Hiring out labor/wage labor		
12	Renting out land, animals, tools, carts, etc.		
13	Sand quarrying		
14	'Soda ash' or bole soil mining		
15	Petty trading		
16	Local beverage production & sale (e.g. traditional drinks)		
17	Handicraft		
18	Others (specify)		

2.2. What are the main sources of energy for the household? (*you can tick more than one*)

Code	Energy source	Tick	Rank *(only for the top three)*
1	Fuel wood		
2	Charcoal		
3	Crop residue		
4	Animal dung		
5	Electricity		
6	LPG (Liquefied Petroleum Gas)		
7	Kerosene		
8	Biogas		
9	Solar panel		
10	Other, specify		

2.3. How do you assess your current living condition as compared to some 5 years ago? 1. Much better 2. Better 3. About the same 4. Worse 5. Much worse

2.4. How do you assess your current living condition as compared to some 10 years ago? 1. Much better 2. Better 3. About the same 4. Worse 5. Much worse

2.5. How do you assess your current living condition as compared to some 30 years ago? 1. Much better 2. Better 3. About the same 4. Worse 5. Much worse

2.6. If your living condition has improved over the last five years, what are the contributing factors? (*multiple response*) 1. Better awareness 2. Better extension service 3. Better access to credit and saving 4. Good governance 5. Better supply of agricultural inputs 6. Better access to market (for livestock & crops) 7. Better climatic condition 8. Other, specify _____

2.7. If your living condition has worsened what are the impeding factors? (*multiple response*) 1. Lack of awareness 2. Poor extension service 3. Lack of access to credit and saving 4. Poor governance 5. High input prices & supply problem 6. Recurrent drought 7. Shortage of rainfall 8. Lack of grazing land 9. Lack of access to market (for livestock and crops) 10. Other, specify _____

3. Status of woodlands and their management

3.1. Is there woodland in your area? 1. Yes 2. No

3.2. If yes, for which of the following are woodlands important for your household?

Code	Importance of woodlands	Tick
1	Firewood	
2	Charcoal	
3	Construction wood	
4	Farm implements	
5	Source of income	
6	Food (edible fruits, leaves, pods etc.)	
7	Fodder (animal feed)	
8	Shade	
9	Medicinal value	
10	Watershed protection	
11	Soil fertility improvement	
12	Gum and incense	
13	Scenic beauty	
14	Others, specify _____	

3.3. Do you agree that woodlands are important source of livelihood for your household? 1. Strongly agree 2. Agree 3. Cannot decide 4. Disagree 5. Strongly disagree

3.4. Under what circumstances does your dependence on woodlands increase? 1. During times of crop failure 2. During times of drought 3. During times of cash income shortage 4. Others, specify _____

3.5. Have you seen changes in the woodland cover of the area over the last 30 years? 1. Yes 2. No 3. Don't know

3.6. If yes, how do you perceive the changes in woodland cover? (*choose only one*) 1. Rapidly declining 2. Gradually declining 3. Completely disappeared 4. Increasing 5. No opinion

3.7. If the woodland area has declined or disappeared what are the reasons? (*fill the table below*)

Code	Reason	Tick	Rank *by order of importance*
1	Clearing for agriculture		
2	Clearing for grazing		
3	Cutting for charcoal making		
4	Cutting for firewood		
5	Cutting for construction purposes		
6	Harvesting for industrial purposes		
7	Clearing to keep away pests		
8	Pests and diseases		
9	Others, specify		

3.8. What do you think are the major drivers of the woodland cover change? (*see the list below*)

Code	Drivers of woodland cover change	Tick	Rank
1	Population increase		
2	Poverty		
3	Occurrence of drought		
4	Lack of energy sources		
5	Lack of income sources		
6	Lack of awareness about the importance of woodlands		
7	Lack of woodland policies		
8	Policy changes with changes in government		
9	Weak institutions to implement woodland policies		
10	Lack of clear tenure right/unambiguous ownership regime		
11	Other, specify		

3.9. If the woodland cover has improved what are the reasons? (*multiple response*)

Code	Reason	Tick	Rank
1	Better information through better extension work		
2	Improved awareness about woodland importance		
3	Better restoration efforts such as enclosures		
4	Stopping or reducing cutting of trees		
5	Better woodland policies and laws		
6	Better enforcement of laws		
7	Better institutions to implement woodland policies & laws		
8	Secured tenure right for woodlands		
9	Improved sense of ownership		
10	Others, specify		

3.10. Do you have your own woodland? 1. Yes 2. No.
3.11. If yes, is that enough to satisfy your wood related requirements? 1. Yes 2. No
3.12. If the woodland you have is not enough or you do not have your own woodland, where do you get wood materials for domestic use? (*multiple response*) 1. Own trees on farm 2. Nearby community woodland 3. Nearby government woodland (park) 4. Buying from the market 5. Other, specify ____
3.13. If you have your own woodland, what are you doing to protect it and improve its cover? 1. Enclosing it from human and animal intervention 2. Fencing 3. Constructing soil & water conservation structures 4. Nothing 5. Other, specify _____
3.14. How do you assess the availability of firewood and charcoal as compared to the past 5 years? 1. Increasing 2. Decreasing 3. Remain the same
3.15. How do you assess the price of firewood and charcoal as compared to the past 5 years? 1. Increasing 2. Decreasing 3. Remain the same
3.16. Who do you perceive owns the surrounding woodland? *(can choose more than one)* 1. The government 2. The community 3. Private individuals 4. Other, specify _____
3.17. Which management strategy do you think is better to restore the woodlands? 1. Better if managed by the government 2. Better if managed by the community 3. Better if managed by individual farmers 4. Better if managed jointly by the government and the community 5. Better if managed jointly by the government and individual farmers 6. Better if managed jointly by the community and individual farmers 7. Other, specify _____
3.18. Are you willing to plant trees? 1. Yes 2. No
3.19. If no, what are the reasons? 1. Lack of motivation 2. Lack of technical support 3. Lack of suitable tree species 4. Lack of land/tree tenure security 5. Shortage of land 6. Other, specify _____

4. Perception to climate change *(circle one of the choices)*

4.1. Have you noticed any long-term change in the mean temperature over the last 30 years? 1. Yes 2. No 3. Don't know
4.2. Has the number of hot days over the last 30 years 1. Increased 2. Decreased 3. Stayed the same 4. Don't know
4.3. Have you noticed any long-term change in the mean annual rainfall over the last 30 years? 1. Yes 2. No 3. Don't know
4.4. Has the number of rainfall days over the last 30 years 1. Increased 2. Decreased 3. Stayed the same 4. Don't know
4.5. Have you noticed changes in the pattern of distribution of rainfall over the last 30 years? 1. Yes 2. No 3. Don't know
4.6. If yes, how was the distribution of rainfall over the season in recent years? 1. It is erratic 2. It starts late and stops soon 3. It starts late and stops longer 4. It starts early and stops soon 5. It starts early and stops late
4.7. Have you encountered drought over the last 30 years? 1. Yes 2. No 3. Don't know
4.8. If yes, how do you describe the frequency of occurrence of drought in recent years as compared to the past 30 years? 1. Increased 2. Decreased 3. Followed a similar trend
4.9. Have you encountered a flooding problem over the last 30 years? 1. Yes 2. No 3. Don't know
4.10. If yes, how do you describe the frequency of occurrence of flood in recent years as compared to the past 30 years? 1. Increased 2. Decreased 3. Followed a similar trend

4.11. Do you believe that the overall climate condition of the area has changed over the last 30 years? 1. Yes 2. No 3. Don't know

5. Impact of climate change

5.1. Has the household been affected by a serious climate-related hazard over the last 30 years? 1. Yes 2. No

5.2. If yes, which major climate-related hazards have affected the household during the last 30 years? (*Enter only code numbers in the lines given below and you can choose more than one*)

No.	**Type of climate-related Hazard** 1. Drought 2. Shortage of rain 3. Change in rainfall timing 4. Change in the pattern of rainfall distribution 5. Frost 6. Hailstorm 7. Increased temperature 8. Erosion 9. Flooding 10. Landslide 11. Crop pest outbreak 12. Animal disease outbreak 13. Human disease outbreak 14. Fire outbreak 15. Other, specify_____	**When did the hazard occur** [*year(s) within the last 30 years*]	**What was its impact on livelihood?** 1. Loss of income 2. Loss of assets 3. Death of livestock 4. Decline in crop yield 5. Decline in consumption 6. Food shortage, food insecurity 7. Other, specify _____	**What was its impact on natural resources?** 1. Reduced productivity of agricultural land 2. Reduced productivity of pastureland 3. Degraded woodlands 4. Increased irrigation demand 5. Reduced water availability 6. Reduced water quality 7. Increased competition for water 8. Shrinking lakes 9. Loss of habitat & species 10. Other, specify _____	**Rank by degree of impact -** among the hazards listed *(1 for severe impact & 15 for less impact)*
1					
2					
3					
4					
5					
6					
7					
8					
9					
10					
11					
12					
13					
14					
15					

5.3. In general, how do you assess the effect of such climate-related hazards on your livelihood? 1. Worsened 2. Improved 3. No change 4. No idea or don't know

5.4. If the household has noticed climate-related health problem, what kind of health problems were they? 1. Infectious diseases 2. Respiratory problems 3. Malaria cases 4. Other, specify _____

5.5. If malaria was one of the problems, what happened to the number of cases in recent years as compared to the past 30 years? 1. Increased 2. Decreased 3. Remained the same

5.6. Do you think that the transmission of malaria is widespread spatially and temporally? 1. Yes 2. No 3. Don't know

6. Adaptation measures/practices

6.1. Have you changed your livelihood strategies/practices as a result of any observed climate-related changes? 1. Yes 2. No

6.2. If yes, what measures have you made in order to adapt to any observed climate-related changes/hazards? (*Read the list below & write the response*)

Code	Adaptation Measures taken	1. Yes	2. No
1	Changing crop types		
2	Changing crop variety		
3	Diversifying crop types		
4	Changing planting/sowing dates		
5	Storing grains		
6	Saving money		
7	Borrowing money from relatives		
8	Borrowing money from bank and other institutions		
9	Reducing meals per day and overall food intake		
10	Using inputs such as fertilizer, pesticide, insecticide, etc.		
11	Reducing number of livestock		
12	Changing livestock herd composition		
13	Temporary sending of livestock to relatives		
14	Moving animals from place to place (pastoralist way)		
15	Selling animals		
16	Selling wood		
17	Selling charcoal		
18	Storing feed for animals (grasses, crop residues, etc.)		
19	Feeding animals the leaves, shoots, pods, & barks of trees		
20	Planting trees		
21	Maintaining trees for shading		
22	Building a water harvesting scheme		
23	Implementing soil conservation techniques		
24	Implementing woodland restoration techniques (protecting from animals, fencing, reduce cutting trees)		
25	Using irrigation more		
26	Using woodlands more (for domestic consumption & sale)		
27	Migrating to urban area		
28	Migrating abroad		
29	Finding off-farm and non-farm jobs		
30	Leasing land		
31	Using social interconnectedness (e.g. helping each other)		
32	Participating in safety net programs		
33	Receiving aid		
34	Other, specify		

6.3. Have any climate-related changes been beneficial to the livelihood of the household? 1. Yes 2. No 3. Don't know

6.4. If yes, what were the benefits? *(multiple response)* 1. Provided opportunities to cultivate different crop types 2. Increased agricultural productivity 3. Increased livestock productivity 4. Increased tree productivity 5. Other, specify: _____

6.5. If no adaptation measure was taken, what were the main barriers of change? (*multiple response*) 1. Lack of knowledge 2. Lack of information 3. Shortage of land 4. Shortage of water 5. Shortage of labor 6. Shortage of money 7. Others, specify: _____

7. Natural capital

7.1. Farm Land

7.1.1. Do you have your own land? 1. Yes 2. No.
7.1.2. If yes, what is your land size in 'timads' by land use types as specified below?

Code	Classification of land	Size in 'timads'	Hectare equivalent
1	Farm land		
2	Grassland		
3	Wooded grassland		
4	Woodland		
5	Shrubland		
6	Bare land		
7	Settlement		
8	**Total land area**		

7.1.3. How did you acquire your land? (*you can tick more than one*)

Code	Means of acquisition	Tick
1	First distribution	
2	Redistribution	
3	Inheritance	
4	Gift	
5	Sharecropping	
6	Renting in	
7	Encroaching communal land (Woodland and grazing land)	
8	Others, specify_____	

7.1.4. How do you assess the productivity of your farmland? (*fill the table below*)

Code	Productivity of the farmland	Size in 'timads'	Hectare equivalent	Percent from total
1	Very poor			
2	Poor			
3	Medium			
4	Productive			
5	Very productive			
6	**Total farmland area**			

7.1.5. How has your farm land size changed since you start farming? 1. Increased 2. Decreased 3. Remained the same
7.1.6. If increased, what are the reasons for the increment of your cultivated land? 1. Redistribution of cultivated land 2. Distribution of cultivated land within the family 3. Conversion of woodlands to cultivated land 4. Conversion of grazing land into farmland 5. Other, please specify_____
7.1.7. If decreased, what are the reasons for the decrement of your cultivated land? 1. Degradation of land 2. Increase of rangeland 3. Distribution of cultivated land within the family 4. Redistribution of cultivated land by the government 5. Other, please specify_____
7.1.8. What is the trend of your farm land productivity since you have started farming? 1. Increasing 2. Decreasing 3. Remain the same
7.1.9. If farmland productivity is increasing, what are the reasons? 1. Use of inputs such as fertilizer and compost 2. Increased soil fertility 3. Better soil moisture because of conservation measures 4. Suitable weather conditions 5. Other, please specify_____
7.1.10. If farmland productivity is decreasing, what are the reasons? 1. Land degradation 2. Rainfall variability 3. Drought 4. Pests and crop diseases 5. Other, please specify_____

7.2. Grazing land

7.2.1. Do you have livestock? 1. Yes 2. No

7.2.2. If yes, where do you graze your animals? (*multiple response*) 1. In communal grazing land 2. In private grazing land 3. In communal wooded grassland 4. In private wooded grassland 5. In communal woodland 6. In private woodland 7. Through cut and carry system 8. Others, specify__

7.2.3. How do you assess the adequacy of the grazing land? 1. Very scarce 2. Inadequate 3. Adequate 4. Very adequate 5. Plenty, no problem of grazing land

7.2.4. If grazing is a problem what are the reasons? (*multiple response*) 1. Shortage of grazing land 2. Low productivity of grazing land 3. High population of animals 4. Others, specify_____

7.3. Water resources

7.3.1. What are the sources of water for the household? (*fill the table below*)

Code	**Source of water**	**Tick**	**Tick for type of use**				**Distance** *from home in hours*
			drinking	domestic use	livestock	irrigation	
1	Spring						
2	River						
3	Lake						
4	Private hand-dug well						
5	Private drilled well						
6	Public hand-dug well						
7	Public drilled well						
8	Public stand-pipe water *(communal tap outside)*						
9	Public tap water *(piped into home)*						
10	Rain water						
11	Irrigation canal						
12	Other, specify_____						

7.3.2. How do you assess your access to water resources? 1. Very scarce 2. Inadequate 3. Adequate 4. Very adequate 5. Plenty, no problem of water

7.3.3. How do you assess the quality of water you are using? 1. Very poor 2. Poor 3. Medium 4. Good 5. Very good

8. Physical capital

8.1. Do you have access to the following basic services?

Code	**Basic services**	**1. Yes**	**2. No**	**If yes, since when?** *(year)*	**If yes, distance (***in walking hours)*
1	Primary school				
2	Secondary school				
3	Medical center				
4	Veterinary health center				
5	Market *for commodities: e.g. food market*				
6	Market *for livestock*				
7	Microfinance/Bank/credit & saving institution				
8	Extension service: *agriculture, health etc.*				

8.2. Which of the following physical assets do you have?
(*Note that you do not need to fill data for the shaded parts of the table*)

Code	Asset type	1.Yes 2. No	How many?	Year obtained	Original price	Replacement cost
1	House (*observe & identify the type of house*)					
	1. Thatch roof, thatch/wood and mud wall					
	2. Thatch roof, stone and mud wall					
	3. Tin roof, stone/wood/brick and mud wall					
	4. Other, specify _____					
2	Mobile phone					
3	Radio					
4	Television					
5	Refrigerator					
6	Solar panel					
7	Cable telephone line					
8	Electricity					
9	Gold /Jewelry					
10	Iron cooking pans					
11	Modern bed					
12	Toilet					
13	Grinding mill					
14	Bajaj					
15	Car					
16	Access to road					
	Walking distance to nearest road in hours					
17	Irrigated land					
	- Size of the irrigated land in 'timad'					
	- Percentage from the total land					
18	Agricultural tools					
	- Value of all the agricultural tools in Birr					
	Farm/agricultural tools 1. "Gejera" 2. Hoe 3. Spade/shovel 4. Pick axe 5. "Deger" 6. Winnower 7. Plough and yoke for animals 8. Reaper/Sickle 9. Manual sprayer 10. "Wagel" tip 11. "Erfe" (handle) 12. Rake 13. Wheelbarrow 14. Carts (hauling) 15. Other Light Machinery, specify _____ **Farm machineries** 16. Tractor 17. Plougher 18. Trolley/Trailers 19. Thresher 20. Fodder cutting machine 21. Generator/Diesel Pumps 22. Spraying machines (chem./fertilizer) 23. Harvester/combiner 24. Other Heavy Machinery, specify _____					
19	Other, specify_____					

9. Financial capital

9.1. Which of the following represent your financial assets?

Code	Financial asset	1. Yes	2. No	Amount in Birr *for last year*
1	Sale of livestock			
2	Sale of wood			
3	Sale of charcoal			
4	Sale of cash crops			
5	Sale of vegetables			
6	Remunerative income sources			
	- salaried job,			
	- skilled non-farm job, and			
	- remittance			
7	Total household saving			
8	Total loans obtained during the previous year			
	- formal loans from banks & credit & saving institutions			
	- informal loans based on kinship or other ties			
9	Others, specify _____			

10. Social capital

10.1. Structural social capital

10.1.1. Are you or someone in your household a member of any local organization? 1. Yes 2. No.
10.1.2. If yes, please complete the table below.

No.	Household member	Name of organization	Type of organization 1. Farmers group 2. Fishermen's group 3. Cooperative 4. Credit/finance group 5. School committee 6. Health committee 7. Water group 8. Cultural association 9. Religious group 10. Neighborhood association 11. NGO 12. Youth group 13. Women's group 14. Parent group 15. Sports group 16. Other, specify _____	Degree of participation 1. Leader 2. Very active 3. Somewhat active 4. Non-active	Most important organizations to your household (*list up to three types of organizations using their codes*)
1					
2					
3					
4					
5					

10.1.3. In general, how effective is the organization's leadership? 1. Very effective 2. Somewhat effective 3. Not effective at all
10.1.4. Do you think that by belonging to the organization(s) you have acquired new skills or learned something valuable or obtained some advantages? 1. Yes 2. No

10.1.5. If there were a problem that affected the entire village/neighborhood, for instance livestock disease, crop disease, water shortage, or violence, who do you think would work together to deal with the situation? (*see the table below & answer*)

No.	Networks & mutual support organizations	1. Yes	2. No	Who would take the initiative (act as leader)?
1	Each person/household would deal with the problem individually (*if yes, skip the questions below*)			
2	Neighbors among themselves			
3	Local government/peasant association leaders			
4	All community leaders acting together			
5	The entire village/neighborhood			
6	Other, specify_____			

10.1.6. Differences often exist between people living in the same village/neighborhood. To what extent do differences such as the following tend to divide people in your village/neighborhood?

Code	Possible source of exclusion	1. Not at all	2. Somewhat	3. Very much
1	Differences in education			
2	Differences in wealth/material possession			
3	Differences in landholdings			
4	Differences in social status			
5	Differences between men & women			
6	Differences between younger & older generations			
7	Differences between long time inhabitants & new settlers			
8	Differences in political party affiliation			
9	Differences in religious beliefs			
10	Differences in ethnic background			
11	Other differences, specify _____			

10.1.7. Do these differences cause problems? 1. Yes 2. No

10.1.8. If yes, how are these problems usually handled? (*you can tick more than one*)

No	Handling mechanisms	Tick
1	People work it out between themselves	
2	Family/household members intervene	
3	Neighbors intervene	
4	Elderly people mediate	
5	Community leaders mediate	
6	Religious leaders mediate	
7	Judicial leaders mediate	
8	Other, specify _____	

10.1.9. How often in the past year have you joined together with others in the village/neighborhood to address a common issue, development or other socioeconomic issue? 1. Never 2. Once 3. A couple of times 4. Frequently

10.2. Cognitive social capital

10.2.1. If your household suffered an economic loss, say "crop failure" or "death of livestock", who do you think would assist you financially? (circle the first three mentioned)
1. No one would help
2. Family
3. Neighbors
4. Friends
5. Religious leader or group
6. Community leader
7. Police
8. Political leader
9. Mutual support group to which you belong
10. Assistance organization to which you do not belong
11. Other, specify _____

10.2.2. If, for instance, someone from the village/neighborhood had to go away for a while, along with their family, in whose charge do you think they leave "their fields"? (*Circle the first three mentioned*) 1. Other family member 2. Neighbor 3. Anyone from the village/neighborhood for this purpose 4. No one 5. Other, specify_____

10.2.3. Do you think that in this peasant association people generally trust one another in matters of lending and borrowing? 1. Do trust 2. Do not trust

10.2.4. Do you think over the last few years this level of trust has gotten better, gotten worse, or stayed about the same? 1. Better 2. The same 3. Worse

10.2.5. Do you agree or disagree that people here look out mainly for the welfare of their own families and they are not much concerned with village/neighborhood welfare? 1. Strongly agree 2. Agree 3. Neither agree nor disagree 4. Disagree 5. Strongly disagree

10.2.6. In your opinion, is this village/neighborhood generally peaceful or conflictive? 1. Peaceful 2. Conflictive

10.2.7. Are the relationships among people in this village/neighborhood generally harmonious or disagreeable? 1. Harmonious 2. Disagreeable

10.2.8. Suppose two people in this village/neighborhood had a fairly serious dispute with each other. Who do you think would primarily help resolve the dispute? 1. No one; people work it out between themselves 2. Family/household members 3. Neighbors 4. Community leaders 5. Religious leaders 6. Judicial leaders 7. Other (specify)

10.2.9. Are there informal local institutions in your locality? 1. Yes 2. No

10.2.10. If yes, are you a member of any of the community based organizations (CBO's)? 1. Yes 2. No

10.2.11. Do you think the neighborhood social networks are strong? 1. Yes 2. No

10.2.12. Do you get the support of the community in cases you needed their support? 1. Yes 2. No

10.2.13. According to your opinion, how is the level of relationship among the members of the family? 1. Very much weak 2. Weak 3. Good 4. Strong 5. Very much strong

10.2.14. Is there a tradition of cooperation to carry out farming activities? 1. Yes 2. No

10.2.15. How do you asses your access to credit and saving schemes? 1. I need but no access 2. I use credit only for subsistence purposes 3. I use credit for productive investments 4. I use credit for both productive investment and subsistence purposes 5. I don't need credit

11. Human capital

11.1. Do you think the household have enough labor to carry out the household's economic activities? 1. Yes 2. No

11.2. If no, how do you overcome the problem? 1. Hiring outside labor 2. Finding support from relatives 3. Finding support from neighbors 4. No solution, just leaving the activities 5. Other, specify, _____

11.3. Do you or the household members have skills other than the skill required to carry out farming activities? 1. Yes 2. No

11.4. If yes what are those skills? 1. Weaving 2.Carpentry 3. Pottery 4. Producing charcoal 5. Mason work 6. Blacksmith work 7. Tailoring 8. Other, specify _____

11.5. Have you or your household members taken trainings related to your livelihood? 1. Yes 2. No

11.6. If yes, how many times did you or your household members get trained last year? _____ times

11.7. How do you rate the importance of the training to guide your livelihood practices? 1. Very important 2. Important 3. Somewhat important 4. Less important 5. Not important at all

11.8. How do you state your current state of health as compared to people at the same age as you? 1. Excellent 2. Good 3. Fair, average 4. Poor 5. Very poor

11.9. In general, would you say the health of the household members is: 1. Excellent 2. Good 3. Fair, average 4. Poor 5. Very poor

12. Institutions and entitlements

12.1. What are the most important formal local organizations that your livelihood depends on? (*you can tick more than one from the list below and rank them in order of importance*)

Code	Formal local Organizations	Tick	Rank
1	'*Kebele*' administration		
2	Agricultural development station		
3	Credit and saving		
4	Cooperatives		
5	Health center/clinic/health post		
6	Veterinary health centers		
7	Others, specify_____		

12.2. What are the most important informal local organizations that your livelihood depends on? *(you can tick more than one from the list below and rank them)*

Code	Informal local Organizations	Tick	Rank
1	Social networks		
2	Community networks		
3	Market access and arrangements		
4	Community Based Organizations (CBO's)		
5	Women's support groups		
6	Others, specify_____		

N.B. – *Institutions could be formal or informal unless specified*
– *CBO's could be institutions such as Idir, Equb, Mahiber and the like.*

12.3. Which local institutions are relied upon for livelihood support particularly during times of climate hazard? (*you can tick more than one and rank them in order of importance*)

Code	Local institutions	Tick	Rank
1	Relatives support		
2	Neighbors support		
3	Marriage ties		
4	Community support		
5	Safety nets		
6	Local farmer associations (e.g., '*Kebeles*')		
7	Local government organizations		
8	Others, specify_____		

12.4. Are all households able to equitably access the support provided by local institutions in times of climate hazard? 1. Yes 2. No 3. Don't know

12.5. Do local institutions regulate access to key resources such as water, land & woodland resources during times of climate hazard? 1. Yes 2. No 3. Don't know

12.6. If yes, which type of institutions regulates access to woodland resources during times of climate hazard? 1. Formal 2. Informal 3. Both formal and informal institutions

12.7. Do you think access to key resources is equitable amongst households in the '*Kebele*'? 1. Yes 2. No 3. Don't know

12.8. Are there people who lack equitable access to key resources during times of climate hazard? 1. Yes 2. No 3. Don't know
12.9. If yes, who are they? 1. Rich farmers 2. Poor farmers 3. Households living far from the resources 4. Women farmers 5. Young farmers 6. Others, specify _____
12.10. Are there people who are more heavily dependent on outside support from local institutions during times of climate hazard in comparison with the surrounding community? 1. Yes 2. No 3. Don't know
12.11. If yes, who are they? 1. Poor farmers 2. Landless farmers 3. Women farmers 4. Young farmers 5. Fishers 6. Others, specify _____
12.12. Do local institutions play a role in informing adaptation strategies for households in response to climate change? 1. Yes 2. No
12.13. Are there local rules and norms that prevent certain social groups such as women or youth from undergoing adaptation strategies in light of climate change? 1. Yes 2. No 3. Don't know
12.14. Is decision making within local institutions participatory including women, youth and marginal groups? 1. Yes 2. No 3. Don't know

13. Knowledge and information

13.1. Do you use climate-related information & knowledge to guide your livelihood practices? 1. Yes 2. No
13.2. If yes, what climate-related information & knowledge do you use to guide your livelihood practices? 1. Indigenous farmer knowledge of rainfall timing/seasonality 2. Radio/television broadcasts of weather patterns 3. Drought and flood early warning systems 4. Climate impact data by government offices 5. other, specify _____
13.3. If you are using climate-related information from formal sources, are they delivered in a timely and appropriate manner to help you make the right decision? 1. Yes 2. No
13.4. Which source of information do you trust more to guide your livelihood practices? 1. Traditional climate information 2. Formal climate information such as those from meteorology and extension agents 3. I don't trust any of them
13.5. Are you provided with knowledge and information on appropriate adaptation strategies relevant to your livelihood and area? 1. Yes 2. No
13.6. If yes, who provides you the information? 1. Extension agents 2. District officers 3. '*Kebele*' councils 4. Other, specify _____
13.7. Do you think that the knowledge and information you are provided are adequate? 1. Yes 2. No
13.8. Are there systems in place for data gathering, information analysis and dissemination in relation to climate hazards relevant for your area? 1. Yes 2. No 3. Don't know

14. Innovation

14.1. Have you adopted new practices because of noticeable climate-related changes? 1. Yes 2. No
14.2. If yes, what positive effects have any new practices had on the livelihood of the household? 1. Improved household income 2. Enabled to overcome the adverse effects of climate change such as drought 3. Improved social relations 4. Improved the natural resource base 5. Other, specify _____
14.3. If yes, what negative effects have any new practices had on the livelihood of the household? 1. Resulted in the loss of assets 2. Depleted the natural resource base 3. Spoiled social relations 4. Other, specify _____
14.4. Are you taking risks and exploiting new opportunities presented by any climate-related changes? 1. Yes 2. No
14.5. Have taken advantage of new opportunities in the face of changing climate? 1. Yes 2. No
14.6. Are you able and willing to adapt and adjust to climate- related changes? 1. Yes 2. No
14.7. Do you have access to new and improved technology needed to cope with climate-related changes? 1. Yes 2. No
14.8. Are there mechanisms in place to accommodate for, and promote the sharing of risk and innovation within the community? 1. Farmer insurance schemes 2. Collective innovation and risk taking 3. Local support systems 4. other, specify _____
14.9. What are the ideal conditions needed in-order to foster innovative action, diversification, and try new practices within each livelihood? 1. Local farmer networks and indigenous knowledge 2. Sharing of suitable crop/livestock varieties 3. No conflict 4. Other, specify _____

15. Flexible and forward looking decision-making and governance

15.1. Tick one of the choices given for the following questions that are made with regard to decision making and governance at the local level.

Code	Issues of decision making & governance	1. Yes	2. No	3. Don't know
1	Do formal organizations have access to relevant climate information in guiding policy and decision-making?			
2	Do local organizations have the capacity to deal with a range of climate-related hazards?			
3	Do formal organizations provide support to you to adapting to any observed changes in climate?			
4	Have formal organizations developed plans to help you deal with climate-related hazards?			
5	Are formal organizations learning from past climate-related events and incorporating them within their decision-making processes?			
6	Are the right measures put in place by local organizations to accommodate for climate-related uncertainty and future potential new hazards?			
7	Are formal organizations flexible in their decision making processes in responding to new threats posed by climate-related changes?			
8	Are there systems in place for reviewing and adjusting priorities over time?			
9	Is decision making by local organizations regarding climate change transparent to the household?			
10	Are there land use regulations that protect natural resources particularly woodlands while allowing moderate use?			

16. Source of household income *(both consumption and sale)*

16.1. Crops

Code	Type of crop	Amount in Quintals	Quantity		Unit price	Total Cash Equivalent *(Sold & consumed)*
			Sold	Consumed		
1	Maize					
2	Haricot bean					
3	Barley					
4	Teff					
5	Wheat					
6	Millet					
7	Sorghum					
8	Other *(specify)*					

NB. The sold and consumed items refer to the last complete farming year.

16.2. Livestock

Code	Type of livestock	Number of animals currently available	Animals		Unit Price	Total (*sold & consumed*)
			Sold	Consumed		
1	Oxen					
2	Cow					
3	Sheep					
4	Goat					
5	Donkey					
6	Horse					
7	Mule					
8	Chicken					
9	Beehives					
10	Others					

16.3. Livestock products

Code	Type of product	Unit	Quantity		Unit price	Total
			Sold	Consumed		
1	Butter					
2	Milk					
3	Cheese					
4	Egg					
5	Honey					
6	Fish					
7	Wool					
8	Leather					
9	Other, specify					

16.4. Vegetable production

Code	Type of vegetable	Units	Quantity *units/year*	Quantity		Unit price	Total
				Consumed	Sold		
1	Potato						
2	Tomato						
3	Pepper						
4	Carrot						
5	Cabbage						
6	Onion						
7	Other *(specify)*						
8	Total						

16.5. Fuel wood collection from woodlands

Code	Type of species	Unit	Quantity		Unit price	total
			Sold	Consumed		
1						
2						
3						
4						
5	Others (specify)					

16.6. Construction wood collection from woodlands

Code	Type of species	Unit	Quantity		Unit price	total
			Sold	Consumed		
1						
2						
3						
4						
5	Others (specify)					

16.7. Charcoal making from woodlands

Code	Type of species	Unit	Quantity		Unit price	total
			Sold	Consumed		
1						
2						
3						
4						
5	Others (specify)					

16.8. Sand quarrying

Code	Type of sand *(1.white 2. brown)*	unit	Quantity		Unit price	Total
			Sold	Consumed		
1						
2						

16.9. 'Soda Ash' mining

Code	Type of soda ash	unit	Quantity		Unit price	Total
			Sold	Consumed		
1						
2						
3						
	Total					

16.10. Remittance

Code	Remittance	Amount *in Birr per year*
1	From Abroad	
2	Within the country	
3	**Total**	

16.11. Other income sources: *renting/hiring out, petty trading, safety net transfer, gifts, local beverage*

Code	Source income	Income per year
1	Renting out Land	
2	Renting out animal including cart	
3	Renting out House	
4	Renting out tools and machineries including farm implements	
5	Labor (Wage labor)	
6	Income from petty trading	
7	Income from selling local beverage (traditional drinks)	
8	Safety net transfer	
9	Gifts	
10	Handicraft	
11	Other, specify	

17. Is there anything uncovered that you would like to tell us?

1. _____
2. _____
3. _____

End of questionnaire. Thank you very much!! Gelatooma!!