Addis Ababa University
College of Development Studies
Center for Environment and Development Studies

A Comparative Study of Farmers' Vulnerability and Adaptation to Climate Change in Three Agro-ecologies of Northwest Ethiopia

Menberu Teshome Zeleke

Thesis Supervisor: Dr. Yohannes Aberra/Associate professor

A Comparative Study of Farmers' Vulnerability and Adaptation to Climate Change in Three Agro-ecologies of Northwest Ethiopia

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Menberu Teshome Zeleke

Addis Ababa University
Addis Ababa, Ethiopia
March 2014

Declaration

I, the undersigned, declare that this thesis is my original work and has never been submitted at any university for any degree or other purpose. All references have been fully acknowledged and cited in the text.

Signature ____________

Name: Menberu Teshome Zeleke

Date: March/2014

Declaration

As thesis supervisor, I hereby certified that I have read and evaluated this thesis entitled "A Comparative Study of Farmers' Vulnerability and Adaptation to Climate Change in Three Agro-ecologies of Northwest Ethiopia" Prepared under my guidance by Menberu Teshome Zeleke. I confirm that this PhD thesis has been submitted with my approval as a thesis supervisor.

Signature: ____________

Name: Yohannes Aberra

Date: March/2014

Addis Ababa University
School of Graduate Studies

This is to certify that the thesis prepared by Menberu Teshome Zeleke, entitled: 'A Comparative Study of Farmers' Vulnerability and Adaptation to Climate Change in Three Agro-ecologies of Northwest Ethiopia' and submitted in fulfillment of the requirements for the Degree of Doctor of Philosophy in Development Studies (Specialization in 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

A Comparative Study of Farmers' Vulnerability and Adaptation to Climate Change in Three Agro-ecologies of Northwest Ethiopia

Menberu Teshome Zeleke
Addis Ababa University
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Climate change is adversely affecting the livelihood of Ethiopian farmers who depend on rain-fed agriculture with differential impacts from place to place, from community to community and from individual to individual depending on the adaptive capacity of the systems. Although better knowledge of vulnerability levels, perceptions and adaptation is vital for policy making, not much is studied as to how these inter-related issues impact on the lives of famers from the perspectives of five livelihood assets. To fill these knowledge gaps, this study focused on three central themes: description of the biophysical and economic characteristics of the *dega*, *woyna dega* and *kola* sites, an assessment of vulnerability levels of farmers in terms of exposure to climate change, access to five livelihood assets including the adoption of different adaptation methods and examination of farmers' perceptions and adaptation to climate change. The quantitative and qualitative approaches have been used to achieve the objectives of the study. The biophysical and economic characteristic of the study sites was analyzed using simple regression, different indices, coefficient of variation and one-way-Analysis of Variance (ANOVA). Livelihood vulnerability index was used to analyze the vulnerability levels of the surveyed households. The farmers' perceptions and adaptation to climate change were assessed using percentage, index of adoption, and binary logistic regression. The results revealed that agro-ecological settings are the most important conditions that have created differential vulnerability situations of the households. The biophysical and economic contexts in the dissected landscapes of Abay-Beshilo River Basins (*kola* sites), where recurrent droughts, land degradation, low production, and poor access to infrastructural facilities are serious problems, are found to be worse than in *woyna dega* and *dega*. Correspondingly, the livelihood vulnerability indices (LVI) indicated that the *kola* households are found to be more vulnerable by all capital assets and low index of adaptation. By climatic exposure index, *woyna dega* households stood first closely followed by those in *kola*. Analyses of perceptions and adaptation also revealed that the majority of the farmers had observed an increase in temperature and a decrease/erratic rainfall in the three sites. The farmers have adopted different adaptation strategies, but the rates of their adoption vary by agro-ecology. The most common adaptation strategies are: the use of manure-compost, terracing, replanting, change of planting dates, use of fertilizers (*woyna dega* and *dega*), planting different crops, being engaged in non-farm activities and shifting to cheaper food items. Of which, the most statistically significant determinants of adopting each strategy were agro-ecological zone and farmer-to-farmer extension. Other significant determinants of adaptation were: farm size, age, family size, and livestock ownership, access to water, formal extension services, and perception of temperature and rainfall changes. For building more climate-resilient community the government and other stakeholders should provide appropriate environmental management systems, infrastructure and extension services to the community.

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CHAPTER ONE
INTRODUCTION

1.1. Background of the study

Climate variability is integral part of the earth's history although its change is accelerated in recent times. Climate parameters are naturally variable from year to year, from decade to decade and from century to century (Smithers &Smit, 1997; Smit et al., 1999) due to the variability in the distribution of solar radiation in the earth (Houghton, 2009). Following the Industrial Revolution anthropogenic climate change adds unpredictable threats to societies not only due to the occurrence of extreme events, but also due to failures to adequately address pervasive poverty (Schipper, 2004) and land degradation, particularly in the less developed nations (World Bank, 2008; FAO, 2009). As a result, media headlines have highlighted the most extreme dangers such as droughts, heat-waves, flooding, sea-level rises, melting of ice, intensified storms and land degradation in recent decades.

Nowadays, the majority of the scientific evidences confirm that the climate is changing at an accelerated rate and will continue so in the coming century (Adger et al., 2003; IPCC, 2007; Houghton, 2009). It is asserted that the warming of the climate system is unequivocal as is evident in the increasing atmospheric concentration of CO_2 from a pre-industrial value of 278 parts per million (ppm) to 379 ppm in 2005 and raising the average temperature by 0.74° C, and the increased in the frequency of the extreme events over the past century (IPCC, 2007, 2013). Since accurate records began about 100 years ago, a particular increasing rate of warming took place over the last 30 years. Indeed, 12 of the 13 warmest years occurred between 1995 and 2007.

The Fifth IPCC (2013) report stated that the atmospheric concentrations of the greenhouse gases such as carbon dioxide (CO2), methane (CH4), and nitrous oxide (N2O) have all increased since 1750 due to human activity. In 2011 the concentrations of these greenhouse gases were 391 ppm[1], 1803 ppb[1], 324 ppb and exceeded the pre-industrial levels by about 40%, 150%, and 20%, respectively. Concentrations of these GHGs now substantially exceed the highest concentrations recorded in ice cores during the past 800,000 years. The mean rates of increase in atmospheric concentrations over the past century are, with very high confidence, unprecedented in the last 22,000 years. Consequently, the globally averaged

[1] ppm (parts per million) or ppb (parts per billion, 1 billion = 1,000 million) is the ratio of the number of gas molecules to the total number of molecules of dry air. For example, 300 ppm means 300 molecules of a gas per million molecules of dry air

combined land and ocean surface temperature data as calculated by a linear trend, show a warming of 0.85 [0.65 to 1.06] °C, over the period 1880–2012, when multiple independently produced datasets exist. The total increase between the average of the 1850–1900 period and the 2003–2012 period is 0.78 [0.72°C to 0.85" °C] based on the single longest dataset.

Despite the UNFCCC's mandating of the developed countries to reduce their emissions, human activities through fossil-fuel burning and land use-land-cover changes are continuing to emit greenhouse-gases into the atmosphere, which, in turn, alter radiative balances, and hence tend to raise the amount of heat from the sun withheld in the earth. This increase in heat, therefore, has led to the greenhouse effect, resulting in climate change (Watson et al., 1997; UNFCCC, 2007; Houghton, 2009).

The IPCC's (2007) projections for the 21st century show that global warming will continue to accelerate even with an ambitious reduction of greenhouse-gas emissions. The IPCC model projections vary from 4th to 5th assessment reports. For example, predictions conducted by the 4th assessment report in 2007 for 2100 ranges from 1.4°C to 5.8^{0}C increase in average temperature whilst the recent IPCC (2013) report projected temperature increase from 1^{0}C to 4.8^{0}C, both of which are far more than human experience. Temperature rise is accompanied by changes in precipitation patterns and other extreme events such as drought, run-off/flooding, shifting in the timing of rainfall (IPCC, 2007; UNFCCC, 2007; Houghton, 2009), with tremendous impact on basic life-support systems such as agriculture, water resources, the ecosystem, and human health. These have in turn could make development unsustainable in many places by shifting growing seasons of crops, increasing melting of glaciers, destructing species' habitats and creating favorable conditions for vector borne-diseases, which in turn put people at risks from malaria, dengue fever, and waterborne-diseases (UNFCCC, 2007).

Many more effects of climate change on natural and human systems are emerging, being coupled with other non-climatic drivers (Turner II et al., 2003; IPCC, 2007). The population growth has put the pressure on the environment by raising demands for natural resources and by the invention of new technologies that let people destroy their environment, knowingly or unknowingly. Climate change and associated extreme events have aggravated land degradation processes through flooding, landslide, soil erosion, and saline concentrations (World Bank, 2008; FAO, 2009). This implies that climate change and land degradation are intimately inter-linked and are creating tremendous influences on natural and human systems.

Rift Valley Basin River tributaries. Flooding in these areas is happening every year with varied magnitude from year to year. Climate change projections show an increasing trend of heavy rainfall events, particularly in the late wet months. Therefore, Ethiopia will be under increasing threat of flooding in the coming decades (NMA, 2007; McSweeney, 2010).

The scientific agreement on the reality of climate change and the recognition of the high-level of vulnerability of the global economy to its impact has led to increasing concerns from the scholarly community. This has been reiterated in the need to understand how societies adapt to climate change in order to offer adaptation strategies in the future (Pielke, 1998; Nilsson, 2007; Mentez et al., 2008). Domestic and international policy-makers proposed mitigation and adaptation as the two fundamental response options for reducing the risks posed by climate change (Pielke, 1998). Mitigation focuses on the prevention of future climate impact on society through intentional alteration of the climate system by limiting greenhouse-gas emissions and by enhancing their sinks while adaptation is on adjustments in individual, group, and institutional behavior in order to reduce society's vulnerability to climate change impacts (Pielke, 1998).

Negotiators from industrialized and developing countries meet each year in the most contentious and critical international environmental agreements of the UNFCCC, which focuses on mitigation as the most political attention in the world (Pielke, 1998; Adger et al., 2003). More than 10 years of climate policy negotiations produced the Kyoto Protocol in 1997, the first binding agreement on climate protection, which has been challenged by some developed countries, however (Smit & Skinner, 2002). Opponents to the Protocol have described it as a deeply flawed agreement, for it is both economically inefficient and politically impractical (Fussel, 2007; Schipper, 2009).

Scientists and policy-makers claim that the current efforts under the UNFCCC and the Kyoto Protocol to limit and to reverse climate change trends have not been effective. Some have characterized abatement endeavors as a 'collective failure' (Schipper, 2004). As a result, reducing emissions from deforestation and forest degradation (REDD) became part of the ever-expanding climate change agenda. REDD was first discussed in 2005 by the UNFCCC at its COP 11 at the request of the Coalition for Rainforest Nations with the twin objectives of mitigating climate change through reducing emissions of GHGs and removing greenhouse gases through enhanced forest management in developing countries. COP 11 entered the request to consider the document as agenda item 6; however, the United States challenged the proposal but failed in its attempts ([http://reddplussafeguards.com].

Negotiators later explored adding forest degradation to the mechanism in 2007 by the Bali Action Plan (McBean & Rodgers, 2010). REDD also covers land-use changes to forest areas with lower carbon stocks. REDD-plus aims to incentivize sustainable forest management thereby developed countries would compensate developing countries for undertaking initiatives that could cut their deforestation rate. This is considered as an important mitigation action because approximately 18% of total GHG emissions come from deforestation and forest degradation [Agrawal et al., 2011; http://reddplussafeguards.com].

In the New York climate change summit, on the eve of the Copenhagen Conference, the UN Secretary General made his point very strongly on the delay of concerted actions by reminding world leaders that 'the world's glaciers are melting faster than the climate negotiations'. Since the UN Framework Convention for Climate Change (UNFCCC) entered into force in 1994, the signatories' conference of parties held 16 annual meetings where no legally binding emission-reduction deals were sealed (Yohannes, 2012). Thus, an increasing interest has grown to adaptation as reflected much in the development of climate-change assessment, increasing consideration by governments and organizations to design different adaptation projects (Smit et al., 2000; Fussel, 2008; World Bank, 2008), and an attempt to search for resources to finance adaptation.

Many global and regional studies have been carried out. Studies in Africa indicated that increasing temperature and declining precipitation significantly affect agricultural and livelihood resources (Eriksen et al., 2004; Madison, 2006; Hassen and Nhemachena, 2008). National level studies in Tanzania (Rowhania, 2001), in Sudan (Elasha et al., 2005), in Kenya (Kabubo-Mariara & Karanja, 2006) and in South Africa (Gbetibouo, 2009) also confirmed the situation. However, the results were highly aggregated over larger geographical areas, and the parameters have limited value to analyze country-specific vulnerability and adaptation methods, given the heterogeneity of the countries. Accordingly, decisions for different scales with varied contexts require different evidence. This is because, an indicator developed to measure household vulnerability in South Africa or Egypt may not be relevant for the Ethiopian context. Therefore, this study intends to use integrated vulnerability assessment framework to show how climate change, vulnerability, perception, and adaptation are interconnected in the local agro-ecological settings of northwest Ethiopia.

1.2. Statement of the problem

The Ethiopia's population relies on the fragile natural resource bases for livelihood security. The country's farming systems have been subject to critical climate change leading to fluctuations in production and, in some years, severe food crises in the parts of the country. The current evidence suggests that climate change will lead to greater temperature increase, rainfall variability and/or decrease, extreme events (drought and flood) and severe soil erosion (IPCC, 2007), which will further impede the country's farming sector and overall development efforts. Apart from agriculture, other key sectors such as energy, water supply and health are extremely sensitive to climate change (NMA, 2001, 2007).

The continued rapid population growth and the expansion of agriculture under the dryer, warmer climate regime in the fragile ecosystems have damaged the livelihood resources of the poor people. The ecological system gets disturbed, land management structures short-lived, poor people's livelihood bases disrupted, traditional coping mechanisms failed, conflicts over scarce resources increased and dependency on external support continues to be the case. The adverse impact of climate change-induced extreme events, have gradually changed productive lands into unproductive areas, indicating the intimate inter-linkage between climate change and land degradation processes. In relation to this, ACCRA (2011) underlined that the combined effects of all these processes now ranking Ethiopia 11th out of all the countries in the world in terms of its vulnerability to physical climate impact, and 9th in terms of overall vulnerability, defined as physical impact by considering coping ability. While media headlines, scholars, and policy-makers have highlighted the risks associated with climate change and potential policy responses, little is studied on the inter-related nature of vulnerability, perception and adaptation to climate change using the integrated climate change assessment framework at local level from the perspectives of the five livelihood assets. The extent to which the farmers are vulnerable and by which livelihood assets is not addressed well, except blaming the recurrent drought conditions, the severe land degradation processes and the misdeeds of the previous regimes.

To mention a few, some studies tend to focus on the different shocks in relation to growth and/or consumption (Dercon, 2004; Dercon et al., 2005). Others examined the relationship between rainfall and crop production at the zonal, regional and national levels (Segele & Lamb, 2005; Woldeamlak, 2009). Still some others yet analyzed yield or monetary impact of climate change and adaptation measures using Climate Models (NMA, 2001; Yosuf et al., 2008, Temesgen, 2007; Temesgen & Hassen 2009; You & Ringler, 2010). Other scholars also examined climate induced-hazards, impacts, responses and local innovations to climate change adaptation, restricted to the pastoral lowlands (Aklilu & Alebachew, 2009; Yohannes & Mebratu, 2009). Other studies were also done on perception and adaptation without integrating vulnerability (Conway & Schipper, 2010; Falco et al., 2010; Temesgen et al., 2009). In this regard, the climate change research scholars contend that without understanding the nature of vulnerability and adaptive capacity, it is difficult to acquire better knowledge of adaptation to the impacts of climate change (Smit et al. 1999; You & Ringler, 2010). Hinkel (2011:200) also explained the need for a combination of vulnerability (exposure and sensitivity) and adaptive capacity as: "This combination is essential just as the way tires, engine and coachwork are combined in order to attain a car".

Only Temesgen (2010) analyzed the vulnerability of agriculture dependent farmers and their adaptation strategies using the integrated vulnerability assessment framework. However, it was highly aggregated at regional level, covering a wider area of land characterized by different biophysical and socio-economic attributes. In this regard, Adger and colleagues (2004) argue that the national and regional levels are not appropriate scales for vulnerability analysis as vulnerability and adaptation are highly context specific. Moreover, his study did not explore the role of agro-ecology in the choice of the possible adaptation measures. His study can also be questioned on the basis of the conceptual approach he employed, that is, for he took poverty as a proxy to vulnerability based on the current level of consumption that is heavily determined in Ethiopia by seasonality, annual rainfall and food aid receipts. Neither is vulnerability determined only by income and consumption.

Upon reviewing the previous studies, there is no research work that treated vulnerability, perception and adaptation in an integrated manner from the perspectives of five livelihood assets. This situation therefore inspired me to address the levels of vulnerability of the farmers to climate change by integrating these inter-related components in the *dega* (cool, humid highland), *woyna dega* (temperate, sub-humid, midland), and *kola* (warm, semiarid lowland) agro-ecological settings of northwest Ethiopia.

1.3. Objectives of the study

The main objective of this study is to investigate climate change vulnerability, perception and adaptation strategies of farmers in the three agro-ecological settings of northwest Ethiopia. The specific objectives of the study are to:

1. Analyze biophysical and economic contexts of *dega*, *woyna dega* and *kola* study sites
2. Analyze the vulnerability levels of rural households by agro-ecology with respect to five capital assets, climatic exposures and adaptation practices
3. Examine farmers' perception to climate change and its effects on adaptation
4. Identify the most commonly used adaptation strategies by rural households and analyze the determinants of their' choice of adaptation options

1.4. Research questions

Based on the specific objectives, this thesis tried to answer the following research questions.

1. What the biophysical and socio-economic contexts of the three study sites look like?
2. What is the level of vulnerability of rural households to climate change in the different agro-ecological contexts with respect to the five livelihood asset/capitals?
3. How do farmers perceive climate change and its impact on livelihood assets?
4. What are the determinants of adopting the most commonly used adaptation options?

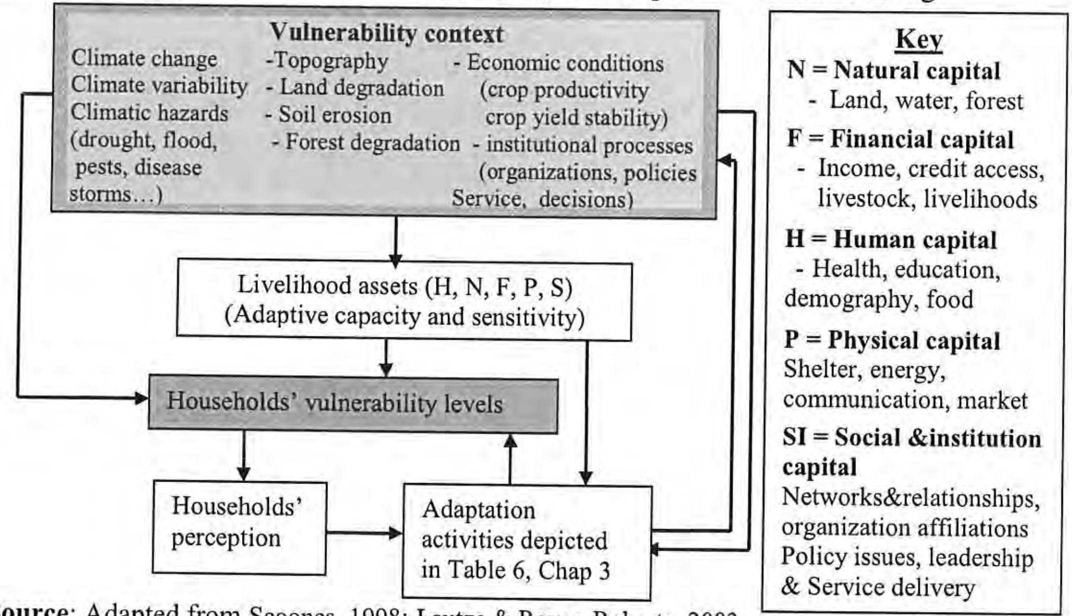
1.5. Conceptual framework

The vulnerability literature provides insights regarding how and why individuals, households, social groups, and public institutions are likely to be affected by climate change and extreme events. Numerous vulnerability frameworks emphasized to the specific contextual factors that influence exposure and the capacity to respond to the change (Adger, 1999; Obrien et al., 2008). Some authors developed a place-based framework that focuses on the coupled human-environment system and examines as to how hazards affect the systems (Turner II et al., 2003; Schroter et al., 2004; Gallopin, 2009). Other types of vulnerability frameworks include capabilities, assets, and livelihoods approach, focusing on the factors that constrain or enable people in pursuing outcomes that they value (Chambers & Conway, 1992; Scoones, 1998, Benson & Twiggs, 2007).

In order to guide the whole process of this study the conceptual framework is sketched based on a sustainable livelihood framework/SLF (Scoones, 1998; Lautze & Raven-Roberts, 2003). The SLF can capture the major factors influencing household welfare and it can provide the most important analytical tools for evaluating the vulnerability levels of households and adaptation strategies. Ellis and Allison (2004) pointed out that the term livelihood attempts to capture not just what people do in order to make a living, but the resources which provide them with the capability to build a satisfactory living, the risk factors they must consider in managing their resources and the institutional and policy processes which either helps or hinders them in their pursuit of viable living standards. Other scholars added that the SLF can link local-level livelihood activities to macro-level policies thereby indicate the gaps from various angles and areas of revision for intervention (Benson & Twigg, 2007; Luers, 2005).

In order to assess the vulnerability of rural households, a vulnerability index was applied. In the context of this vulnerability assessment, vulnerability indicators are operationalized for the five livelihood resources/assets and climatic indicators in many ways. For this study vulnerability is defined as the degree of defenselessness or propensity of rural households to live in poverty because of the adverse effects of climate change and lack of access to livelihood resources.

Figure 1: Conceptual framework of vulnerability and adaptation to climate change



Source: Adapted from Scoones, 1998; Lautze & Raven-Roberts, 2003

The conceptual framework is depicted in Fig. 1 by encompassing the relevant components modified from the sustainable livelihood framework presented in Fig. 8. It is clear from Fig. 1 that vulnerability contexts can influence households' livelihood assets, perception and adaptation activities. The vulnerability context in this study includes climatic factors (changes in temperature, rainfall, and the frequency of other climatic hazards), topographic characteristics, farmland erosion and farmland fertility levels and forest degradation; economy conditions (agricultural production, crop productivity and trend of yield stability) and institutional processes (policies, organizations, leadership and decisions).

Adaptive capacity which is measured by access to livelihood resources/assets (such as human, natural, economic, physical and social capital assets) is affected by changing biophysical and socio-economic contexts as well as institutional processes, all of which in turn have determined the vulnerability situations of rural households to climate change impacts. Natural capital was measured by households' access to farmland, water and forest resources while human capital is represented by health, skills, training, education, demographic indicators and food components. Economic capital was addressed by income, credit access, livestock ownership and livelihood activities while physical capital includes

Ethiopia. In the context of this study, *dega* agro-ecology was delimited to areas having elevation from 2500 to 4517m above sea level and with rainfall from 1200 to 2200mm, *woyna dega* from 1500 to 2500m with a rainfall ranging from 900 to 1200mm and *kola* from 854 to 1500m with a rainfall ranging from 500 to 900mm (Chapter Three, Table 4). The study was carried out in three woredas and 11 kebeles (lowest administrative tiers of Ethiopia). Special attention was given to the exploration of biophysical and economic contexts such as location, temperature, rainfall, extreme weather events, topography, forests resources and agricultural production trends. Vulnerability levels of the rural households by human, natural, financial, physical, and social capital assets integrated with climatic factors were other focus areas of this research. Issues such as perception of rural households and their adaptation strategies to climate change including the determinants of the choice of adaptation measures with respect to socio-economic and biophysical factors were also other concerns of the present study.

1.7. Thesis structure

This thesis is organized into seven chapters. The introductory part is discussed in Chapter One. Chapter Two presents the literature review on the theoretical and methodological frameworks of vulnerability and adaptation as used in previous researches. In Chapter Three, the research method is presented comprised of the research design, sampling techniques and methods of data collection and methods of analysis. The main findings and discussions of the study are presented from Chapter Four to Chapter Six. Chapter Four presents the biophysical and economic characteristics of the study sites which have created differential vulnerability situations and the choice of adaptation measures within and across the rural communities of the three agro-ecologies. Analysis of the vulnerability levels of farmers under the guidance of the sustainable livelihood framework of the notion of five livelihood assets and climate exposures and adoption indices is discussed in Chapter Five. Chapter Six addresses farmers' perceptions and adaptation measures, including determinants of the choice of adaptation options. Summary, conclusions and implications of the study are presented as the last section.

CHAPTER TWO
REVIEW OF RELATED LITERATURE

In order to develop appropriate proactive adaptation plans that are tailored to the needs of the exposed communities to climate change risks and in turn to allocate scarce resources for adaptation, the study of vulnerability, perception and adaptation is a necessary first step. To this end, critical review of the theoretical/conceptual, methodological and empirical literature on these major themes is imperative. Accordingly, this literature review is organized into seven main sections. Global climate change and variability, climate system and climate change in Ethiopia; the theoretical frameworks and the methods to measure vulnerability to climate change, sustainable livelihood approach, and perception of farmers to climate change and determinant factors of perceptions. The issues of adaptation were also critically reviewed and presented in this chapter. The literature review contributed much to design the conceptual framework depicted in Section 1.5 and the research methods presented in Chapter Three.

2.1. Global climate change and variability

2.1.1. Climate science and the concept of climate change

The climate of the earth is part of the wider environmental landscape. Climate depends on the interaction of the atmosphere, oceans, land surface and its features, including albedo, vegetation, soil moisture, ice and snow, and other biophysical processes (Schipper, 2004). The earth's atmosphere is made up of a combination of different gases. Apart from nitrogen, oxygen, and argon, it contains several trace gases, including carbon dioxide ($C0_2$), methane (CH_4), nitrous oxide (N_20), ozone (0_3) and water vapor which is known as greenhouse-gases (IPCC, 2007, 2013; UNFCCC, 2007; Houghton, 2009). These gases absorb and emit infrared radiation and thereby permit the sun's energy to reach the surface of the earth through the atmosphere, but hinder the heat radiated back to space, and thus warm the atmosphere, what is called the greenhouse effect (UNFCC, 2007; Houghton, 2009). Total radiative forcing is positive, and has led to an uptake of energy by the climate system. The largest contribution to total radiative forcing is caused by the increase in the atmospheric concentration of CO2since 1750 through human activity (IPCC, 2013).

Natural and anthropogenic substances and processes that alter the Earth's energy budget are drivers of climate change. Radiative forcing (RF)[2] quantifies the change in energy fluxes caused by changes in these drivers for 2011 relative to 1750. Positive RF leads to surface

[2] The strength of drivers is quantified as Radiative Forcing (RF) in units watts per square meter

warming whilst negative RF leads to surface cooling (IPCC, 2013). Some emitted compounds affect the atmospheric concentration of other substances and the RF can be reported based on the concentration changes of each substance. Alternatively, the emission-based RF of a compound provides a more direct link to human activities including contributions from all substances affected by that emission. The total anthropogenic RF of the two approaches is identical when considering all drivers of change (IPCC, 2013).

The warming effect of greenhouse-gases in the atmosphere was first renowned by the French scientist Jean-Baptiste Fourier in 1827. He pointed out the similarity between what happens in the atmosphere and in the glass of a greenhouse, which led to the name 'greenhouse effect'. A British scientist, John Tyndall, measured the absorption of infrared radiation by carbon dioxide and water vapor around 1860 and suggested that the cause of ice ages might be a decrease in the greenhouse effect of carbon dioxide. A Swedish chemist, Svante Arrhenius also calculated the effect of an elevated concentration of greenhouse-gases in 1896. He estimated that the doubling concentration of carbon dioxide would increase the global average temperature by 5 to 6^0C, an estimate not too far from the present projection. Nearly 50 years later, around 1940, G. S. Callendar was the first to calculate the warming effect of the increasing $C0^2$ from fossil fuels burning (Houghton, 2009).

The first concern of climate change due to increasing greenhouse-gases was expressed in 1957, when Roger Revelle and Hans Suess of the Scripps Institute of Oceanography in California, indicated the increasing trend of carbon dioxide in the atmosphere. In the same year, measurements of carbon dioxide were started from the observatory on Mauna Kea in Hawaii. The rapidly increasing use of fossil fuels, together with growing interest in the environment, has led to global warming, moving up the political agenda through the 1980s, and eventually to the Climate Convention signed in 1992 (Houghton, 2009). Climate scientists have devoted great efforts to distinguish anthropogenic climate change from the natural variability for several decades. Nowadays, evidences confirm that greenhouse-gas emissions are attributed to human activities, primarily fossil-fuel burning and deforestation (IPCC, 2001; Houghton, 2009). IPCC attributed the enhanced greenhouse effect to climate change, and declared that there is a discernible human influence on global climate (IPCC, 2001). Human influence on the climate system is clear evidenced by increasing GHG concentrations in the atmosphere, positive radiative forcing, observed warming, and understanding of the climate system (IPCC, 2013). Climate change results in both positive and negative effects on the human and the natural systems. The negative outcomes rouse significant concern among scientists (Smithers & Smit, 1997; Watson et al., 1997).

Fluctuation in the elements of climate from the normal or baseline values referred to as climate variability (Smither & Smit, 1997). Climate is inherently variable in time and space even within countries. Scholars expressed climate variability as variations in the mean state and other statistics of the climate on all temporal and spatial scales, which may be due to internal processes within the climate system, or anthropogenic external forcing (IPCC, 2001; Fussel & Klein, 2005). Seasonal and inter-annual climate variability, including extreme weather events forms an important component of a system's exposure to environmental stimuli (Fussel & Klein, 2005; Ericksen et al., 2007). Climate change will largely affect existing climate variability, including the frequency, intensity, and location of harmful weather events. Onset, duration, and distribution of rains as well as decreasing predictability of extreme weather events result in increased seasonal variability (Fussel & Klein, 2005; Ericksen et al., 2007). Some inter-seasonal variability is well understood, but much of the variation over long years is poorly understood and largely unpredictable. Thus, decisions on climate-sensitive sectors or activities are usually carried out under uncertainty or risk (Smithers & Smit, 1997).

Climate change is a change in the long-term average value of a particular climate parameter – including both more variability and more extreme weather events. Most people define it as the alteration of the earth's climate that is attributed directly or indirectly to human activity (UNFCCC, 2007). However, scientists in the network of IPCC (2007) often use the term for any change in the climate, whether arising naturally or from anthropogenic causes. They define it as a change in the state of the climate that can be identified by changes in the mean and/or the variability of its properties and that persists for an extended period, typically decades or longer (Fussel & Klein, 2005; IPCC, 2007).

Anthropogenic climate change resulting from emissions of GHG into the atmosphere has adverse effects for the global societies and ecosystems. Carbon dioxide is produced when fossil-fuels are used to generate energy and when forests are cut down and burned and other human practices. Methane and nitrous oxide are emitted from agricultural activities, changes in land use and other sources. Artificial chemicals called halocarbons (CFCs, HFCs, and PFCs) and other long-lived gases such as sulfur hexafluoride (SF6) are released by industrial processes. Ozone is generated indirectly by automobile exhaust fumes and other sources (IPCC, 2001; 2007; Houghton, 2009). Carbon dioxide is the most important of GHGs and its concentration in the atmosphere has increased exponentially since the industrial revolution as a result of fossil-fuel combustion and deforestation. The atmospheric concentration of carbon dioxide was about 280 parts per million (ppm) in 1800; today it rose to 391 ppm in 2011 and will continue so. Increases have also been detected for methane, nitrous oxide and other gases (Klein et al., 2005; Houghton, 2009, IPCC, 2013).

Observational and model studies of temperature change, climate feedbacks and changes in the Earth's energy budget together provide confidence in the magnitude of global warming in response to past and future forcing. Estimates of these quantities for recent decades are consistent with the assessed likely range of the equilibrium climate sensitivity to within assessed uncertainties, providing strong evidence for our understanding of anthropogenic climate change (IPCC, 2013). The rising level of GHG is already changing the climate system by absorbing long-wave infrared radiation in the upper atmosphere. Observations show that global atmospheric temperatures have risen by about 0.6°C and other changes in the climate system over the 20th century (IPCC, 2001, 2007, 2013; Klein et al., 2005; Houghton, 2009). The IPCC (2013) Report indicated that the global average combined land and ocean surface temperature trend determined by linear regression from one data set indicated a warming of 0.85°C [0.65 to 1.06°C] over the period 1880–2012.

The disasters are increasing exponentially, from about 200 per year in1980s to 300 in 1990s to over 400 per year for the period 2000–2008. In the last period (2000-2008) climate-related disasters resulted in about 220 million of the victims (deaths plus people affected) and US$ 82 billion in damages per annum (McBean & Rodgers, 2010). Now the rate of occurrence has increased to more than one such event per day. The enormity of the problem is evidenced by the fact that in the last two decades (1988–2007), 76% of all disaster events were hydrological, meteorological, or climatological, which accounted for 45% of the deaths and 79% of the economic losses caused by natural hazards. Although the increase in these events cannot be attributed only to climate change, the large raise maintains the long-term patterns of droughts, severe storms, heavy rainfall, and floods (McBean &Rodgers, 2010).

The weight of the warming trend is manifested in its impact on human life and national economies. Munich Re has shown that the number of devastating catastrophes with more than 500 deaths and/or overall losses of more than US$ 500 million, has increased from 5–15 events per year in the 1980s to 15–25 events in the period 1990–2005. These catastrophic events rose to 28–41 in the 2006–2008 periods, 41 were recorded in 2008, which was the largest number ever (McBean & Rodgers, 2010). In the context of this research, both the variability and changes are forms of climate stress that affect the livelihood constructions of the poor and to which people have to cope in the short-term and adapt in the long-term.

2.1.2. Projected changes in global climate

Future projections of climate change are based on global scenarios of GHG. These emission scenarios are subjected to great uncertainty, as they reflect patterns of economic development, population growth, consumption, and other factors that are not easy to predict over a 100-year period (Klein et al., 2005). A large number of emission scenarios are used to account for this high degree of uncertainty. The most-recent emission scenarios were published in the IPCC Special Report on Emission Scenarios by 2100. Carbon cycle models project atmospheric carbon dioxide concentrations of 540–970 ppm, with a range of uncertainty of 490–1260 ppm (Houghton, 2009). Based on these projections and those of other GHGs and sulfate aerosols, IPCC predicts an increase in global average surface temperature of 1.4–5.8^{0}C over the period 1990–2100. The IPCC further states that it is very likely that nearly all land areas will warm more rapidly than the global average, particularly in northern high latitudes in the cold season (Klein et al., 2005; Houghton, 2009).

The IPCC (2007, 2013) concluded that the 'warming of the climate system is unequivocal'. Given the impact of climate-related hazards in the past, and the apparent relationships with the past changing climate, the projected warming over the next few decades will be about 0.2◦C per decade. By 2040, the temperatures will start to diverge with a lower emission scenario leading to warm between 1^{0}C and 6^{0}C by 2100 (IPCC, 2007). This change would be much larger than any climate change experienced over at least the last 10,000 years. The projection is based on a wide-range of assumptions about the main forces driving future emissions (such as population growth and technological change), but does not reflect any effort to control GHG emissions (IPCC, 2007; Houghton, 2009).

The IPCC stated that these warming trends likely lead to greater incidence of hazards, especially the increase in heat-wave was given a 90% probability rating. Frequency of heavy precipitation events, drought affected area, intense tropical cyclones, and the incidences of high sea-levels are projected to increase with greater than 66% probability (IPCC, 2007). Sea-level rise is a critical problem for the billions of people who live on or near the coasts. IPCC (2007) projected closer to a meter rise by 2100. Consequently, some coastal cities will be at risk of rising sea-levels leading to flooding, which will be intense during the strongest typhoons. As a result, the need for-risk reduction strategies, and capacity to implement them, will be larger in the future (McBean & Rodgers, 2010).

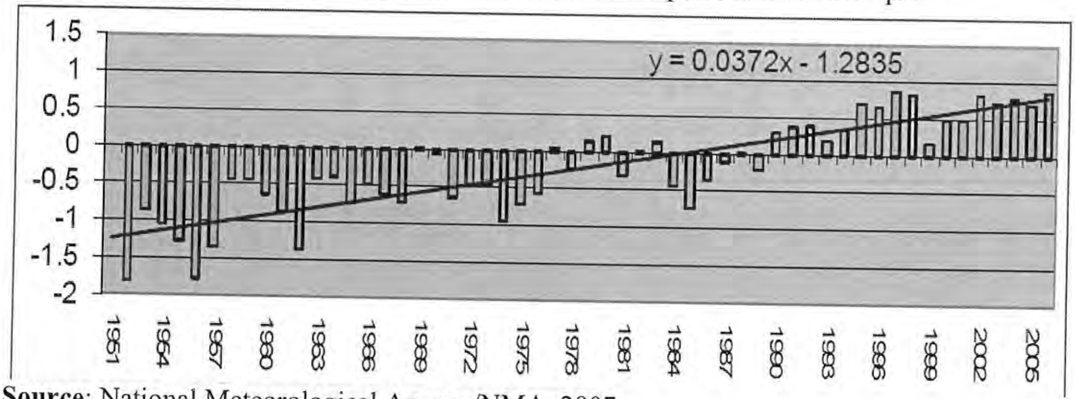
(Temesgen, 2010). The most widely applied methods are the traditional and the agro-ecological zones (AEZs). Based on the traditional classification system, which mainly relies on altitude and temperature, Ethiopia is divided into five agro-ecologies namely *wurch* (upper highland), *dega* (highland), *woyna dega* (Midland), *kola* (Lowlands), and *bereha* (desert) (Temesgen et al., 2008; Temesgen, 2010). The agro-ecological zone classification method is alternatively based on combining growing periods with temperature and moisture regimes. According to this method, Ethiopia has 18 major AEZs, which are further sub-divided into 49 AEZs (Temesgen, 2010). These zones are also grouped under six major categories as arid, semiarid, sub-moist, moist, sub-humid and humid, and per humid.

The *Arid zone* is less productive and pastoral, occupying 53.5 million hectares (31.5% of the country) while semiarid zone consists of less harsh areas and occupies 4 million hectares (3.5% of the country). The *sub-moist* zone occupies 22.2 million hectares (19.7% of the country) and highly threatened by severe erosion, whereas the *moist* zone covers 28 million hectares (25% of the country) of the most important agricultural land of the country where cereals are the dominant cultivated crops. The sub-humid and humid zones cover 17.5 million hectares (15.5% of the country) and 4.4 million hectares (4% of the country) respectively. They provide the most stable and ideal conditions for perennial crops and are homes to the remaining forest and wildlife, having considerable biological diversity while the *per-humid* zone covers about 1 million hectares (close to 1% of the country and is suited for perennial crops and forests. Over these diverse agro-ecological settings, there is wider variation in rainfall and temperature. Mean annual rainfall ranges from about 2,000mm over some pocket areas in the southwest to less than 250mm over the Afar lowlands in the Northeast and Ogaden in the Southeast. The mean annual temperature varies from about 10^0C over the highlands of the northwest, central, and southeast to about 35^0C on the northeastern edges (UNESCO, 2004; Tesfaye, 2003; Temesgen, 2010). The arid and semi-arid regions experience a coefficient of variation of 50% while rainfall fluctuation in the Southwestern regions is usually less than 20%. Higher rainfall deviation coupled with the expected rise in evapo-transpiration due to increasing temperature aggravates the vulnerability situations of these areas to drought (Tesfaye, 2003; UNESCO, 2004).

2.2.2. Climate change in Ethiopia

Many studies prove that temperature and rainfall have changed from time to time. According to NMA (2001), the mean annual minimum temperature over the country has increased by 0.25^0C every decade, while the average annual maximum temperature has increased by 0.1^0C every ten years. These changes have now further increased from time to time. In line with this, McSweeney (2010) underlined that the mean annual temperature has increased by 1.3°C between 1960 and 2006, an average rate of 0.28°C per decade. The increase in temperature has been most rapid in July, August and September ('JAS') at a rate of 0.32°C per decade (McSweeney, 2010). Over the same period, there has been an increase in the number of hot days and nights in a year by 20% and 38% respectively. The rate of increase is strong in June, July and August ('JJA') when the average hot days and nights has increased by 32% and 59% in order. The frequency of cold days per year has decreased on average by 6%, and a decrease is found in all seasons, except December-January-February (DJF). The frequency of cold nights per year has decreased rapidly (by 11%) across all seasons (McSweeney, 2010).

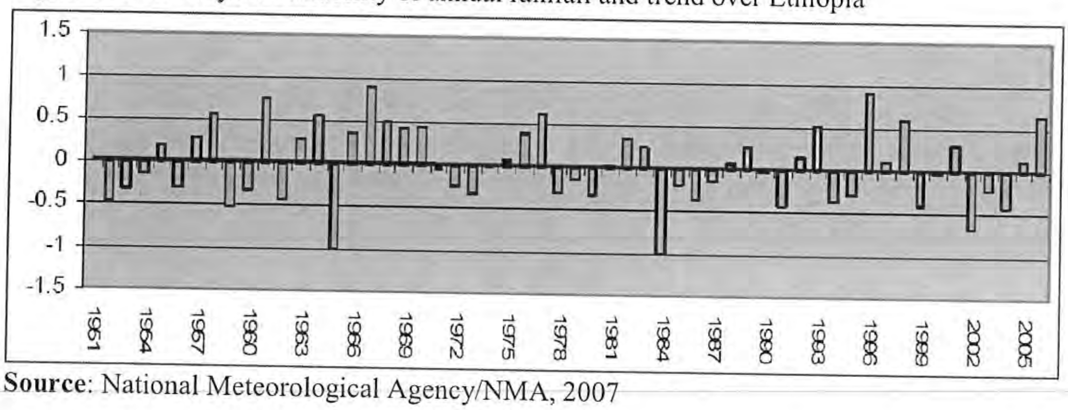
Figure 2: Year-to-year variability of annual minimum temperature over Ethiopia



Source: National Meteorological Agency/NMA, 2007

Although the change in precipitation is not as pronounced as the change in temperature, there is a decreasing trend (NMA 2001). However, there is no significant trend in observed mean rainfall between 1960 and 2006 (NMA, 2007). Global climate prediction models also provide controversial results in that some provide increasing precipitation while some show decreasing trend (Temesgen et al., 2008).

Figure 3: Year-to-year variability of annual rainfall and trend over Ethiopia



Source: National Meteorological Agency/NMA, 2007

As Figure 3 shows the most common characteristic of the Ethiopian rainfall over the past 60 years was a very high inter-annual variability. Some of the years were characterized with dry conditions resulting in droughts while some other years with wet conditions. In addition, its climate is characterized by extreme events, namely droughts and floods, which have made the country to be known by its long history of famine and food crisis in the world (UNESCO, 2004; NMA, 2007; UNDP, 2010). The problem of famine and food shortage traced back to 250 BC in the country consistent with the history of drought, which has been occurring in various parts of the country in different time. Starting from the 9th century, about 30 major drought episodes have been recorded over the last nine centuries, 19 of which covered the whole country and were reported to be severe and the rest affected mainly Wollo and Tigray (UNESCO, 2004). The frequency and spatial coverage of droughts has increased over the past few decades. The last two decades have been marked by widespread droughts and food insecurity occurring every 2-3 years as compared to every 7-10 years over the previous decades (UNESCO, 2004; NMA, 2007).

The World Bank study on natural disaster hotspots reveals that 69% of Ethiopians are at risk of mortality from two or more hazards, which is the highest in the world (McSweeney, 2010). The country is most at risk from drought that affects the majority of the population as compared with any other hazards and results in loss of life, damage to crops, and migration (Table 1). In 2009, for example, a delay in the main rainy season, particularly in northeastern parts, was resulting in only 50-70% of agricultural land being covered by crops. As Ethiopia produces 90-95% of its total cereal output during this season, any rainfall variability has substantial implications for crop yield. Droughts in Ethiopia can shrink the households' farm production by up to 90% of a normal year output (Temsegen, 2010; McSweeney, 2010).

Table 1: Natural hazard events, deaths and affected population in Ethiopia (1991-2010)

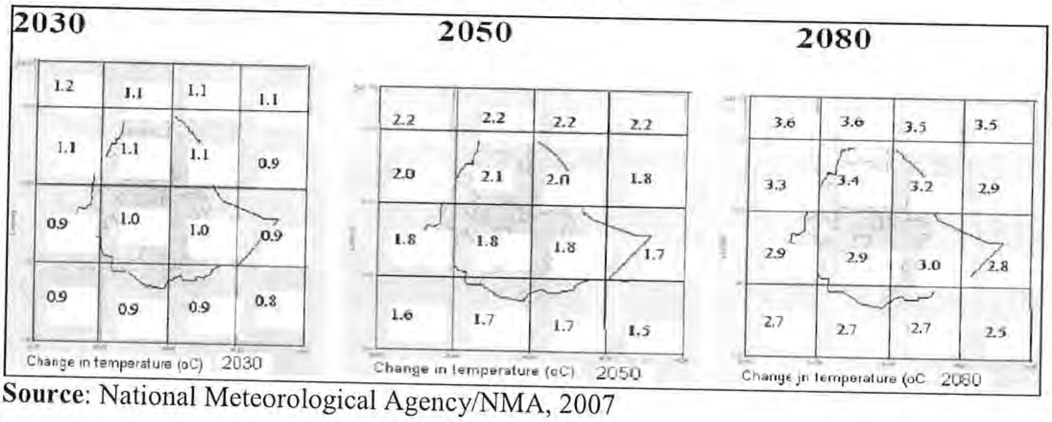
Hazard	No. of events	Deaths	Total population affected
Droughts	12	402	54,936,200
Average per event		33,531	4,578,017
Flood (unspecified)	23	136	195,240
Average per event		11	15,019
Flood (flash)	6	735	436,278
Average per event		123	72,713
Flood (general)	28	1,086	1,637,578
Average per event		39	58,485
Landslide	3	39	194
Average per event		13	65
Forest fire	1	-	5
Average per event		-	5
Locust infestation	4	-	-
Average per event		-	-

Source: CRED (2010) cited in McSweeney, 2010

Ethiopia has also experienced major floods in 1988, 1993, 1994, 1995, 1996 and 2006 with lamentable effects on the life and properties of the community. For example, flooding of the Tekezie River in 2006 killed several hundred and displaced over 10,000 people (UNESCO, 2004; NMA, 2007; McSweeney, 2010). However, unlike drought and famine, the trend of the flood and its consequences have not been properly documented (UNESCO, 2004).

Knowledge of the climatic conditions of the country and the adaptation options available to the farmers will assist in decreasing vulnerability to future climate change. All models agree that temperature in Ethiopia will increase in the coming years. For instance, forecasts by NMA (2007) show that the temperature will increase in the range of 0.9 -1.1°C by 2030, 1.7-2.1°C by 2050 and 2.7-3.4°C by 2080 as compared to the 1961–1990 normal record. Other estimates indicate that mean annual temperature will increase between 1.8 and 2.7°C by 2060s and of 2.3 to 4.2°C by 2090s. Maximum increases in mean temperature are projected to be 3.1°C and 5.1°C for the 2060s and 2090s respectively. All projections have indicated the increasing frequency of days and nights with hot temperatures (McSweeney, 2010).

Figure 4: Change in temperature relative to 1961-1990 normal



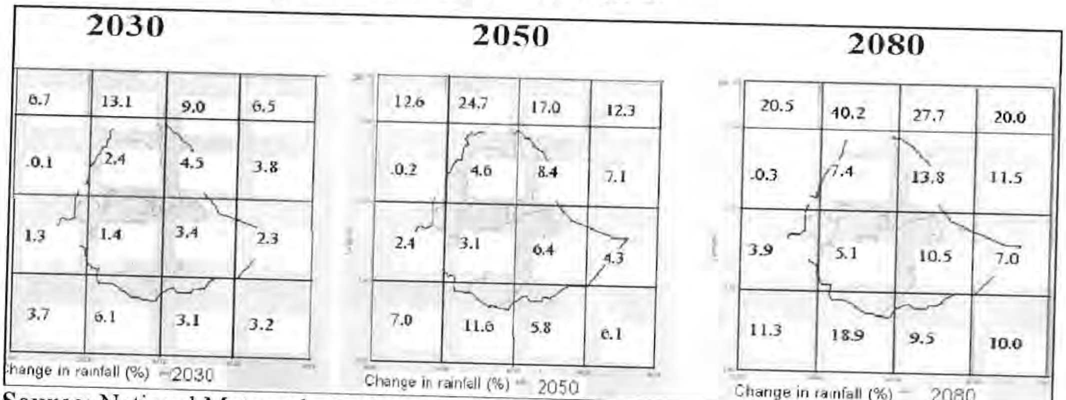
Source: National Meteorological Agency/NMA, 2007

Annual projections indicate that hot days will occur up to 40% of days by 2060s, and 69% of days by 2090s. The most rapid increases are projected for July, August, and September (JAS). Hot nights are projected to increase more quickly occurring on up to 66% of nights by 2060s and 87% of nights by 2090s. Hot nights are also projected to increase most rapidly in July, August, and September (JAS). All projections indicate decreases in the frequency of days and nights with cold temperatures. Cold nights decrease in frequency more rapidly than cold days, not occurring in most model projections by 2090s under the highest emission scenario (McSweeney, 2010).

There are many uncertainties about the magnitude, scale, and impacts of global projected climate change, particularly at regional, national, and local levels (IPCC, 2001, 2007; Hahn et al., 2009). Because of the delaying effect of the oceans, surface temperatures do not respond immediately to greenhouse-gas emissions, so climate change will continue for hundreds of years after atmospheric concentrations have stabilized (IPCC, 2001). As a result, global climate projection models are uncertain about providing accurate predictions for community development planning (Hahn et al., 2009). In addition, an important uncertainty of all climate scenarios relates to the effect of a changing climate on the frequency, magnitude and spatial occurrence of extreme events such as floods, cyclones and droughts. To date, climate models have been presented ambiguous results for severe climatic events (Klein, 2003). Similarly, climate models predictions give controversial results of both increasing and decreasing precipitation for Ethiopia unlike the temperature trend (Temesegen et al., 2008, Temesgen, 2010). However, projections from different climate models are consistently indicating increases in annual rainfall. These increases are largely a result of intense rainfall in the short rainy season (October-November-December (OND) in southern Ethiopia. For instance, estimates by McSweeney (2010) shows increased annual changes of 3% to 9% by the 2090s, but this increase could be as much as 42%. Estimates for rainfall in the OND season show increases of 17% to 36% by 2090s, but up to 70% at the upper end of the projections. Percentage increases in OND rainfall in the driest, easternmost parts of Ethiopia are large (McSweeney, 2010). The reason for the increasing trend of rainfall in the southern part of Ethiopia might be attribute to the high pressure system created in the Indian oceans while low pressure system in southern Ethiopia so that moisture carrying winds blow towards southern Ethiopia. In line with this speculation, Molg et al. (2009) found out that precipitation in East Africa, including southern Ethiopia, obtained moisture from the Indian Ocean during March-April-May (MAM) and October-November-December (OND) as compared to the northern part of Ethiopia.

Projections of change in the rainy seasons of April, May, and June (AMJ) and July, August, and September (JAS) are more mixed, but tend towards slight increases in the southwest and decease in the northeast. Predictions show an increase in the amount of rain falling in heavy events, with annual increases of 18% by the 2090s. The largest seasonal changes are observed in JAS and OND, with increases up to 16% and 25% respectively (McSweeney, 2010).

Figure 5: Rainfall change in relative to 1961-1990 normal



Source: National Meteorological Agency/NMA, 2007

The trends of increasing temperature, erratic/decreasing precipitation, and frequency of droughts and floods are predicted to increase in the future particularly in northeast Ethiopia (NMA, 2007) as major social, economic, and environmental disruptive forces closely interlinked with land degradation. Flooding has also very serious implications for Ethiopia, causing loss of life and property. Many areas suffer from regular seasonal flooding of major rivers such as: The Afar Region along the Awash River; the Somali Region along the lower reaches of Wabi Shebele River; The Gambella Region along the vast plains of Baro-Akobo River Basin; the Southern Region along the Omo-Gibe River; other Rift Valley Basin River tributaries; the Bahir Dar Zuria and Fogera areas along the Abay River in the Amhara Region. Flooding in these areas is happening every year with varied magnitude from year to year. Climate change projections show an increasing trend of heavy rainfall events, particularly in the late wet months. Therefore, Ethiopia will be under increasing threat of flooding in the coming decades (NMA, 2007; McSweeney, 2010).

2.3. Vulnerability to climate change

2.3.1. The concepts of vulnerability

The most differently defined term by various scholarly communities is 'vulnerability', which refers to the degree to which a system is likely to experience harm due to exposure to a hazard usually associated with floods, droughts, and poverty (Turner II et al., 2003; Fusel & Klein, 2005). The term vulnerability is now a central concept in the livelihood, food security, sustainability science, land-use change, natural hazards; disaster risks management, public health and global environment and climate change research communities (Schroter et al., 2004; Fussel, 2006). Numerous scholars have conceptualized it (Cutter, 1996; Adger, 1999; Kelly & Adger, 1999, 2000; Moss et al., 2001; UNEP, 2002; Cardona, 2003; Cannon et al., 2003; Brooks, 2003; Cutter et al., 2003; Prowse, 2003, Turner II et al., 2003; Wisner et al., 2004; Fussel & Klein, 2005) to mention a few.

Liverman (1990 cited in Fussel, 2007a) related vulnerability to the concepts of resilience, marginality, susceptibility, adaptability, fragility, and risk and proposes a distinction between vulnerability and political economy. Fussel and Klein (2005) added exposure, sensitivity, coping capacity, criticality, and robustness to this list. Wisner et al. (2004) defined vulnerability as the characteristics of a person or group in terms of their capacity to anticipate, cope with, resist and recover from the impact of natural hazards. They argue that vulnerability is a measure of a person or group's exposure to the effects of a hazard including the degree to which they can recover from the impact of that event. Cutter (1996) defines vulnerability as the likelihood that an individual or a group will be exposed to and adversely affected by a hazard. It is the interaction of the hazards of the place with the social profile of the communities. The same author identifies three distinct clusters of definitions for vulnerability: as risk of exposure to hazards, as a capability for collective response, and as an attribute of places and proposes a hazard-of-place model that bridges various definitions and states. Finally, she argues that it is a place that forms the fundamental unit of analysis for vulnerability.

Watson and colleagues (1997) define vulnerability as the extent to which a natural or social system is susceptible to damage from climate change. Vulnerability is a function of the system's sensitivity and ability to adapt to a given change in climate. Under this framework, a highly vulnerable system would be the one that is more sensitive to changes in climate, where the sensitivity includes the potential for substantial harmful effects, and one for which the ability to adapt is severely constrained (Watson et al., 1997). Similarly, Adger (1999) defines it as the extent to which a natural or social system is susceptible to sustaining damage from climate change. It is commonly perceived to be a function of two components: the effect that an event may have on humans (social vulnerability) and the risk that such an event may occur (exposure). Brooks (2003) grouped the definitions of vulnerability into two categories, viewing vulnerability either in terms of the amount of damage caused to a system by a particular climate-related event, or as a state that exists within a system before it encounters a hazard event. Although vulnerability is a multidimensional concept, which is difficult to define, quantify, and apply in practice (Cutter, 1996), it is the manifestation of environmental settings and social, economic and political structures. Most definitions agree on the broad explanation of vulnerability at the capacity to be harmed resulting from exposure to hazards and coping-adaptive capacity of the system to reduce the risk from exposures. However, most explanations have failed to include susceptibility of the system to the risks posed by climate change and variability. This means, the definition of vulnerability should be expressed as the function of exposure, sensitivity, and adaptive capacity. Scholars contend that the inclusion of exposure only in the definition appears to be problematic since exposure by itself does not necessarily contribute to negative outcomes (Moss et al., 2001; Turner II et al., 2003).

Some scholars also define vulnerability by considering natural hazards and human systems as separate entities (Wisner et al., 2004) while others define it from the human sensitivity and/or adaptive capacity (Adger, 1999; Kelly & Adger, 2000) without explaining the relationship between vulnerability and climate change. Still some others use the combination of nature-triggered hazards and human-induced exposures (Cutter, 1996; Turner II et al., 2003; Schroter et al., 2004; Wisner et al., 2004).

Variations in terms of definitions have emanated from the perceptions and professional backgrounds of the researchers. Fussel (2009:2-3) contends it as: "Definitions of vulnerability differ so widely that the term becomes almost useless in an interdisciplinary context without further specification". Key conceptual ambiguities include: whether it is a starting point, intermediate, or outcome of an assessment; whether it should be defined in relation to an external stressor such as climate change, or in relation to an undesirable outcome such as famine; whether it is an inherent property of a system or reliant upon a specific scenario of external stresses and internal response; and whether it is a static or a dynamic concept (Fussel & Klein, 2005). These diverse definitions demand for a range of methodologies in vulnerability and adaptation research (Devereux, 2007; Fussel, 2009). For instance, natural scientists and engineers tend to apply the term in a descriptive manner, whereas social scientists tend to use it in the context of specific explanatory models (Fussel, 2009). The definitions and methodologies used, however, revolve around the explanation of lack of adaptive capacity both in terms of socio-economic and biophysical systems.

2.3.2. Vulnerability to climate change

One of the heavily relied up on definitions of vulnerability in the context of climate science is from IPCC (2001, 2007), which defined it as the degree to which a system is susceptible to, or unable to cope with, adverse effects of climate change, including climate variability and extremes. The IPCC provides two more definitions that are not specified as natural or social vulnerability, but fit into the separate climate research streams. From the natural standpoint, the IPCC defines vulnerability as "a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity" (IPCC, 2001:

995). From a social standpoint it describes vulnerability as the "degree to which a system is susceptible to injury, damage or harm". Along the same line, Houghton and Khandker (2009) explain vulnerability as a risk of falling into poverty in the future, even if the person is not necessarily poor now; it is often associated with the effects of shocks such as drought and floods with a drop in farm production. Thus, social vulnerability is typically broken into three overlapping components: exposure, sensitivity and adaptive capacity - also called resilience and coping capacity (Turner II et al., 2003).

Exposure is the magnitude, frequency, and duration of climate hazards such as a drought, floods, and storms, increasing temperature, and decreasing precipitations which expose farmers' livelihood assets (IPCC, 2007). Sensitivity is the degree to which the farmer is adversely affected by the exposure which can be measured by the proportion of people who faced with food shortage, water scarcity, number of months in a food shortage, and access to different services. Adaptive capacity on the other hand refers to people's ability to adapt and recover from climate exposure by facilitating access to livelihood resources for adaptation. Sensitivity and adaptive capacity largely depend on the main livelihood activities practiced by a farmer and the specific livelihood resources needed to carry out these activities, as well as the impact of climate hazards on these key livelihood resources (IPCC, 2007; Luers et al., 2003; Turner II et al., 2003).

In this line of argument, Schroter et al. (2004) noted that agricultural vulnerability to climate change in terms of not only exposure to higher temperatures, but also crops yield sensitivity to high temperatures and farmers' ability to adapt to the effects of that sensitivity such as, by planting more heat-resistant cultivars or by planting different crops. Thus, one can conclude that exposure, sensitivity, and adaptive capacity are inherently linked (Gallopin, 2006). For example, greater amounts of exposure will give to greater sensitivity, while adaptive capacity can reduce the system's sensitivity. In practice, these steps do not happen chronologically, but instead play a continuous role in enhancing or diminishing each other. Consequently, many studies combine sensitivity with exposure or combine sensitivity with the adaptive capacity depending upon the indicator under consideration.

2.4. Vulnerability assessment

2.4.1. Evolution of vulnerability assessment

There is a long history of vulnerability studies which have been concerned with identifying population groups that are most likely to face the negative effects of the natural hazards and the socio-economic catastrophes (Wisner et al., 1994; Cannon, 1994; Cutter, 1996; Cutter et al., 2003; Klein, 2003). However, it is an emerging concept for climate science and policy (Fussel & Klein, 2005). Efforts over the past decade triggered a process of theory development and assessment practice thereby the reports of the IPCC and other several works show it. For vulnerability assessments, there are three distinct research streams, each of which dates from at least the 1960s and the root problems, policy/research questions, concepts and definitions of vulnerability vary so. These research streams are impact-assessment, risk-hazard, and food security studies (Schroter et al., 2004; Fussel, 2006). However, they overlap in motivation, concepts, and methods. The first two traditions, namely impact assessments and risk-hazards researches widely investigate the multiple effects of a single stress (Schroter et al., 2004).

Climate change impact assessments check the potential effects of one or several climate change scenarios on one or more impact domains, and compare them to a constant climate. In so doing, they aim to give levels of greenhouse-gas concentrations that would prevent dangerous anthropogenic interference with the climate system, referred by Article two of the UNFCCC (Fussel & Klein, 2005). For instance, studies in the impact assessment traditions might look at the environmental or social effects of constructing a highway in a given place while in the case of risk-hazard research it can analyze the effects of droughts or floods. These two traditions differ in that impact assessments tend to de-emphasize the processes by which society can unintentionally amplify the impact of a stress, or enact anticipatory adaptations to cut future impact as compared to risk-hazard researches (Schroter et al., 2004).

The third, research stream is food security studies which mainly focus on the multiple causes of a single effect, namely hunger or famine. Such research demonstrates that hunger is not only the inevitable outcome of a single cause, but also the contingent result of multiple causes, such as the co-occurrence of political marginalization with the environmental stress (Schroter et al., 2004). The emerging field of climate change vulnerability assessment draws heavily from the combination of these three research streams (Schroter et al., 2004). Same authors added that global climate change vulnerability assessment as a special concern for future trends in human sources of change (impact assessments), for multiple and unintended effects associated with the social amplification or reduction of risk (risk/hazard assessments), and for adaptation constraints associated with multiple and interacting stresses (food security assessments). Fussel (2006) argues that vulnerability assessment approaches, emanated from the theoretical evolution of risk-hazards researches, has passed through four stages: the first stage assumes that nature causes hazards (pure determinism); the second one emphasizes that technology can reduce vulnerability and losses (mechanistic engineering approach); the third stage argues that human behavior and perceptions were important (the human ecology approach); and the fourth stage argues that structure not nature, technology, or agency creates vulnerability (the political economy approach) (Fussel, 2006).

2.4.2. Theoretical vulnerability assessment frameworks

Derived from the three research traditions and four theoretical evolutions of risk-hazards researches, there are three main frameworks for explaining vulnerability to climate change (Schroter et al., 2004). All of them revolve on identification of people, places, and systems that are susceptible to harm and searching for actions that may reduce vulnerability. These major theoretical frameworks used to explain vulnerability include: the biophysical, the socio-economic, and the integrated frameworks. This section places the foundation for the thesis by presenting these theoretical frameworks used to conceptualize vulnerability to climate change impact. Identifying the focus, strengths and weaknesses is crucial to critically evaluate the frameworks from the perspective of the present study in the sections to come.

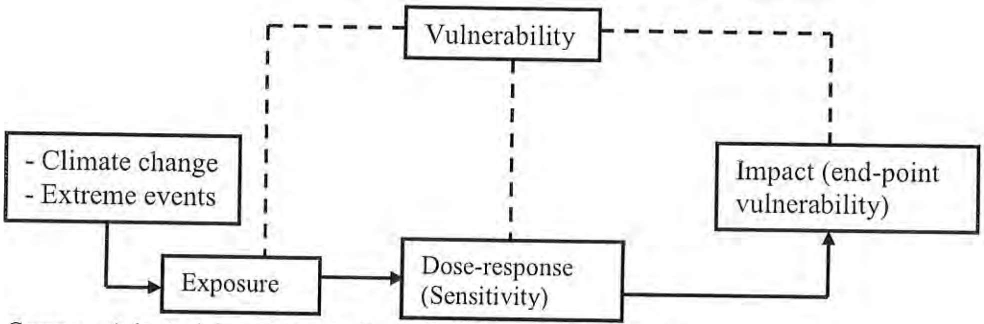
2.4.2.1. Biophysical frameworks

This vulnerability assessment framework focuses on disaster-risk management through assessing the risks and levels of damage to certain exposed units that arise from exposure to the hazards of a particular type and magnitude (Schroter et al., 2004; Fussel, 2006). Past quantitative use of this model focused on exposure and sensitivity of biophysical and socio-economic systems to the given environmental perturbations and stressors (Turner II et al., 2003). This approach is widely applied by engineers and economists posited on disasters, and epidemiology also used a similar concept (Fussel, 2006). A key aspect of the biophysical approach is the clear distinction between two factors: the hazard characterized by its site, intensity, frequency and probability (Benson & Twigg, 2007), and the vulnerability, the degree of damage caused by a hazard (Fussel, 2006).

Some authors labeled this approach as a risk-hazard framework (Fussel & Klein, 2005; Fussel, 2007). The vulnerability relationship in this framework is differently explained as a hazard-loss relationship in natural hazards research, the dose-response relationship between a hazard and adverse effects of a system (Turner II et al., 2003; Schroter et al., 2004; Fussel & Klein, 2005), or the exposure-effect relationship in epidemiology, the damage function in macroeconomics (Turner II et al., 2003; Fussel & Klein, 2005; Fussel, 2006), biophysical vulnerability (Brooks et al., 2004) and anthropocentric (Smit & Skinner, 2002). Kelly and Adger (2000) also considered this approach as the outcomes' endpoint vulnerability responding to research questions such as: 'What is the magnitude of the climate change problem'? and 'Do the cost of climate change exceeded the cost of greenhouse-gas mitigation'? The end point vulnerability results from climate change which consists of losses from climatic hazards.

The biophysical framework assesses the levels of damage based on forecasts or estimates of climate prediction models or by creating indicators of sensitivity for real or potential hazards, including their frequency. Therefore, biophysical vulnerability is the function of hazard exposure and sensitivity (Turner II et al., 2003; Fussel, 2006). For example, the yield impact of climate change can be analyzed by modeling the relationship between crop yields and climate variables (Kabubo-Mariara & Karanja, 2006; Yesuf et al., 2008). Similarly, monetary impact of climate change on agriculture can be analyzed by modeling the relationship between climate variables and farm income. Other impact assessment studies include the impact of climate change on human mortality and health (Fussel, 2007b); and on food security (Parry et at., 2004; Devereux, 2007).

Figure 6: Risk hazard-outcome vulnerability assessment framework



Source: Adapted from Turner II et al. 2003 and Luk, 2011

In the figure, the chain sequence begins with hazard such as climate change and extreme events; concept of vulnerability commonly implicit as noted by dotted lines. Climate change and weather extremes create exposure of the given system and then exposure affects the sensitive systems (exposure units). Both exposure and sensitivity can pose tremendous damage on the system subject to analysis. Sensitivity of a system denotes the dose–response relationship between its exposure to climatic stimuli and the resulting impacts.

The framework is derived from the Act of Nature paradigm and categorized under first generational studies (Fussel & Klein, 2005) in which nature and society are two distinct entities and the assessment focuses on vulnerability caused by exposure to a hazard (Brooks, 2003; Luk, 2011). In this type of vulnerability, the indicators mainly consider the outcome of the event and not the state of the system before the occurrence of a hazard (Brooks, 2003; Turner II et al., 2003), which could not show variations in yield or revenue for different households – between the poor and the rich. This means, a 30% crop yield reduction because of climate change may not the same for the rich and the poor people. Local people in rural areas could be heavily affected by climate change even in circumstances when the total agricultural sector in the country does fine. Minor changes in crop yields and income seriously affect poor people; whereas, rich people can buffer their loss by withdrawing money from savings and selling of livestock or some other assets. Besides, this approach targets physical condition and rarely connects to the experience of the affected group.

The biophysical framework does not consider the role of political economy, especially social and economic structures and institutions that shape differential exposure and consequences (Turner II et al., 2003). Along the same line, Fussel (2006) noted the difficulty of applying this approach to people whose exposure to hazards largely dependent on their behavior. This argument pointed out the failure of the biophysical approach to consider the adaptive capacity of the people or social groups because households who have access to livelihood resources and better social networks are less vulnerable to climate change. Communities supported with a strong institutional set up for effective preparedness response, extension services and timely information could be less vulnerable to the negative impact of climate change as compared to communities who are weak in such cases. For example, a series of droughts may have similar impact on crop yields in two regions, but differing economic and institutional arrangements in the two regions may result in quite different impact on farmers and hence in quite different adaptive responses, both in the short and long-terms. We can imagine the case of Somalia in this case. Drought occurred in Eastern African countries, but Somalia has been severely affected because of the political turmoil happening in the country for the past 20 years or so. In this regard, Cutter et al. (2003) argued that to help policy development that effectively address options for adaptation and hence reduce potential impact, there is a need to assess levels of vulnerability generated by social, economic, and political processes.

There are also common limitations of the use of model scenario projection of climate. Information on sources of measurement error in secondary data set is often lacking making sensitivity analysis difficult. Studies relying on climate scenario projections from General Circulation Models (GCMs), for example, suffer from the uncertainty associated with these models and how to map results (O'Brien et al., 2004; Hahn et al., 2009). In addition, methods relying on advanced climate projections and multiple international and national databases may be impractical for development planners working at the community level.

2.4.2.2. Socio-economic frameworks

The socio-economic framework has expanded from social constructionist framework, mostly prevailed in the poverty and development researches. Political economists and human geographers apply it to analyze the vulnerability level of a system to multiple stresses (Schroter et al., 2004; Fussel, 2007a). The framework regards social vulnerability as a priori condition of a household or a community conditioned by socio-economic and political contexts (Wisner et al., 2004; Adger & Kelly, 1999; Fussel & Klein, 2005). Some authors termed this approach as socio-economic vulnerability (Brooks, 2003; Adger et al., 2004) while others chose to use social vulnerability (Adger, 1999; Kelly & Adger, 1999; Vincent, 2004), and still some others explained it as contextual vulnerability (O'Brien et al., 2007).

The second generation‖ vulnerability studies apply this approach focusing on the local scale to enhance local capacity in the face of climate change. The theoretical approach focuses exclusively on people, asking who is most vulnerable, how they susceptible are, and why (Fussel, 2006). This approach assesses vulnerability based on variations in socio-economic dynamics, institutional characteristics, political status of people and social groups in the community–to measure adaptive capacity. Variation in the levels of vulnerability among the people, social groups, and places is accountable to the ability to carry out adaptation measures, not availability of adaptation measures alone (Fussel & Klein, 2005). The proponents of this framework consider vulnerability as the 'starting point', which is linked to the context and human security. The assumption is that socio-economic and political factors can worsen the impact of shocks by increasing sensitivity of the system.

There are many works, which are good examples in explaining vulnerability in their political economy approach (Wisner et al., 2004; Adger, 1999; Adger & Kelly, 1999; Wisner et al., 2004; Vincent, 2004). Wisner et al. (2004) point-out various social factors that can lead to vulnerability. Among these factors are economic imbalances, disparity in power among social groups, knowledge dissemination, and discrimination in welfare and social protection. However, it is contend that violent conflict and illness can lead to more loss of life than the natural and human-induced hazards like earthquake, drought, flood, and famine.

The focus of this approach on variation within society only in terms of socio-economic and political factors is the main limitation. In line with this, studies argue that in reality, environmental factors are creating variation in society (Cutter et al., 2003; Temesgen, 2010). This approach takes environment-based intensities, frequencies of occurrence, and probabilities of hazards such as droughts and floods as exogenous. However, two or more social groups found in similar socio-economic conditions, but characterized by different environmental attributes can have different levels of vulnerability. For instance, Fogera, Dmebia and Dera *woredas* of Amhara region are more vulnerable to floods than of Chilga and other *woredas* because of geographic exposure keeping other socio-economic factors equal. The framework also does not account for natural resource endowments to counteract the negative impact of environmental shocks. Although resource-rich households experience greater losses than the resource-poor, they can recover more quickly from a stress. For instance, areas endowed with permanent river water or groundwater that can be easily diverted or accessed for irrigation better cope with droughts by utilizing these resources.

Table 2: Two interpretations of vulnerability in climate change research

Main approaches	End-point vulnerability	Starting-point vulnerability
Definitions of vulnerability	Expected net damage for a given level of global climate change	Susceptibility of climate change and variability as determined by socio-economic factors
Root problem	Climate change impact	Social vulnerability
Policy concept	▪ climate change mitigation ▪ Compensation ▪ Technical adaptation	▪ Social adaptation ▪ sustainable development
Policy question	What are the benefits of climate change Mitigation?	How can the vulnerability of societies to climate hazards be reduced?
Research questions	What are the expected net impacts of climate change in different regions?	Why are some groups more affected by climatic hazards than others?
Vulnerability & adaptive capacity	Adaptive capacity determines vulnerability	Vulnerability determines adaptive capacity
Reference for adaptive capacity	Adaptation to future climate change	Adaptation to current climate variability
Starting point analysis	Scenarios of future climate Change	Current vulnerability to climate stimuli
Analytical function	Descriptive, positivist	Explanatory, normative
Main discipline	Natural science	Social science
Vulnerability approach	Integrated-risk-hazard	Political economy

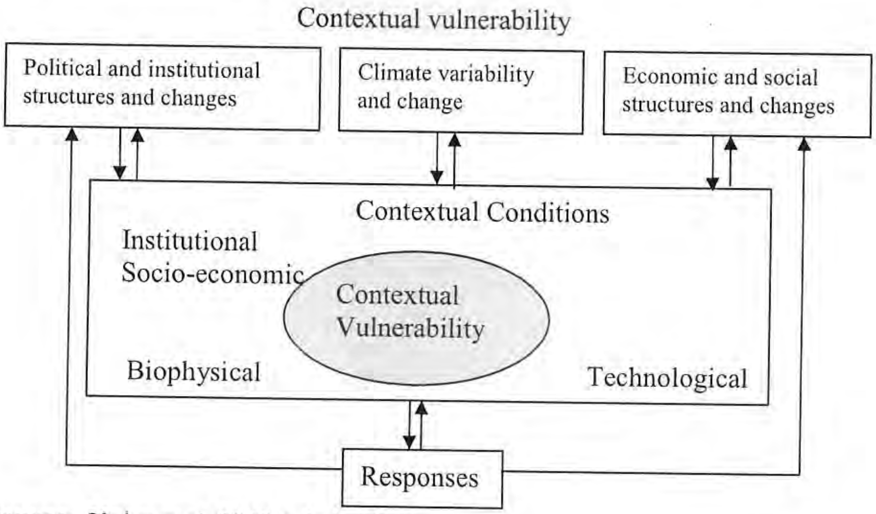
Source: Extracted from Fussel, 2006; Luk, 2011

The interpretations of the two theoretical frameworks presented above (Section 2.4.2.1 & 2.4.2.2) are summarized in table 2 above. The end-point vulnerability is linked with the biophysical vulnerability framework while the starting-point vulnerability characterizes the socio-economic vulnerability framework. These different interpretations of vulnerability do not only produce different rankings of vulnerable regions or systems; they also suggest different strategies for reducing vulnerability. End-point (outcome) studies tend to focus on technological adaptation for reducing particular impact of climate change while starting-point (contextual) studies tend to focus on sustainable development strategies that increase the response capacity of human populations for dealing with a large variety of hazards (Eriksen & Kelly, 2004; O'Brien et al., 2007). There is still a broad common framework by which both the starting-point and the end-point vulnerability perspectives can abide. The integrated framework provides the minimum requirements to define, summarize, and compare vulnerability research within the respective streams.

2.4.2.3. Integrated framework

Various lines of investigation show the inadequacies of biophysical and socio-economic frameworks. This recognition has led to the emergence of integrated vulnerability assessment framework, which draws a range of physical, biological and social science disciplines using a range of methods (Houghton, 2009). This framework is the most recent IPCC framework that is most prominent in global change and climate change studies (Fussel & Klein, 2005).

Figure 7: Integrated climate change vulnerability assessment



Source: Obrien et al. 2007 in Luk, 2011

Vulnerability, according to this framework consists of external and internal dimensions. The external dimension represents an exposure of a system to climate change and associated hazards and the internal dimension comprises sensitivity to climate change impacts and adaptive capacity of the system to reduce or offset negative impacts or exploit the potential opportunities (Fussel & Klein, 2005). This approach can combine socio-economic and biophysical factors by applying the methods and tools from diverse disciplines (Brooks, 2003; and Adger et al., 2004) because the two processes do not present themselves in well-defined boxes. Instead, they interconnect in all kinds of ways. Natural elements are not isolated from the social and economic environment that cannot be interpreted in terms of their impact on people without taking into account social and economic conditions (Luk, 2011).

In this regard, many scholars argue that vulnerability is the human and environmental context that shapes the ability to cope, or secure well-being in the face of climate variability and change (Turner II et al., 2003; Eriksen et al., 2004; Schroter et al., 2004; Gallopin, 2006). The hazard-of-place model (Cutter, 1996; Cutter et al., 2003), the coupled vulnerability framework (Turner II et al., 2003; Schroter et al., 2004) and vulnerability mapping approach (Morrow, 1999; O'Brien et al., 2004; O'Brien, 2007; Gbetibouo & Ringler, 2009; Heltberg & Bonch-Osmolovskiy, 2011) are good examples in combining socio-economic and biophysical indicators to decide on the systems' levels of vulnerability. According to the hazard-of-place model, geographic exposure and the social profile of communities in places influence the hazard potential. For example, Cutter et al. (2003) used this model to make a comparative analysis of social vulnerability to natural hazards among U.S. counties. The result identified distinct spatial patterns of vulnerability. Cutter (1996) argues that it is place that forms the fundamental unit of analysis for vulnerability.

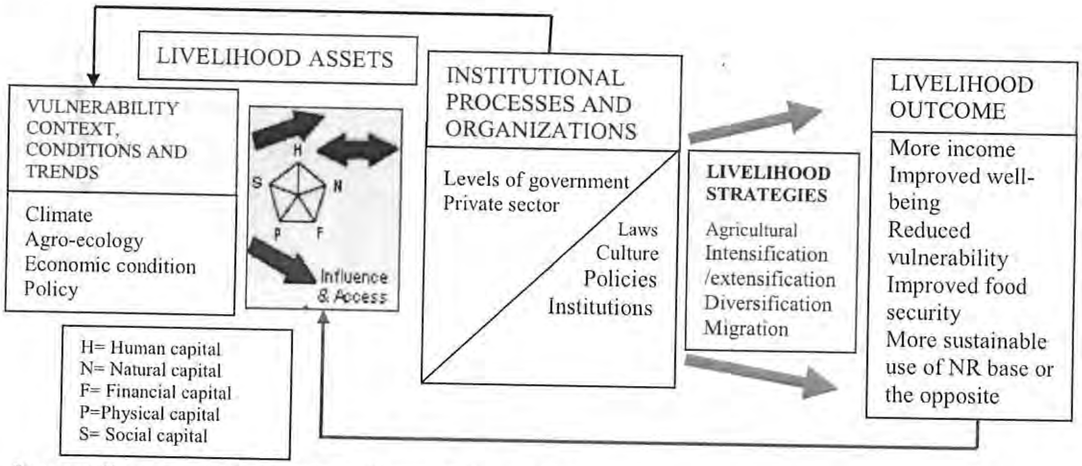
The view of environment–society coupled systems that specify the role of human adaptive responses is further developed in the vulnerability framework of Turner II et al. (2003). The architects of coupled vulnerability framework believe that vulnerability to climate change is the likelihood that a specific coupled human–environment system will experience harm from exposure to stresses, leading to adaptation to the impact in an integrated whole (Tuner II et al., 2003, Ericksen et al., 2004; Gallopin, 2006). Climate change vulnerability assessments include not only the analysis of vulnerability, but also the identification of specific adaptation options for reducing vulnerability. Climate change vulnerability assessment is directly linked with the aim of sustainable development and sustainability science, where scientific merit of the findings and policy advice are measures of successful research (Turner II et al., 2003; Schroter et al., 2004; Gallopin, 2009). Vulnerability mapping is a multidisciplinary framework for identifying, particularly vulnerable or critical regions. For example, O'Brien et al. (2004) in India; Heltberg and Bonch-Osmolovskiy (2011) in Tajikistan, and Gbetibouo and Ringler (2009) in South Africa identified most vulnerable areas and suggest that vulnerability within the country varies according to socio-economic and institutional development. Accordingly, this thesis used integrated vulnerability assessment approach guided with the sustainable livelihood framework discussed in detail in the next sub-sections.

2.4.3. An integrated framework of sustainable livelihood approach

This approach is included under the integrated vulnerability assessment framework by incorporating contexts, livelihoods assets, institutions, livelihood strategies, and livelihood outcomes. Theoretically, livelihoods connote the means, activities, entitlements and assets by which people make a living (Scoones, 1998; Elasha et al., 2005). The Brandt land Commission in 1987 introduced Sustainable Livelihood in terms of resource ownership and access to basic needs and livelihood security, especially in rural areas (Elasha et al., 2005). The sustainable livelihoods framework is concerned with people's capacities, assets, and activities to generate and support their means of living, enhance their well-being, and that of future generations (Lautze & Raven-Roberts, 2003).

Livelihood assessment is a way of looking at how an individual, a household, or a community behaves under specific conditions. One of the ways to understand livelihood systems is to analyze the adaptive strategies pursued by people and communities as a response to external shocks and stresses such as drought, flood, soil erosion, intensified storms and civil strife and policy failures. The approaches are useful for comprehensively analyzing the households' ability to withstand livelihood risks by capturing the issues of exposure, sensitivity and adaptive capacity (Chambers & Conway, 1992; Scoones, 1998).

Figure 8: Sustainable rural livelihood framework



Source: Scoones, 1998; Lautze& Raven-Roberts, 2003

Figure 8 presents the components of sustainable livelihood framework, such as vulnerability context, livelihood assets; institutional processes and organizations; livelihood strategies, and livelihood outcomes (vulnerability/sustainability). The detail of each component is discussed in the sections to come.

2.4.3.1. Vulnerability context, conditions and trends

Understanding the vulnerability context is fundamental to design appropriate interventions that have a positive effect on household livelihood security. The vulnerability context is usually considered the external dimension of a system in which poor people lead their lives people to achieve their livelihood objectives and adapt to climate change (Scoones, 1998; Degefa, 2005). While the physical capital consists of basic infrastructure and producer goods needed to secure the livelihoods. These physical assets include: access to transport, telecommunication, dwelling houses, energy, and access to markets to pursue households' livelihoods (Scoones, 1998; Ellis, 2000; Benson & Twigg, 2007). Infrastructure enables people to use knowledge and skills in their effort to attain secure livelihood and adapt to climate change (Temesgen, 2010). Social capital refers to networks of social groups within the society (Scoones, 1998). In pursuing different livelihood strategies, people, groups, communities and families draw from the resources available to them, through their association with others, social networks and relationships (kinship) and organizational affiliations (Barungi &Maonga, 2011). Adaptation is a social process that requires collective action, and social capital provide, such an opportunity. It enables the society to interact well with other capital assets and appropriate institutions (Adger, 2003).

2.4.3.3. Institutional processes and organization

Assets alone do not determine or delimit the nature of disaster vulnerability or the range of livelihood strategies that households pursue. Scholars have paid increasing attention to the compounding factors that generate vulnerability and complicate efforts to alleviate the consequences of public health threats, natural events, environmental stresses, and socio-political processes (Chambers and Conway, 1992; Scoones, 1998). Formal and informal processes, institutions and policies enable or hinder livelihood strategies, thereby generating or reducing vulnerabilities. All individuals and households live within, shape and are shaped by a set of informal and formal practices, norms and rules that constitute the institutional environment. As Lautze & Raven-Roberts (2003: 7) explained:

> These influencing factors play a key role in mediating access to resources, shaping the context of vulnerability, and setting opportunities or constraints to pursuing various livelihood strategies. Customary practices related to marriage, gender roles, inheritance, ownership, management of and access to resources (land, water) and 'real' markets all fall within the sphere of informal institutions. These are dynamic rather than fixed institutions, and are subject to continual re-negotiation and change according to context and power. Formal institutions relate to the role of the state, for instance in setting and enforcing laws, regulating markets or extracting taxes. There is a constant interplay between the informal and formal institutions.

Institutions are the humanly devised constraints that shape human interaction (North, 1990), which includes the laws, rules, regulations, policies, and services upheld by the state, private sector, civil-society organizations, and agencies. Organizations, on the other hand, refer to government agencies, NGOs, farmers' cooperatives and credit institutions serving the community. Both institutions and organizations can establish a stable structure to human interaction (North, 1990) and determine people's access to resources so that their adaptive capacity depends on the impact created by institutions on the milieu in which they live. Organizations provide extension, credit, and training services as well as diffuse policies thereby influence the rate of adoption of adaptation strategies (Madison, 2006). In addition, institutions can be vulnerable in times of disasters. Government ministries for the provision of social welfare (e.g., the Ministries of Health, Agriculture, or Education) are often drained of resources when governments redirect domestic budgets towards war efforts or when implementing structural adjustment programs. The Ethio-Eritrean war that coincided with the 1999/2000 crisis in Ethiopia reduced economic growth just by 1%, serves as an example (Lautze & Raven-Roberts, 2003).

2.4.3.4. Livelihood strategies

Sustainable livelihoods framework identified three main clusters of livelihood strategies: agricultural intensification/extensification, livelihood diversification and migration. These broadly cover the range of options open to rural people. Either people gain more livelihood from agriculture (crop production, livestock rearing, aquaculture, forestry, etc.) through the processes of intensification (more output per unit area through capital investment or increases in labor inputs) or extensification (more land under cultivation), or they may diversify to a range of off-farm income earning activities, or they move away and seek a livelihood, either temporarily or permanently, elsewhere. Otherwise, mostly, people pursue a combination of strategies together or in sequence (Scoones, 1998).

2.4.3.5. Livelihood outcomes: Sustainability vs. vulnerability

In the Sustainable Livelihoods approach, Livelihood outcomes include more income, increased well-being, reduced vulnerability, improved food security, and more sustainable use of natural resource base. For populations living in hazard-prone zones, these may be remote aspirations (Lautze & Raven-Roberts, 2003; Benson & Twigg, 2007). The actual outcomes of livelihood systems in complex emergencies include starvation, poor health, mortality, destitution, shame and/or displacement. These outcomes, in turn, are mediated back to households through society's policies, institutions and processes, a dynamic that translates these outcomes into assets, but more frequently as liabilities for households, for example, the financial burden of caring for the sick in the absence of functioning health systems, the cost (social, productive, financial) of mourning the dead, or the encumbering impacts of social disgrace (Lautze & Raven-Roberts, 2003) .

reducing welfare. Aggregate shocks are more important than idiosyncratic sources of risk, but households headed by an employed, educated male are less vulnerable to total shocks than are other households. VEP and VEU approaches measure vulnerability at the individual level; summing overall people or households gives a measure of total vulnerability. But this approach uses consumption, which may not show the overall vulnerability status of households as it is the result of a multitude of socio-economic and biophysical factors.

Vulnerability as uninsured exposure to risk (VER) is similar to VEP and VEU approaches in that its concern is assessing welfare losses in a world. The difference is that VER is an ex-post assessment of the extent to which a negative shock caused a welfare loss, not an ex-ante assessment of future poverty (Hoddinott & Quisumbing, 2008). This method assesses the impact of shocks by using panel data, to quantify the change as induced consumption. Skoufias & Quisumbing (2005) employed this approach to analyze the impact of shocks on Bangladesh, Ethiopia, Mali, Mexico, and Russia. All the case studies show that food consumption is better insured than non-food consumption from idiosyncratic shocks. Dercon (2004) using panel data from rural Ethiopia analyzed household consumption expenditures to various shocks, such as drought or idiosyncratic fluctuations in income. The results show that rainfall shocks have a greater impact on consumption, which persists for many years.

There are several weaknesses of the econometric methods. For example, estimates of impact, especially using cross-sectional data are often biased and thus inconclusive without panel data set. To make estimates using a single cross-sectional data, one must make a strong assumption that the cross-sectional variability captures the temporal variability (Hoddinott & Quisumbing, 2008) which may not always real. VER does not measure vulnerability because they do not construct probabilities; instead, they assess whether observed shocks generate welfare losses. It is the ex-post assessment of the extent to which a negative shock causes a household to deviate from expected welfare (Hoddinott & Quisumbing, 2008). Another important problem in using econometric methods is that they only rely on single or limited indicators like income or consumption. The concept of vulnerability is complex, which is difficult to measure using these limited indicators. In this regard, Moss et al. (2001) and Fussel (2009) argue that vulnerability assessment should merge several indicators rather than focusing on isolated traits.

2.4.4.2. Indicator method

Vulnerability is multidimensional and conceptually complex in measuring the potential effects of climate change. Scholars argue that to understand the environmental and the socio-

For example, the significance of rank correlation coefficients can check the degree of correlation between two components of vulnerability. Components-wise rankings can test the unanimity among the components in ranking the regions and components when we consider more than two components. Kendall's coefficients of concordance carry out this test (International Crops Research Institute for the Semi-Arid Tropics/ICRISAT, 2006).

The indicator method does not also account for the dynamism in vulnerability and adaptation as coping and adaptation are in a continual change of strategies to take advantage of opportunities (Cutter et al., 2003; Adger et al., 2004). As time passes, the relative importance of various indicators can change, external factors can come into force and political priorities may change (Sullivan et al., 2002). Despite the weaknesses, the use of indices as policy tools has become widespread for identifying vulnerable people, communities, regions, sectors and areas of adjustment needed for intervention (Sullivan et al., 2002; Temesgen, 2010). Therefore, this study adopted the indicator method framed with sustainable rural livelihood and the IPCC frameworks, the hazard-of-place model, and the livelihood vulnerability index.

2.4.4.3. An index approach to vulnerability study: Reflexive vs. formative models

There is a shift from more qualitative work to quantitative measures of vulnerability. This shift is due to advancement in vulnerability science and the need for empirically derived information to support the adaptation planning processes and the scientific support from IPCC for climate change policies (ICRISAT, 2006). Quantitative assessment of vulnerability is often done by constructing a vulnerability index based on several sets of indicators for identifying the vulnerable places and social groups. It produces a single number to compare different places (Adger et al., 2004; Eriksen & Kelly, 2004; Vincent, 2004; ECRISAT, 2006). Some literature on index construction argues that a good measure of the validity of the index is the internal correlation between the individual indicators used in the index. The relevance of this criterion, however, depends on the relationship between the indicators and the construct they measure. This depends on whether the index is based on a reflexive or a formative measurement model. In a reflexive model, the construct (index) is a measure of underlying construct which influences the indicators (Vincent, 2004; ICRISAT, 2006). For instance, a poverty index is a good example of reflexive measurement because poverty influences the indicators such as literacy, expenditure and so on and all these indicators correlate each other (ECRISAT, 2006).

In a formative measurement model, all the indicators have an impact on the construct. In the case of a vulnerability index, all the indicators have an impact on the vulnerability of the region to climate change. For example, the frequency of extreme weather events and distance to sources of a hazard, all contribute to the vulnerability of the region to climate change. Hence, vulnerability index is a formative measurement and the indicators chosen need not to have internal correlation (Vincent, 2004; ICRISAT, 2006). Different factors can influence a place or an individual positively or inversely, for instance, slope angle, soil degradation, literacy rates, and irrigation, but this need not necessarily correlated each other.

Although an index has many meanings in different disciplines (mathematics, economics, business and finance), for this study, it is a numerical scale calculated from a set of variables selected for all the agro-ecologies and used to compare them with one another or with some reference point (ICRISAT, 2006). That is, this numeric value is used to rank various component indicators and agro-ecological zones. Indices always lie from zero to one and sometimes expressed in percentage, which makes it easy to compare geographical entities and a range of indicators (Vincent, 2004; ICRISAT, 2006; Hahn et al., 2009).

During the past 30 years, a number of indices related to vulnerability, sustainability, and quality of life gained prominence in the literature. Among the well-known indices, which are regularly used for government policy include the consumer price index and the index of industrial output, both of which, measure some economic change over time. Environmental Vulnerability Index (Kaly et al., 1999); Environmental Sustainability Index, Human Development Index, Human Well-being Index, Human Poverty Index, and Water Poverty Index are composite indices which evaluate the performance of countries relative to each other, and over time (Sullivan et al., 2002).

Environmental Vulnerability Index (EVI) developed by the South Pacific Applied Geoscience Commission (SOPAC) is one of the earliest efforts to examine vulnerability to environmental changes (Kaly et al., 1999). It provides a measure of vulnerability for the environment which could be calculated on the scale of entire states of Fiji, Samoa, Tuvalu and Vanuatu. The EVI was initially developed for the purpose of ranking countries and providing a single-figure expression of their relative environmental vulnerabilities. Since 1990, the Human Development Index (HDI) has been prepared annually as part of the Human Development Report of the United Nations Development Program (UNDP, 2010). It consists of three equal weighted sub-indices, which are aggregated by an arithmetic mean: Life Expectancy Index, Education Index, and a Gross National Product (GNP) Index. The HDI has a strong focus on the social dimension of sustainable development (Vincent, 2004; ICRISAT, 2006). Easter (2000) constructed a vulnerability index for the commonwealth countries based on two principles. First, the impact of external shocks that are affecting the countries and second the resilience of the countries to withstand and recover from such shocks (ICRISAT, 2006). Moss and colleagues (2001) identified ten proxies for five sectors of climate sensitivities, which are settlement sensitivity, food security, human health, ecosystem and water availability and seven proxies for three sectors of coping and adaptive capacity, economic capacity, human resources and environmental resource capacity. Proxies were aggregated into sectoral indicators, sensitivity indicators and coping-adaptive capacity indicators and finally constructed vulnerability resilience indicators.

Vincent (2004) created an index to assess relative levels of social vulnerability to climate change induced variations in water availability and allow cross country comparison in Africa. An aggregated index of social vulnerability was formed through the weighted average of five composite sub-indices, which are economic well-being and stability, demographic structure, institutional stability and strength of public infrastructure, global inter-connectivity and dependence on natural resources. The Environmental Sustainability Index (ESI) quantifies the likelihood that a country will be able to preserve valuable natural resources effectively over the period of several decades (Esty et al., 2005). The ESI assesses the sustainability of 146 nations based on five core components: environmental system and stresses, human vulnerability to environmental stresses, social and institutional capacity, and global stewardship. The index uses 76 variables reduced to 21 sub-indices to create an overall vulnerability score by summing each sub-index and then taking the average of five components. For normalization, the standard deviation is calculated for each variable. The three aggregation steps consist of arithmetic means with equal weights.

The livelihood vulnerability index using hybrid indicators of sustainable livelihood and IPCC frameworks were calculated in two districts of Mozambique (Hahn et al., 2009) and Nepal (Lamichhane, 2010). In many literatures quantitative study of vulnerability is usually done by creating the vulnerability index based on several sets of indicators to produce a single number that can be used to compare different regions (Vincent, 2004; Hahn et al., 2009). Both primary and secondary data can be used to construct the livelihood vulnerability index so that it helps avoid the problems of relying on a single data source and dependence on climate models, which need advanced skill and are uncertain to give correct projections for local conditions (Hahn et al., 2009). Very few regional to sub-regional climate change scenarios or empirical downscaling have been constructed in Africa due to lack of climate data, human resources, and computational facilities (IPCC, 2007). In countries like Ethiopia, with diverse topography, regional climate projection likely mask differences in vulnerability among communities. Hahn et al. (2009) proclaimed that rather than structuring vulnerability assessment around climate projections, the LVI approach quantifies the current livelihood systems and community capacities to reduce the adverse effects of climate-related exposures. The LVI is designed to understand biophysical and socio-economic factors contributing to climate vulnerability at the different levels. It is designed flexibly so that future researchers can readjust their analyses to suit the needs of a specific geographic area. In addition to the overall composite index, sectoral vulnerability scores can be segregated to find most susceptible sectors and potential intervention areas (Hahn et al., 2009).

Construction of a vulnerability index consists of several steps: the choice of the study area, which consists of many regions, selecting a set of indicators, collecting data, standardization and calculating the composite indices for different regions (Vincent, 2004; ECRISAT, 2006; Hahn et al., 2009). Two approaches are found: the first expresses the LVI as a composite index consisted of major components (Hahn et al., 2009), which this study applied while the second aggregates the six components into the IPCC's three contributing factors to vulnerability—exposure, sensitivity, and adaptive capacity (Gbetibouo & Ringler, 2009; Heltberg & Bonch-Osmolovskiy, 2011). Again, there are two choices of analyzing vulnerability at any scale using the indicator-method. The first is the equal weighting method, assuming that all indicators have equal importance (Hahn et al., 2009). The second is the unequal weighting method assigning different weights to the indicators used. To make up weight differences of indicators many approaches have been suggested. Some of these methods include: use of expert judgment (Kaly et al., 1999; Vincent, 2004), principal component analysis (Cutter et al., 2003; Temesgen, 2010), correlation with the past events (Brooks et al., 2005) and employing fuzzy logic (Eakin & Bojorquez-Tapia, 2008).

2.5. Perception to climate change

Climate change has become a challenge which touches upon all spheres of life throughout the world in recent times and it will continue to be even more so in the decades to come. It is a new and a huge challenge to humanity. Ethiopia is one those countries that are or going to be severely affected by climate change, the solution of which partly depends on how its key rural households and local practitioners perceive the problem. Scientific evidences now abound about the inevitability of climate change and what measures should be taken to combat it. In spite of this, people of the world, from policy-makers down to the individual, are bogged down in an awkward of conflicting mindsets of urgency, disbelief, reservations or indecision about the extent of the threat and the responses to it. To fight against the problem, understanding the perceptions of all that have stake in it provides with stronger ground for decision-making process. For this reason perception research on climate change becomes extremely crucial (Yohannes, 2012). Referring to several scholars (e.g., Bordl et al., 1998; Leiserowitz, 2005), the same author argued that the likely response of the public to climate impacts and initiatives needs to be known because such responses can attenuate or amplify impacts. He also stresses that public risk perceptions can fundamentally compel or constrain political, economic and social action to address particular risks.

2.5.1. Concepts of perception to climate change

Perception is the process of attaining understanding the elements of the surrounding environment based on what is observed or thought-through physical sensation (Ramanov, 2009). In the case of climate change, it refers to whether farmers understand the changing temperature and rainfall patterns over time and respond to the negative impact through adaptation (Madison, 2006). Based on a study conducted in Switzerland Yohannes (2012) explained that most perceptions of climate change are simply based on human expectations (snow in winter, sunshine in summer) which are little related to observational evidence from instrumental records. Similar observation was reported in northern Ethiopia where divergence between perceptions and rainfall measurements can be associated with changes in peoples' need for rainfall. Reasoning out why perceptions are reduced to the level of everyday experience is pointed to the fact that direct perception of global change is impossible because the changes are too abstract to relate to everyday personal experiences as they have vast spatial and extended temporal scales. For this reason, people are more inclined to make judgments about climate change based on weather rather than on climate where the effects of the later are perceived to be sudden and severe (Yohannes, 2012). Short-term changes which come in the forms of weather extremes are mistakenly taken to be manifestations of climate change. For instance, extreme weather events in the UK, like the historical drought conditions of the 1930s and the 1990s have served as worst-case scenarios providing a 'better' basis for planning (Yohannes, 2012).

The reliance on short-term signs to interpret climate change is quite expected because weather events have greater association with the time horizon of people's everyday life rather than climate change which occurs on a longer time scale. Farmers may unable to accommodate the thought of a global climate change causing the gradual extinction of their agricultural commodities attached the incidence to spiritual dimension (Madison, 2006, Mentez et al, 2008). The traditional perception of risk would contrast the everyday inaccurate and irrational perceptions of people against the real scientific probability of risk (Prowse, 2003). Same author outlines three broad modes of perception of risk of hazards referring Smith (1996): determinate, dissonant, and probabilistic perceptions. Determinate perception refers to an understanding that seeks to impose order upon the random nature of risks and hazards, often by reference to an order or cycle of events. Dissonant perception basically threats denial of occurrence of hazard risks and questions past risks and hazards or rationalizes them as 'freak' events while probabilistic perception is closely connected to rational evaluation and random nature of risks and their potential consequences. This places responsibility of the threat to a higher authority such as God or government (Prowse, 2003).

People have different modes of understanding the risks, and such perceptions will change based on the experience of the individual, the social and cultural settings in which these perceptions are formed. In this sense, it should be recognized that risk perception, and assessment are grounded in the physical, social, and cultural environment. Moreover, there is a need to move away from just viewing perception of risks as being constrained solely by imperfect information, but to recognize the relationship between structure and agency, which can determine awareness and response to risk (Prowse, 2003). Climate change studies have recognized the importance of farmers' perceptions and risk management choices more recently (Smit & Skinner, 2002).

Perception is a prerequisite for adaptation (Madison, 2006; Temesgen et al., 2009; Temesgen, 2010). Perception researchers concluded that perception decides over resource allocation. Without perceiving the risk adequately, all other determents seem meaningless. They therefore saw perception as a precondition for adaptation (Falaki et al. (2013). Public responses have two predictors: accurate understanding of the process of climate change and the perception that the risks associated with the consequences of climate change are of a higher magnitude. Although both are vital predictors, it is the risk perception that to a greater extent influences the public support to or opposition to proposed climate policies than the level of awareness does. However, risk perception as a predictor of the public endorsement of proposed climate change actions should be put in a proper context. The spatial dimension or proximity; i.e. the role of place is critical in shaping such perceptions. That means, how close geographically the manifestations of climate change would be determines how the perceptions of risk are shaped (Yohannes, 2012). Many farmers in most of African countries, including Ethiopia have already perceived increasing temperature, decreasing rainfall, and changes in the timing and duration of rainfall consistent with the reports of Meteorological Services Agencies (Madison, 2006; Mentez et al., 2008; Gbetibouo, 2009; Temesgen et al., 2009; Temesgen, 2010).

2.5.2. Determinants of perception to climate change

Perception determines the social mental picture of climate change. A number of variables like socio-demographic and socio-economic factors or ideological orientations influence perception and the mental picture of climate change. It is highly criticized that previous research works are too much focused on financial, technical, or institutional constraints of perception and adaptive capacity. Although they agreed that systems with limited economic resources, low levels of technology, poor information, unstable or weak institutions, and inequitable empowerment and access to resources are limited when it comes to perception and adaptation to climate change (Falaki et al., 2013).

Yohannes (2012) referring to Kankaanpää et al. (2005) recognized two categories of stakeholders in the climate change perception research: those that are affected by climate change and those that are best positioned to advance adaptation to climate change impacts. He further mentioned some examples of research on climate change perception conducted on the first category of stakeholders: farmers in northern Ethiopia by Meze-Hausken (2004); in the Sahel by Mertz et al. (2009); arable food crop farmers in southwestern Nigeria by Apata et al. (2009) and wine growers in France, Germany and Italy by Battaglin et al. (2009); international tourists in Zanzibar by Gossling et al. (2006) and nature-based tourism entrepreneurs in Finland by Saarinen and Tervo (2006); households in America by Leiserowitz (2005), in rural areas in nine US states by Hamilton and Keim (2009) and Australia by Akter and Bennett (2009) and Portuguese university students by Lázaro et al. (2008). This study is focused on the stakeholders of the first type those that are affected by climate change.

Several empirical works indentified determinants of climate change perception of those that are affected by climate change and associated extreme events. Madison (2006) and Temesgen (2009, 2010) identified farming experience, education, farm income, non-farm income, information on climate, farmer-to-farmer extension, number of relatives in a village as the determinants of farmers' perception. Madison (2006) noted that farmers who have more experience, connection with experienced neighboring farmers, and access to climate information were in a better position to distinguish climate change.

2.6. Adaptation to climate change

The changes in climate alone will not determine the adverse effects of climate variability and change on human welfare and natural systems. The sensitivity and adaptability of the human system to climate change can also determine the impact. Adaptation is one of the fundamental response options to reduce the risks posed by anthropogenic climate change (IPCC, 2001; Klein, 2003; Fussel & Klein, 2005; Fussel, 2007).

2.6.1. The roots of the adaptation concept

Adaptation has existed since the beginning of human presence to minimize the adverse effects of environmental change and take the advantage of the likely opportunities. However, the anthropogenic climate change represents a new need (Smithers & Smit, 1997). The notion of adaptation has roots in physical sciences, namely population biology and evolutionary ecology (Smithers & Smit, 1997) focusing on the development of genetic or behavioral traits, which allow individual systems to cope with environmental changes, to ensure species survival (Smithers & Smit, 1997; Smit & Wandel, 2006). Ecological concepts like tolerance, stability, and resilience have been used to describe the propensity of biological systems to adapt to ecosystem changes (Holling, 1973).

The application of the term adaptation to human systems is traced to anthropology and cultural ecology described as the adjustment of culture cores to the natural environment (Smit et al., 2000; Smit & Wandel, 2006) concerned with the success, or the survival of a culture. Anthropologists and archaeologists suggest that adaptation is a consequence of selection acting on variation in practices, which have allowed a culture to survive. Cultural practices are, thus equated with genetic characteristics in the natural sciences. In this Darwinian view, 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 (Holling, 1973; Smit & Wandel, 2006).

Cultural adaptation referred to as a process of change in response to a change in the environment or in the internal stimuli, such as demography, economics, and organization, thereby human systems adapt beyond biophysical pressure (Smit & Wandel, 2006). Moreover, adaptive strategies are an integral element of development in that they provide societies with the ability to manage not only environmental variability, but also perturbations in social, economic, and political variables. This implies that adaptation paradigm has a wide application in the social sciences in the context of human-environment interaction (Smithers & Smit, 1997; Schipper, 2004). An important distinction between the biophysical and human systems is that humans possess the ability to plan and manage adaptation. While the responses of biological systems to perturbations are entirely reactive, the responses of human systems are both reactive and proactive by incorporating environmental perception and risk evaluation. Furthermore, human systems may adjust in pursuit of goals other than mere species survival, for example, to enhance quality of life or to exploit perceived opportunities (Smithers & Smit, 1997).

The adaptation paradigms are visible in many scholarly fields, including human and cultural ecology, natural hazards research, ecological anthropology, political ecology, cultural geography, ecological economics, the entitlements and food security researches, and more recently, climate impact research. Applications in these various fields of inquiry have led to some distinct interpretations of the concept of adaptation. For example, some models of cultural adaptation focus on the communal behavior of systems, while others give emphasis to the role of individuals as decision-makers (Smithers & Smit, 1997). Still some other scholars have employed the concepts of ecological change with a focus on flows of matter, energy and information and related concepts of resilience, equilibrium and adaptive management. Others, in the natural hazards perspective, have focused on perception, adjustment and management of environmental hazards (Smit & Wandel, 2006). Recently its concept has been linked to climate change adaptation (Fussel, 2007b; IPCC, 2007).

In the context of the human dimension of global change, adaptation usually refers to a process, action or outcome in a system (household, community, sector, region, country, and world) in order for the system to cope with, manage, or adjust to some changing condition, stress, hazard, risk or opportunity (Smit & Wandel, 2006). Watson and colleagues (1997) define adaptability as the degree to which adjustments are possible in practice, process, or structure of systems to projected or actual change of climate. It can be spontaneous or planned, and carried out in response to, or in anticipation of changes in climate. This definition is almost similar to the definitions given by Smit et al. (2000:225), which states adaptation as "adjustments in ecological-socio-economic systems against actual or expected climatic stimuli, their effects, or impact". These definitions have touched all forms of adaptation such as spontaneous, planned, reactive, and proactive.

Pielke (1998: 159) defines adaptations as the "adjustments in individual, groups and institutional behavior in order to reduce society's vulnerability to climate change.'' Brooks (2003:8) describes adaptation as ''adjustments in a system's behavior and characteristics that enhance its ability to cope with external stresses.'' Fussel and Klein (2005) define adaptation as actions targeted at the vulnerable system in response to actual or expected climatic stimuli with the objective of moderating harm and/or exploiting opportunities from climate change. The Canadian National Assessment defines adaptation slightly in different ways that adaptation is making adjustments in decisions, activities and thinking because of observed or anticipated changes in climate, in order to moderate harm or take advantage of new opportunities. These definitions are very similar to that for disaster risk reduction, although limited to climate-related hazards (McBean & Rodgers, 2010).

All the stated theoretical explanations have much in common. They all refer to adjustments in a system in response to climatic stimuli and indicate differences in scope, application, and interpretation of the term adaptation. For instance, the question 'adapt to what?' is answered in different ways. It can refer to climate change and variation, or just to climate and environment. It can be in response to adverse effects of hazards or vulnerabilities, but it can also be exploiting positive opportunities. It can be in response to the past, actual, or anticipated conditions, changes or opportunities (Smit et al., 2000). There are also differences in how the definitions relate to the question "who or what adapts?" It can be people, social groups, economic sectors and activities, natural or ecological systems, practices, processes, or structures of the systems. The nature of adaptation and its effects will vary not only according to whether the object is physical or socio-economic, small or large scale, single sector/species or complex system, but also according to the properties that relate to the adaptation propensity such as adaptability, vulnerability, viability, sensitivity, susceptibility, resilience and flexibility (Smit et al., 2000).

2.6.2. Typology of climate change adaptation

Potential adaptation options to reduce the negative impact of climate change, or exploit the positive opportunities to places or sectors were highlighted. About 228 different adaptation measures, whether they are passive, reactive, anticipatory, planned or autonomous, were identified by IPCC (2001). There are various ways to classify adaptation options.

Depending on their timing, goal, and motive of implementation, Smit (1999) and Klein (2003) classified adaptation strategies as reactive and proactive. Reactive (ex-post) adaptation takes place after impacts of climate change have been observed. Provision of emergency assistance (relief) to flood victims and drought affected people (share losses) and measures to rehabilitate and reconstruct the damaged property and communities are part of this adaptation process (UNEP, 1998). Reactive adaptation is informed by direct experience; hence, resources can be allocated to known risks. In this sense, adaptation historically has been largely, but not entirely reactive (Burton et al., 2006). On the contrary, proactive (anticipatory) adaptation takes place before the impact of climate change is observed. Proactive adaptation, unlike reactive adaptation, is forward-looking and takes into account the inherent uncertainties associated with anticipating change. This means, it aims to reduce

2003; Burton et al., 2006). Others are public adaptations, which are initiated and implemented by the governments on the behalf of society at all levels usually directed at collective needs, sometimes in anticipation of climate change and often in response to human and non-human populations (Adger, 2003; Burton et al., 2006). Thus, autonomous and planned adaptations largely correspond to private and public adaptation respectively.

Autonomous adaptation is the base for evaluating the need for planned anticipatory adaptation (Klein, 2003). Although there is a considerable faith to enhance the capacity of private systems for autonomous adaptation, limited information, lack of knowledge, and low access to resources has shifted the emphasis towards anticipatory planned adaptation (Klein, 2003). Article 3.3 of the UNFCCC suggests that anticipatory planned adaptation (as well as mitigation) deserves particular attention from the international climate change community:

> The Parties should take precautionary measures to anticipate, prevent or minimize the causes of climate change and mitigate its adverse effects. Where there are threats of serious or irreversible damage, lack of full scientific certainty should not be used as a reason for postponing such measures, taking into account that policies and measures to deal with climate change should be cost-effective so as to ensure global benefits at the lowest possible cost (Klein, 2003:4).

Five generic objectives of anticipatory adaptation are identified (Klein, 2003): (1) increasing robustness of infrastructural designs and long-term investments; (2) increasing flexibility of vulnerable systems through allowing mid-term adjustments, change of activities or location, and/or reducing economic lifetimes, including increasing depreciation; (3) enhancing adaptability of vulnerable natural systems by reducing non-climatic stresses and/or removing barriers to migration; (4) reversing trends that increase vulnerability (maladaptation) by introducing setbacks for development in susceptible areas such as flood plains and coastal zones; (5) improving societal awareness and preparedness by informing the public of the risks and possible consequences of climate change and/or setting up early-warning systems.

UNEP (1998) and McBean & Rodgers (2010) classified adaptation measures discussed above into the following generic options or common categories.

1. ***Bear losses and/or share the losses***. Bear loss refers to the response of doing nothing, except accepting the losses when the affected groups have no capacity to respond or where the costs of adaptation measures are very high in relation to the risk or the expected damages (UNEP, 1998). In many less-developed societies, there may be no option other than to bear the loss and try to continue (McBeans & Rodgers, 2010). This category may not be applicable in the real situations as societies can take at least one action at times of climatic

disaster. Sharing the losses involves among a wider community both in traditional and advanced societies. In conventional societies, losses have been shared through extended families in villages and small-scale community assistance at the local level (autonomous adaptation). On the other hand, in more developed societies with additional resources sharing the losses could be through relief, rehabilitation, and reconstruction paid from public funds. Insurance, either through government or private insurance companies, is another way of sharing loses (UNEP, 1998; McBeans & Rodgers, 2010). This adaptation option can be categorized as planned adaptation and mostly falls in the reactive adjustment.

2. Modify the threat and/or prevent the effects: these are actions that provide adaptation benefits by exercising a control over some environmental threats such as drought and floods through possible measures like flood control works (dams, dikes, levees), soil conservation structures and planting trees to modify the threat or prevent the effects over the low-lying coastal areas (UNEP, 1998; McBeans & Rodgers, 2010). Reducing evaporation from ponds through improved shading, and mulching on nursery sites and so forth can also modify the threat or prevent the effects (McBeans & Rodgers, 2010). This can be either reactive or proactive adaptation based on the time of intervention; or planned or autonomous, private or public. If the intervention is after the occurrence of a flood, it can be reactive and if the work is done in anticipating future occurrence, it can be proactive. In agriculture, changing crop management practices such as increased irrigation water, fertilizer use, and pest and disease control can prevent the effects of climate variability or change. For climate change, the major modification possibility is to slow the rate of climate change by mitigation (McBeans & Rodgers, 2010). This category is related to agricultural technology adoption and institutional capacity. The establishment of early-warning systems for flooding or heat waves, or introduction of heat-or drought-resistant crop varieties can also be typical examples (UNEP, 1998; McBeans & Rodgers, 2010).

3. Change use and/or location: these actions are undertaken when the threat of climate change makes the continuation of a given activity impossible or put in the extremely risky situation. For example, crop land could be used to shift to a variety of crops or the crops being threatened could be grown in different locations. A farmer may be able to shift crops to livestock or vice-versa that is better suited to changing climatic conditions. Similarly, crop land may be returned to pasture or forest or other uses may be found such as recreation, wildlife refuges, or national parks (UNEP, 1998; McBean & Rodgers, 2010). Changing location is the most extreme response, for example, relocating major crops and farming regions away from areas of increased aridity and heat to areas that are currently cooler and

Table 3: Characteristics of mitigation and adaptation

Criteria	Mitigation of climate change	Adaptation to climate change
Benefited system	All system	Selected system
Scale of effect	Global	Local to regional
Lifetime	Centuries	Years to centuries
Lead time	Decades	Immediate to decades
Effectiveness	Certain	Generally less certain
Ancillary benefits	Sometimes	Mostly
Polluter pays	Typically yes	Not necessarily
Payer benefits	Only little	Almost fully
Monitoring	Relatively easy	More difficult

Source: Fussel and Klein, 2005

Three schools of thought exist in regard to the adoption of mitigation and adaptation responses to climate change. These thoughts include: preventionist or limitationist, adaptationist, and realist views. Klein (2003) noted the reason for the limited attention to adaptation lies in the existence of two distinct schools of thought (preventionist and adaptationist) about climate change. Preventionist school acknowledges the catastrophic effects of on-going concentrations of atmospheric GHGs and the need for actions to reduce emissions as a vital response (Schipper, 2004; Klein et al., 2005). This paradigm strongly supports the mitigation policy of climate change. The justifications have been: First, mitigating climate change helps reduce the impacts on all climate-sensitive systems, whereas the potential of adaptation measures is limited for many systems. Second, reducing GHG emissions applies the polluter-pays principle, whereas the need for adaptation will be greatest in developing countries, which have quite little contribution to climate change. Third, GHG emission reductions are relatively easy to monitor quantitatively, both in amount and deviation from an established baseline. However, it is more difficult to measure the effectiveness of adaptation in terms of impact avoided, or to ensure that international assistance to facilitate adaptation would be fully additional to existing development aid budgets (Fussel & Klein, 2005).

The adaptationist school supported neither adaptation nor mitigation. Proponents argue that natural and human systems have a long history of adapting naturally to changing circumstances and that active adaptation would constitute interference with these systems, bring high social costs (Klein, 2003). This view signified the 'invisible hand' of either natural selection, or market forces that will ensure adaptation without the need for policy intervention. Scholars argue that both the limitationist and adaptationist views discourage research on adaptation (Klein, 2003; Schipper, 2004).

The third paradigm has been labeled as realist school emerged following the publication of the IPCC Second Assessment Report. The realist school positions itself in between the two extreme views of the preventionists and adaptationists. Realists considered climate change as a fact, acknowledged uncertainty of impact, and considered adaptation as a realistic response option together with mitigation (Pielke, 1998; Fussel, Klein, 2005). Moreover, realists realize that the planning and implementation of effective adaptation options take time and know that a process must be set to consider adaptation as a crucial response option along with mitigation (Pielke, 1998). Klein (2003) argues that the emerging policy responses, such as the funds created by the Marakash Accords to finance adaptation, reflect the realist view. Scholars view these Accords as the most balanced and precautious approach that recognizes the vulnerability and lack of capacity of developing countries to adapt to climate change that is ignored by other two extreme views (Schipper, 2004). Today, the two response options to climate change in the policy highlights are mitigation and adaptation.

2.6.3. Adaptation in the context of UNFCCC

Since the IPCC confirmed that humans are, at least in part, responsible for climate change and that some impacts can no longer be avoided, academic and policy attention has increased sharply for adaptation (Klein et al., 2005; Burton, 2009). The role of adaptation is intricately linked with non-climatic developments and takes place in a dynamic societal context, in which several actors pursue different interests (Klein, 2003; Klein et al., 2005). There are convincing arguments for a more comprehensive consideration of adaptation as a response measure to climate change. First, anthropogenic GHG emissions are already affecting average climate conditions and climate extremes, which can no longer be prevented even by the most ambitious emission reductions (Fussel & Klein, 2005; Fussel, 2007b). Second, climate will continue to change for the foreseeable future as a result of accumulation of GHGs emitted in the past and the rate of global warming in the next decades is projected to be faster than in the last decades (IPCC, 2007). Third, the effect of emission reductions takes several decades to manifest fully, whereas most adaptation measures have more immediate benefits. Fourth, adaptations can be effectively implemented on a local or regional scale, whereas mitigation requires international cooperation, so that the efficacy is dependent on the actions of others. Fifth, most adaptations to climate change also reduce the risks associated with present climate variability, which is a ruthless hazard in many regions (Smit et al., 1999; Fussel & Klein, 2005). Finally, many measures undertaken to adapt to climate change have important ancillary benefits for reducing current climate-sensitive risks (Fussel, 2007b).

From an international policy point of view, the importance of adaptation was first confirmed at the third conference of the Parties (COP-3, 1997) to the United Nations Framework Convention on Climate Change (UNFCCC) in Kyoto (Klein. 2003). The UNFCCC plays an important catalytic role in promoting the development of adaptation strategies and plans. For it, cooperation is a strong theme linked to the preparation for adaptation, research and observation, training, education and public awareness (UNFCCC, 2007; McBean & Rodgers, 2010). Parties to the UNFCCC have all agreed to undertake national adaptation measures and cooperate in preparing for the impact of climate change (UNFCCC, 2007). Article 4.1b of the UNFCCC states that: "Parties are committed to formulate and implement national and, where appropriate, regional programs containing measures to mitigate climate change and to facilitate adequate adaptation to climate change." In addition, the financing of adaptation measures is addressed in Article 4.3, which states that: "The developed country Parties and other developed parties included in Annex II shall provide new and additional financial resources needed by the developing country parties to meet the agreed full incremental costs of implementing measures" (UNFCCC, 2007:11). For developing countries that are particularly vulnerable, Article 4.4 of the UNFCCC contains another, more explicit, commitment to financing adaptation measures (UNFCCC, 2007:11): "The developed country Parties and other developed parties included in Annex II shall also assist the developing country Parties that are particularly vulnerable to the adverse effects of climate change in meeting costs of adaptation to those adverse effects."

The Kyoto Protocol (Article 10 & 12) further entrusts parties to promote and facilitate adaptation, and deploy adaptation technologies to address climate change (UNFCCC, 2007). The Kyoto Protocol defines a Clean Development Mechanism (CDM) that explicitly mentions adaptation as an expenditure goal. At the fourth conference of parties (COP-4) in Buenos Aires (1998) governments decided that funding could be made available to developing countries for preparatory (Stage II) adaptation activities. At COP-5 (Bonn 1999) and COP-6 (The Hague, 2000) governments discussed how the CDM and the decision passed at COP-4 could be made operational. The initial failure at COP-6 to reach agreement among parties on the implementation of the Kyoto Protocol and the functioning of the CDM seemed likely to delay its implementation and thereby the availability of adaptation funding from this source. However, the COP-7 in Marrakech (2001) further developed the adaptation agenda expressed to the increasing need for it.

Agreement was reached on the establishment of three funds in the COP-7 Marakash from which adaptation activities in developing countries can be financed (Klein, 2003; Fussel &

Klein, 2005). These are: Special Climate Change Fund, Least Developed Countries Fund, and Adaptation Fund. The first two of these funds would require additional funding from Annex II Parties via the Global Environmental Facility (GEF) whilst in accordance with Article 12.8 of the Kyoto Protocol the Adaptation Fund would be financed from the share of proceeds on the CDM (Klein, 2003; UNFCCC, 2007). The Least Developed Countries Fund (LDCF) was established to address: the low adaptive capacity of the LDCs; preparation of National Adaptation Programs of Action (NAPA); and support institutional capacity building, in which LDCs can communicate priority activities addressing their urgent needs and concerns relating to adaptation to climate change. As stated in Decision 28/CP.7:

> The rationale for developing NAPAs rests on the low adaptive capacity of LDCs, which renders them in need of immediate and urgent support to start adapting to current and projected adverse effects of climate change. Activities proposed through NAPAs would be those whose further delay could increase vulnerability or lead to increased costs at a later stage (Klein, 2003:5).

In 2002, the World Summit on Sustainable Development adopted a Summit Plan of Implementation as part of the strategy to meet the Millennium Development Goals. The plan connected international development with climate change and natural hazards: 'An integrated, multi-hazard, inclusive approach to address vulnerability, risk assessment and disaster management, including prevention, mitigation, preparedness, response and recovery, is an essential element of a safer world in the twenty-first century.' The Summit called for actions to improve the methodologies for assessing the effects of climate change and strengthening of disaster management systems (McBean & Rodgers, 2010). In order to address these problems, the International Strategy for Disaster Reduction (ISDR) was created to follow and build upon the United Nations International Decade for Disaster Reduction (UNISDR). Additionally, the 2005 World Conference on Disaster Reduction led to the Hyogo Framework for Action which called for actions to strengthen the technical and scientific capacity as well as disaster preparedness for the effective response at all levels. In 2007, the UNISDR Global Platform on Disaster Risk Reduction noted that a core challenge in disaster risk reduction is to scale up proven practices making clear the importance of capacity building of all types (McBen & Rodgers, 2010).

Finally, the 2007 Bali Action Plan gave emphasis on enhanced action on adaptation by linking disaster risk reduction and climate change adaptation. The need for integrated approaches to coping with hazards in the context of climate change and international development was made clear. To realize this linkage, the IPCC is preparing a Special Report on Managing the Risks of Extreme Events and Disasters to Advance Climate Change

Adaptation, which is expected to bring a scientific focus to bear on the linkages between the two issues (Klein, 2003; McBean & Rodgers, 2010).

In response to what many perceived to be a failure to address a major source of global GHG emissions, the Coalition for Rainforest Nations (CfRN) was established and in 2005 they proposed to the Conference of the Parties to the UNFCCC a mechanism for considering the emission reduction stemming from tropical deforestation as a climate change mitigation measure [McBen & Rodgers, 2010; Agrawal et al., 2011; http://reddplussafeguards.com/]. Therefore, reducing emissions from deforestation and forest degradation (REDD) became part of the ever-expanding climate change agenda hoping it is an effective mechanism for reducing emissions that has been a key goal of current UNFCC's climate negotiation for limiting future climate change (Agrawal et al., 2011). COP 11 entered the request to consider the REDD as agenda item 6: Reducing emissions from deforestation in developing countries: approaches to stimulate action. The United States challenged the proposal but failed in its attempts. REDD received substantial attention from the UNFCCC and the attending community at 2007 COP 13, where the first substantial decision on REDD+ was adopted. More interestingly, REDD+ was also included in decision of the Bali Action Plan with reference to all eligible activities of REDD+ (Agrawal et al., 2011).

On the eve of the Copenhagen Conference, in the New York climate change summit, the UN Secretary General made pointed very strongly on the delay of planned actions by reminding world leaders that 'the world's glaciers are melting faster than the climate negotiations'. Since the UNFCCC entered into force in 1994, the signatories' conference of parties held 16 annual meetings where no legally binding emission-reduction deals were sealed (Yohannes, 2012). Thus, an increasing interest has grown to adaptation as reflected much in the development of climate-change assessment, increasing consideration by governments and organizations to design different adaptation projects, and an attempt to search for resources to finance adaptation (Smit et al., 2000; Fussel, 2008; World Bank, 2008).

The failure of international negotiations to finalize a new climate treaty in Copenhagen in 2009, combined with blocked legislative processes in the United States, Canada, and Australia that would have created a large demand for REDD+ offsets, greatly diminished the prospects of a near-term, unified global mechanism for REDD+ financing. In spite of positive developments at the sixteenth Conference of Parties (COP) in December 2010 in Cancun, progress on REDD+is likely to occur through complex, fragmented pathways of international assistance, bilateral and multilateral agreements, and civil society and market-based processes. The only near-term regulatory framework for REDD+ financing is the one under development between tropical states and provinces and the government of California (Agrawal et al., 2011).

2.7. Reviews on methodological and empirical results of adaptation

2.7.1. Approaches of adaptation assessment

Two adaptation assessment approaches namely, top-down and bottom-up assessment approaches have been identified from the literature. Research on the interaction of climate change and agrarian communities has evolved from a top-down to a bottom-up approach. The top-down mode starts with climate change scenarios, and estimates impact through scenario analysis, based on which possible adaptation practices are identified (Gbetibouo, 2009). In this, scenario-based approach, adaptations are assumed and are invariably treated as primarily technical adjustments to the impact. Most of these adaptations represent possible or potential measures, rather than those that have actually been adopted (Gbetibouo, 2009). This approach can be found in spatial analysis, climate impact modeling, and Ricardian studies. Most studies carried out in Ethiopia and Africa using top-down approach predicted the impact of climate change on the agricultural sector with adverse effects on crop yields, which would become unsuitable for the production of main staple crops (NMA, 2001; 2007; Segel & Lamb, 2005; Temesegn. 2010; You & Ringler, 2010).

The bottom-up approach takes a vulnerability perspective where adaptation strategies are considered more as a process involving the socio-economic and policy environments, farmers' perceptions, and elements of decision-making (Gbetibouo, 2009). Vulnerability studies have shifted their focus from impact estimation to the understanding of grass-root-level assessments of vulnerability, adaptation, and decision-making processes (Gbetibouo, 2009). In line with this notion, Schroter et al. (2004) argue that choosing adaptation options to climate change and developing policies to implement these options the affected community should actively participate.

Other studies argue that this type of assessment explores the actual adaptation behavior by analyzing farmers' decisions in different contexts through survey data, in-depth interviews, and focus group discussions with farmers, and experts (Smit et al., 2000; Madison, 2006; Gbetibouo, 2009). These studies have raised new research questions as to how farmers perceive climate change; identify climatic properties for making decisions, and suggest the types of anticipated adaptive responses (Gbetibouo, 2009). One important issue in agronomic adaptation is the way farmers update their expectations of the climate in response to unusual most common adaptation methods used by almost all countries were planting soil conservation, using manure, irrigation, rainwater harvesting, change planting dates (proactive) and replanting (reactive) to modify the threat/prevent the effect; planting different crop varieties, changing crop variety, engaging in non-farm activities (prevent the effect – proactive or reactive), migration (Change location), change farming type (from crop to livestock and vice-versa) - change use, and adoption of new technologies (modify the threat/prevent the effect). Different planting dates are important adaptation practices in Egypt, Kenya and Senegal. Adopting a shorter growing crop variety is practiced in Senegal. In Egypt, the majority of respondents have practiced non-farm activities while in Egypt, Kenya and South Africa, large numbers of farmers have used irrigation. There is increasing use of water conservation in Burkina Faso, Kenya and Niger. In Burkina Faso, Kenya, Senegal and Niger, soil conservations are largely practiced. Shading and sheltering was largely used in Burkina Faso, Niger and Senegal by a third of respondents. Increased use of weather insurance is almost exclusive to Egypt (Madison, 2006). Prayer and ritual offerings are also made in Senegal and Niger. Every Egyptian and every Ethiopian respondent claimed to have made at least one adaptation strategy, which contradicts to other studies (Yesuf et al., 2008; Temesgen, 2010).

Temesgen and colleagues (2008) indicated that use of irrigation was reported only by 5% of the respondents in the Blue Nile Basin of Ethiopia. Same authors and Yesuf et al. (2008) indicate that about 42 and 49.4% of surveyed households did not employ any adaptation methods in the Blue Nile Basin respectively. Most of these adaptation strategies are planned proactive and some are reactive while others can be autonomous. Public and private adaptation strategies are also practiced by farming households. The review on the empirical results of adaptation is also crucial for incorporating adaptation strategies in the conceptual framework presented in Figure 1 and in table 6. Appropriate survey questions for binary logistic regression were also prepared based on the identified adaptation strategies.

2.7.3. Determinants of adaptation to climate change

Studies identified different determinants of adaptation usage. The major ones are: gender, age, farming experience, educational attainment, wealth status, farm income, access to technology, poverty, environmental awareness, farm size, tenure status, access to extension services, market access, credit availability, climatic conditions, topographic features, information on climate change and adaptation options, family size, labor force, and access to water (Burton et al., 2006; NMA, 2007; Ghebetibouo, 2009).

technology. Third, social networks can facilitate cooperation to overcome collective action dilemmas, where the adoption of technologies involves externalities. Some studies show that participatory social affiliations act as forms of social capital in the decision to adopt fertilizer (Isham, 2002; cited in Temesgen et al., 2008). Yesuf and colleagues (2008) argue that households with good access to farmer-to-farmer extension tend to apply adaptation measures on their farms in comparison with those households that do not have this access. Hence, this study hypothesizes that social capital positively influences adopting adaptation measures to offset climate change impact.

Distance to output and input markets have negative relationships with adaptation to climate change. Proximity to market is an important determinant of adaptation, most probably because the market serves as a means of acquiring inputs for adaptation and exchanging information with other farmers (Madison, 2006). There is also significant difference in the likelihood of households' employing climate change adaptation strategies across different agro-ecologies. They found that households in *dega* and *Woyna dega* were less likely to take climate change adaptation measures than being households in *kola* (Yesuf et al., 2008). It is also hypothesized that different households living in different agro-ecological settings use varied adaptation methods. This is because climatic conditions, soil, and other factors vary across agro-ecologies, influencing farmers' perceptions of climate change and their decisions to adapt. Access to water increases the likelihood of adopting adaptation measures. However, financial resources constrain farmers for accessing the necessary technologies. Thus, poor farmers cannot afford to invest in irrigation technologies for adaptation, or sustain their livelihoods during drought seasons.

Perception of climate change increase or decrease the likelihood of adopting different adaptation measures depending on the adaptation type. Households living in areas with higher annual mean temperature were more likely to adapt to climate change. Higher annual mean temperature increases the likelihood of using different crop varieties, changing planting dates, and irrigation. Similarly, decreased precipitation increase the likelihood of using soil conservation methods, changing crop variety, changing planting dates, irrigating (Temesgen et al., 2010), water harvesting, and tapping underground water.

All the aforementioned adaptation strategies and determinants of adaptation were the bases for selecting the logistic regression (one of the econometric methods), computational method of composite index of adoption for both methods of analysis suitable dependent and independent variables presented in Table 6 were identified and operationalized.

CHAPTER THREE
RESEARCH METHODOLOGY

As already discussed in chapter one, this study was designed to assess the vulnerability levels, perceptions and adaptation strategies of rural households to the likely impact of climate change in the three agro-ecologies of northwest Ethiopia. The study did so using integrated vulnerability framework of sustainable rural livelihood approach (SLA). The overall framework and the research methods that are appropriate to conduct comparative analysis using these elements across the three agro-ecological zones were selected. Therefore, this chapter discusses the research methods and procedures employed in this thesis by organizing it under five sections: research design and approaches, site selection and description, sample size determination, data sources and data collection tools, and methods of quantitative and qualitative data analysis.

3.1. Research approach and design

Chapter Two indicated that numerous disciplines address the study of vulnerability and human adjustment to climate variability and change. This thesis is based on an interdisciplinary approach to explore global climate change and as such the research does not emerge from any single discipline. While a mono-disciplinary approach allows statistical tests within a known and confined spectrum of theories, climate change cannot be pigeonhold as either a natural or social science issue. Its study therefore requires an inherently interdisciplinary approach (Schipper, 2004). The reason is mainly attributed to the fact that climate change is a complex problem interacting with a range of natural and socio-economic processes (Schipper, 2004; Adger et al., 2009). As presented in the preceding chapters, the thesis approached the vulnerability of households to climate change in the less developed areas with awareness that such a study requires both an examination of biophysical and socio-economic indicators and climatic hazards. From this we can understand that the study of vulnerability and adaptation to climate change requires different approaches derived from numerous disciplines so as to attain a holistic understanding of the different dimensions of the problem (Schipper, 2004; Hahn et al., 2009; Temesgen, 2010; Luk, 2011).

Conducting research is more than engaging in the major steps in the process of research including designing and writing the research in one of the three major tracks: quantitative research or qualitative research or mixed research. The way that this unfolds is illustrated in the flow of the research process as shown in Figure 9 based on Creswell (2012). Based on the data or computational techniques. The objective of quantitative research is to develop and employ mathematical models, theories and/or hypotheses pertaining to the phenomena under consideration. The process of measurement is central to quantitative research because it provides the fundamental connection between empirical observation and mathematical expression of quantitative relationships (Adger et al., 2003; Raune, 2005; Molg et al., 2009).

Qualitative research is a method of investigation employed in many different disciplines, traditionally in the social sciences, in market research and other contexts. Qualitative research aims to an in-depth understanding of the phenomena/process and the reasons that govern such phenomena/process. The qualitative method investigates the 'why' and 'how' questions, not just 'what', 'where', 'when' (Johnson & Onwuegbuzie, 2004; Raune, 2005; Creswell, 2012). Hence, smaller but focused samples are more often used than large samples. That is, qualitative methods produce information only on the particular cases studied, and any more general conclusions are only propositions (Creswell, 2012).

Mixed research approach is the third wave that moves the past paradigm wars by offering a logical and practical alternatives (Johnson & Onwuegbuzie, 2004). The pragmatic approach enables to select various methods and ways of explanation; to improve communication among researchers from a range of paradigms; and to mix different approaches for answering important research questions. However, its goal is not to replace either quantitative or qualitative approaches, but rather to draw lessons from the strengths and minimize the weaknesses of each method. Qualitative research anchored at one pole and quantitative research anchored at the other, mixed methods research is in the middle area which sits in a new third chair. The use of quantitative research method has the potential of covering many subjects to enable generalization and to address various indicators (Johnson & Onwuegbuzie, 2004; Raune, 2005). In this case, quantitative method was used to analyze biophysical contexts such as meteorological records, hazard frequencies, vulnerability indicators, and predictor variables on adaptation.

The qualitative methods corroborate the quantitative method and enable to get in-depth information about the opinions and perspectives of respondents articulated in their own words (Adger et al., 2003; Raune, 2005). Qualitative research method was employed to examine farmers' perceptions and interpretations of their experiences in the context of their lives. It can answer the 'how' and 'why' questions regarding vulnerability of farmers, their perception and adaptation strategies as was used by (Adger et al., 2003; Vincent, 2004; Mertez et al., 2008). Although surveys have several strengths, Henry (2009) cited in Yohannes (2012) argued that they cannot be substitutes for qualitative methods which can uncover the unexpected in ways that surveys cannot. This implies that integrating both approaches can have best effect. The application of mixed method with the pragmatic approach provides the opportunity to avoid deficiencies and weaknesses that come from using a single method. Accordingly, this thesis applied mixed-method based upon the sustainable livelihood conceptual framework (SLF) anchored with the IPCC framework to analyze vulnerability of farmers in different agro-ecological settings.

This thesis employed a comparative mixed research design with a cross-sectional survey using sequential data collection procedures (quan-qual) by which the quantitative data was collected through household survey first and then the qualitative data was gathered using focus group discussions (FGDs), in-depth interview and field observation. The research was framed in such a way that it was possible to compare the vulnerability levels and adaptive capacities of the rural households by agro-ecology. The units of analysis were mainly households since the data on the livelihood assets and adaptation strategies were mainly taken at the household level although meteorological, population, crop production and elevation data were analyzed at agro-ecology level. The research questions presented in the first chapter were the bases to use sustainable rural livelihood approach. This approach in turn guided the research to analyze the vulnerability levels of the households and the relationship between the different predictor variables and decisions on a number of adaptation options.

3.2. Study site selection, description and sample size

Three woredas were purposively selected from northwest Ethiopia namely; Dabat, Dembia and Simada (see fig.10). The motivation was to examine the differences in the variables of interest as these woredas represent different locations with varying agro-ecological setting, population pressure, climatic conditions, land degradation, access to different infrastructure such as roads, water supply, education, health, markets and many other related factors excluding the western cash crop farming areas. The purpose was to examine whether or not there is significant variation in biophysical contexts, vulnerability levels and adaptation strategies of subsistence households to climate change across the three agro-ecological zones.

Both Dabat and Dembia are located in the North Gondar Zone of the Amhara Regional State. Figure 10 clearly depicts that Dabat is bounded by Debark *woreda* in the north, Wogera in the south, Tsegede and Tach Armachiho in the west, and Debark and Wogera *woredas* with Estie *woreda*, and on the north and northeast by Lay Gaynt and Tach Gaynt *woredas* respectively. This indicates that the *woreda* is totally inclusive in the Abay River basin.

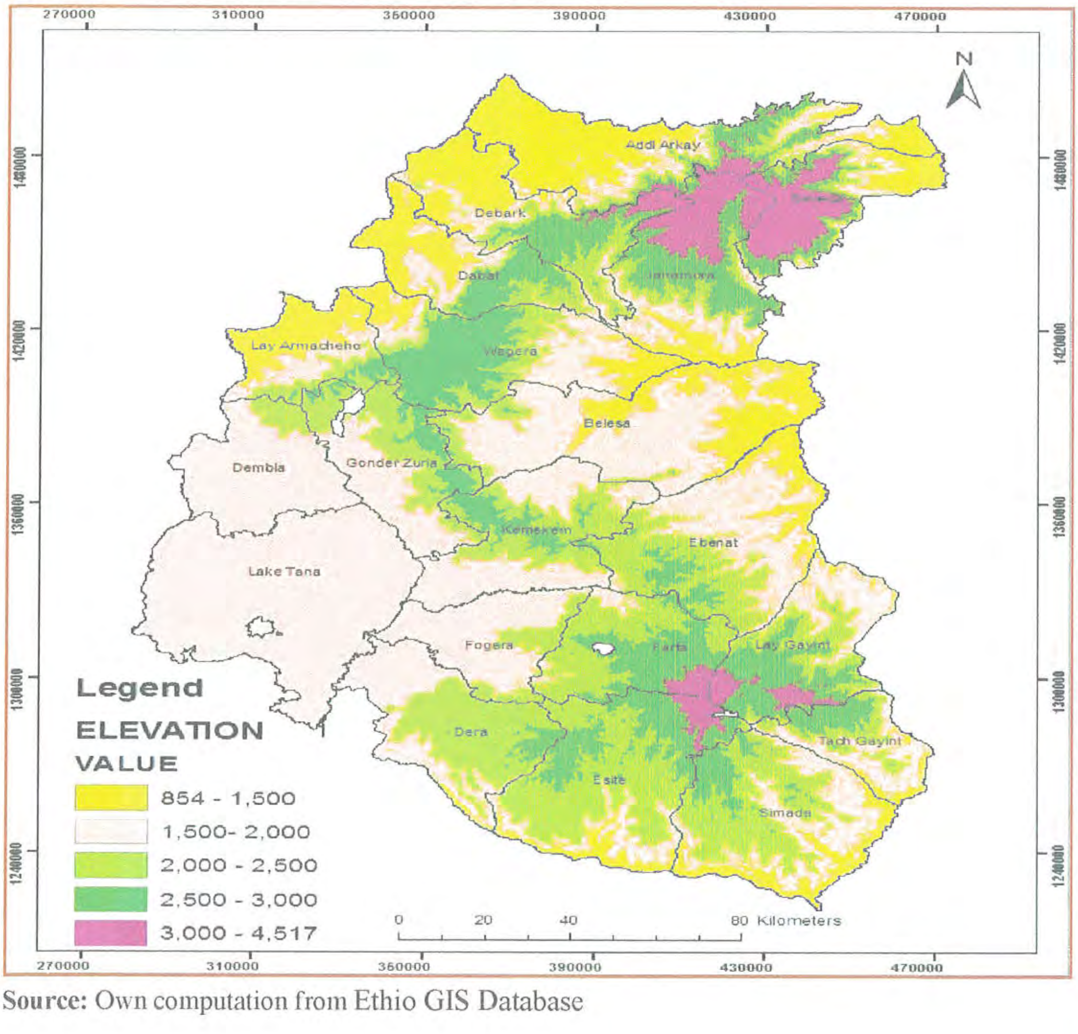
The three study sites are situated in northwest Ethiopia stretching from the Abay-Beshilo Basin to the northern (Semien) highlands, bearing similarities in some socio-economic aspects, but highly differing in agro-ecological setting. For further understanding the sampling area is presented by elevation, temperature and rainfall limits in Table 4 below.

Table 4: Sampling frame by elevation, temperature and rainfall limits

Agro-ecology	Elevation limit	Range of temperature (0C)	Range of rainfall (mm)
Dega	2500 – 4517m	10–17/18	1200 - 2200
Woyna dega	1500 – 2500m	17/18–20/24	900 - 1200
Kola	854 –1500m	20/24–28	200/500 - 900

Source: Based on FAO, 2003

Figure 11: Elevation classification of the study sites



Source: Own computation from Ethio GIS Database

Figure 11 illustrates the study area by elevation. FAO (2003) recognized that elevation with different terrain characteristics is a factor that determines the distribution of climatic factors and land suitability, which, in turn influence the crops to be grown, the rate of crop growth, natural vegetation types and their species diversity. In addition, the distribution of soil, land surface and climatic hazard frequency and severity, and production potential vary by terrain characteristics. In line with this, human sensitivity to climate change is strongly influenced by terrain characteristics settled by human population and pursuing their livelihood activities.

Dega kebeles of Dabat are located in the north highland wheat-barley-sheep livelihood zone of the flat highland topography following the Gondar-Debark highway near to the highest peak of Ethiopia. The altitude of the study sites ranges from 2500 to 4517m above sea-level (See Figure 11). Although this site is located in the northern highlands of Ethiopia, fortunately the area is relatively flat highland with less soil erosion as compared with the *kola* site. The selected site also has relatively abundant water resources for agricultural and domestic purposes (ACCRA, 2011) as compared to the *kola* site.

The *woyna dega* site is situated in Dembia *woreda* with an elevation ranging from 1500 to 2500m above sea-level characterized by flat terrain, flood-plain, and swamps. The *woreda* is entirely located in the Tana zuria livelihood zone, which is considered to have good potential for agricultural production (*Woreda* Office of Agriculture, 2011), but found to become vulnerable to climate change and associated extreme events. As such, the site is heavily affected by flooding, malaria and other water-borne diseases, crop pests and disease as well as livestock diseases.

The *kola* site is located in dissected landscapes of Abay-Beshilo Basin of Simada *woreda* where land degradations, drought, food insecurity and famine are serious problems mainly since 1980s. It is totally included in the Abay River Basin. Based on Figure 11 above, the elevations of the chosen study site range from 854m to 1500m above sea-level though the elevation of Simada *woreda* ranges from 854 to 3000 m above sea level.

Once the selection of the woredas was done, kebele administrations in the three woredas were grouped into three such as *dega*, *woyna dega* and *kola*. Then, a total of eleven kebeles were randomly selected from all the woredas (3 from *dega*, 4 from *woyna dega* and 4 from *kola*). Further stratification of households in terms of annual income, household size, gender, etc was not done as the comparative nature of the study further complicates the application. Most importantly, it was assumed that systematic random sampling can accommodate households having these different criteria so as to obtain representative sample population. In the third sampling stage, sample size determination was carried out to obtain reliable data for the thesis. The Israel (1992) statistical formula was checked within the determination of the sample household size for a better representation of the study population. Accordingly, 576 households were randomly (simple) selected from the chosen kebeles (Refer to Table 5).

$$n = \frac{N}{1+N(e)^2} \quad (3.2A)$$

where, n = designates the sample size the research uses;

N = designates total number of households in all *kebeles*;

e = designates maximum variability or margin of error 5% (.05);

1= designates the probability of the event occurring.

The formula provided 387 sample populations which represent 3.29% of 11,732 households of the eleven chosen kebeles. This calculated sample size was considered as the minimum requirement based on the arguments of Feige & Marr (2012). They contend that assuming the calculated sample size as sufficient to comply with the requirements is a typical mistake. The non-response and incomplete responses are mentioned as some of the reasons so that they suggest a compensation for such effects by increasing the calculated sample size by some proportion. Accordingly, the sample size for this study was increased to 576 (5%). Then, the 576 households were distributed to each *kebele* using probability proportional to size (PPS) method to ensure equal representation of households as there are different household sizes in each agro-ecological zone and respective kebeles. That is:

$$ni = \frac{n \times Ni}{\sum Ni} \quad (3.2B)$$

where, n_i = proportional sample size of the i^{th} *kebele*; Ni = population size of the i^{th} *kebele*.

The sample size determination formula provided larger number of household heads for *kola* (363) distantly followed by *Woyna dega* (181) and then *dega* (132). The reasons are: 1) the *kola* kebeles in Simada cover larger area consisting of 4 to 6 church administrations while one kebele considered from one to two church administrations in other study sites. 2) The *kola* site is located around the upper Blue Nile Basin which was once very fertile but now highly degraded and still densely populated. In line with this, the CSA (2007) population and Housing Census of Ethiopia and other office documents indicate that most of the *kola* kebeles have hosted high population while *dega* kebeles hosted low population number. From this, we can understand that global, continental and national generalizations are inconclusive in the dissected landscapes of northwest Ethiopia.

Table 5: Sample size by agro-ecology and *kebele* administration

	Sample *Kebeles*	No. of households	Sample size
	- Keta	863	44
Kola (lowland)	- Goshmeda	1011	54
	- Yequsa	1857	96
	- Shasho	1302	69
	Total	**5033**	**263**
	- Girarge	586	28
Woyna dega (midland)	- Achera	676	33
	- Jenda-Kobla	1264	60
	- Semra-Kekeza	1240	60
	Total	**3976**	**181**
	- Dequa	882	42
Dega (highland)	- Dara	1326	64
	- Abtera	514	26
	- Total	**2722**	**132**
	Grand Total	**11732**	**576**

*NH = North Highland **Source**: *Woreda* Administration Offices

The lists of rural households were taken from the kebele offices as a sampling frame from which, the households were drawn from the respective agro-ecologies and kebeles using systematic random sampling technique. In order to complete this procedure, sampling interval (K) was determined by dividing the total number of households in the population by the desired sample size of each kebele. Next, a number was selected between one and the sampling interval (K) using lottery method, which is called the random start and was used as the first number included in the sample. Then, every K^{th} household head after that first random start was taken until reaching the desired sample size for each kebele. Systematic sampling is to be applied only if the given population is logically homogeneous within the respective strata (agro-ecologies in this case), because systematic sample units are uniformly distributed over the population (Feige & Marr, 2012). In the case of this study, the sampling units are rural farmers who are uniformly distributed in the respective agro-ecology-based study sites.

3.3. Data sources, types and data collection methods

Three overriding themes in the thesis are vulnerability contexts, actual vulnerability levels, perception and adaptation to climate change. As such, the study aims to contribute to thinking about adaptation, and address whether an adaptation approach have been recognized as a new development strategy for minimizing climate change risks and supporting adaptive capacity of vulnerable communities. Identification of the basic research questions were presented in Chapter 1. This section discusses about what and how to approach for addressing each research question/component.

Assessing the biophysical and socio-economic contexts of vulnerability to climate change, actual vulnerability levels of surveyed households and then adaptation strategies require good-quality data and/or information. Four main data sources were identified as relevant for investigation in that they indicate the situations of vulnerability, perception and adaptation to climate change in the three study sites. The first is the scholarly researches on theories, methodological approaches, and empirical findings which helped to gain initial insights regarding to climate change, vulnerability, perception and adaptation. The second is the international policy discussions on adaptation. The third source is meteorological records such as temperature, rainfall and extreme events, farmland covered with different crops, number of population by kebele and flood affected people in Dembia (*woyna dega*) which helped to gain initial insight into the research problem and acquire baseline information about the study sites. The fourth data sources include mostly non-climatic data such as human, natural, economic/financial, physical and social capital assets; climate change hazards, and perceptions based on Hahn et al.(2009) and (Lamichhane, (2010) for analyzing vulnerability through household survey. The actual experience of adaptation to climate change in the vulnerable communities is considered important, because such information indicates whether and how adaptation is taking place and how vulnerability and adaptation strategies are related. While the discussion in this thesis is dominated by the quantitative examinations of vulnerability context, vulnerability level of households and perception and adaptation based on the sustainable livelihoods framework, focus group discussions, in-depth interviews and field observations were also used to elaborate further on these aspects, but remains a primary source of data collection.

The survey questionnaire was designed in such a way that is to addresses the vulnerability indicators listed in Annex 2 and types of adaptation strategies and determinants of adaptation presented in Table 6. All of these four elements therefore serve as sources for data collection. The data collection methods used in this study is discussed in detail in the sections to come.

3.3.1. Secondary data sources and collection procedures

Sources of quantitative secondary data include internet, policy and strategy documents and office reports. Meteorology data from Ethiopian Meteorological Service Agency and global weather data center [http://globalweather.tamu.edu/], and land-used for different crops, , and crop production/productivity, kebele population data and flood prone people were gathered from *woreda*, Zonal, Regional, and Federal level offices.

The meteorological records helped to analyze vulnerability contexts such as rainfall and temperature trends and yearly and monthly deviations, drought duration, magnitude and intensity/severity, precipitation concentration index, and aridity index; exposure levels of households; population to determine sample size, cultivated land covered with different crops to compute crop diversification index, and flood prone population in Dembia (*woyna dega*). However, one of the biggest challenges in each site was the scarcity of the temperature and rainfall records. Literatures provide different interpolation techniques to alleviate this problem. These include Arithmetic Mean (Local Mean) method, Normal Ratio method, Inverse Distance method and Aerial Precipitation Ratio method (Silva et al., 2007). Same authors suggest that the Inverse Distance method for semi-arid lowland stations, Aerial Precipitation Ratio method for midland and Arithmetic Mean methods for highland stations as the most suitable methods. Accordingly, Inverse Distance method was employed for *kola* sites to interpolate the rainfall data. In all cases, the center of gravity of the study sites was determined using ARCGIS 9.3, and the distances from the center of gravity were measured. After measuring the distances between the center and the gauged stations, weighting factors were calculated by the inverse distance method. If W_1 refers to weighting factor-1 $w1= 1/d^2$, where d is the distance between the ungauged area and the gauged rainfall station. The same procedure was applied for all the stations used for rainfall computation to ungauged sites. Thus, the rainfall for ungauged area:

$$Pu = \left(\frac{P_1 W_1 + P_2 W_2 + P_3 W_3 + P_4 W_4 --- + P_n W_n}{W_1 + W_2 + W_{3\_} W_4 --- + W_n}\right) \qquad (3.3.1A)$$

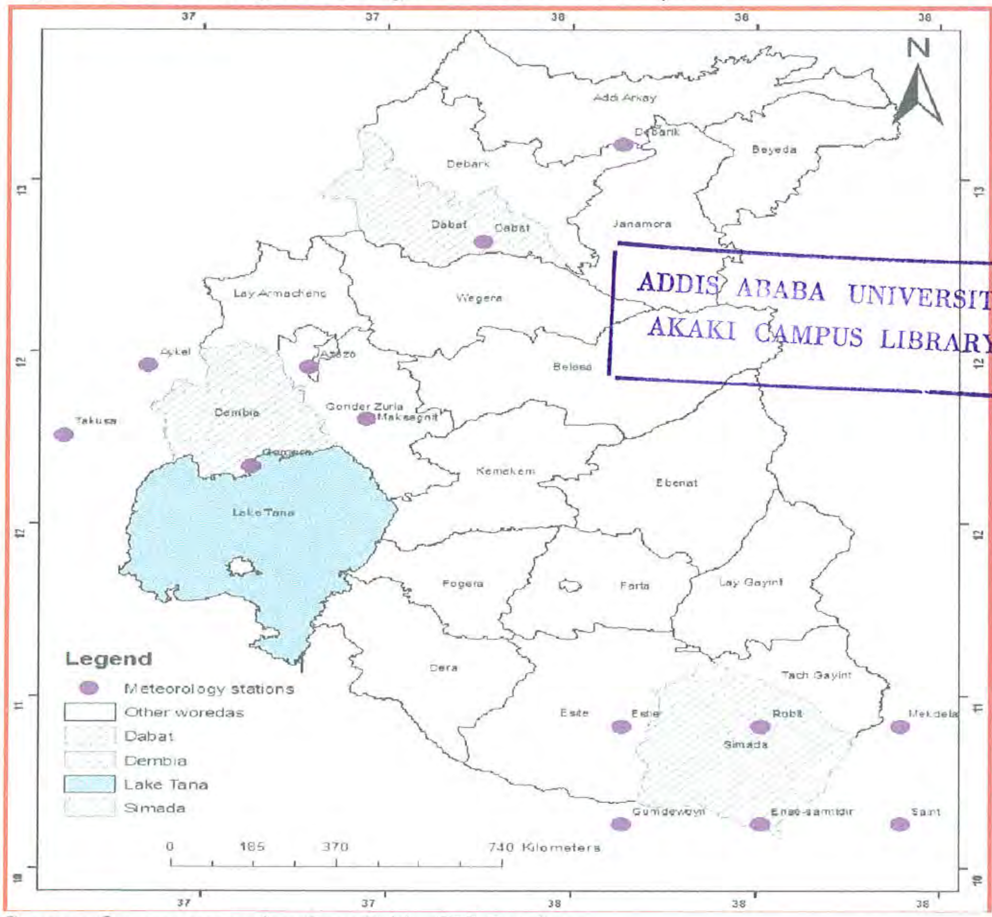
Pu = rainfall computed for ungauged area (station); P_1, P_2, P_3, $P_{4,}$ represents rainfall records at the gauged stations; W_1, W_2, W_3, W_4 refers to weighting factors, i.e. ratio of 1 and distance square between the gauged station and ungauged stations (Silva et al., 2007). To keep spatial representativeness, 6 stations for *kola* and 5 for *woyna dega* which totally surrounded the study sites were identified. In line with this, Mongi et al. (2010) justify the use of climate data collected from multiple stations has higher reliability. However, lack of continuous data, particularly for meteorology records, was found to be a pressing challenge. Thus, numerous missed values for monthly meteorological records were filled by the linear interpolation method. In addition to the NMA record, daily rainfall and temperature data were generated from Global Weather Data for SWAT [http://globalweather.tamu.edu/] from 1979 to 2010 for all agro-ecologies to validate the gauged data and to represent the areas that do not have neighboring meteorological stations. These daily data was summarized into monthly and yearly data using pcpSTAT soft ware and then interpolated using inverse distance method.

In the *woyna dega* site, the area ratio method was employed to interpolate rainfall data (Garg, 2005; Silva et al., 2007). The selected stations were tested by the Thiessen polygon method to know to what extent, they are influencing the study sites. By doing so, the stations which have no more influence on the sites were excluded from computation. The percentage of the areas influenced by each station and area ratio was calculated using ARC GIS 9.3. By multiplying the ratio with rainfall data from gauged stations, areal rainfall for the study sites was interpolated using the weighted average of each gauged station using the following relationship as was used by Garg (2005).

$$P = \frac{\sum A_i P_i}{A} \qquad (3.3.1B)$$

where; 'A' denotes the total area of the polygon; 'P_i' represents the precipitation of the i^{th} gauge, 'A_i' is the area of the specific polygon using the Theissen method corresponding to the precipitation; i refer to the i^{th} precipitation gauge.

Figure 12: Surrounding meteorological stations of the study sites



Source: Own computation from Ethio GIS Database

For *dega* site, arithmetic mean of the rainfall was generated (Silva et al., 2007) using the meteorology data from Debark (NMA) and Dabat stations (Global Weather Data for SWAT) because only these two representative stations are located in the *dega* agro-ecology. Other neighboring stations are mostly situated in *kola* and *woyna dega* agro-ecological zones surrounding the *dega* site of Dabat. The temperature data which was generated through arithmetic mean or from the nearby stations based on the recommendations of FAO document (FAO, 1998) was used for the three sites. Accordingly, the mean temperature of Mekdela and Robit for *kola*, the mean of Gorgora and Azezo for *woyna dega*, and the mean of Dabat and Debark stations for *dega* were used. The reason is that within small area coverage temperature is less variable than the rainfall so that one or few station temperature records can represent those particular areas (FAO, 1998).

3.3.2. Quantitative and qualitative primary data

As it is discussed in the preceding section 3.3.1, data from secondary sources include only meteorology data, land-used for different crops, and crop production/productivity, kebele population data and flood prone people. Thus, the secondary data was found insufficient to answer all the specific research questions for the study populations. Therefore, it was determined that primary data collection methods to be the major data sources for this thesis. Accordingly, primary data was collected using household survey, focus group discussion, field observation, and in-depth interview which have brought the study to fruition.

(A) Quantitative primary data: The household survey was employed to collect a range of quantitative data on capital assets (human, natural, financial, physical, and social), climate-related hazards, perceptions of climate change, and adaptation strategies used by the households. The questions were prepared on the bases of the indicator method of vulnerability assessment discussed in the literature review Chapter and the conceptual framework depicted in Fig.1. The data sets are very important for calculating livelihood vulnerability indices in terms of five livelihood assets; analyzing of variance and composite adoption indices; binary logistic regressions to identify the most vital determinants of households' adaptation choices; statistical descriptions such as mean, frequency/percentage, maximum and minimum values.

The household survey was conducted in the period between March and September 2012. Household heads were approached, but if he/she were not available, the spouses were contacted. When difficulties were faced to meet the selected households due to absenteeism (after repeated visits) or when they became involuntary to take part, he/she was replaced by the household listed next to him/her. Most of the farmers were contacted on the homesteads and a few of them were consulted on Saturdays, Sundays, and other holidays around churches and community gathering places.

The actual household surveys were administered by data collectors with close supervision of me and assistants. My former university students had played paramount role in the process of data collection. They also played an important role in choosing the data collectors who have been working in the community in the areas of agriculture, healthy and teaching, with the academic status of diploma and bachelor degree. As a matter of fact they are living in the community for many years with the objective that they better know the area and easily approach and handle respondents.

In order to maintain the validity and reliability of the data, the questions were extensively reviewed by experts from different disciplines, working in the Offices of Agriculture, Health, and Food Security and Disaster Prevention. Additional pre-tests of questions were made by distributing questionnaires to 10 farmers in each site who were not involved in the actual survey to assess whether the instruments were appropriate and suited to the study at hand, and to delete or modify confusing and sensitive question and ideas. Necessary amendments were made based on the comments obtained from experts and responses from farmers to ensure reliability and validity; whether the questions made respondents feel uncomfortable and ensure the clarity of the questions as to whether they could be easily understood. Pre-testing of the questions was also used to determine the mean interview length and mean time required for covering the samples in order to plan the time and days required for the field survey and the number of data collectors. Data collectors were also trained with respect to the survey techniques and confidentiality protocol. Internal quality control procedures were established during the training. For example, in case survey questions contained ambiguous language that might lead to different answers depending on respondent's interpretation, data collectors were told to have common understanding. After the training, the data collectors acquired practical experience while I was making face-to-face interview in the actual data collection in the field.

(B) Qualitative primary data

The qualitative primary data was collected using focus group discussions (FGDs), in-depth interviews, and field observation particularly for the purpose of checking the quantitative data (both primary and secondary). The 'why' and 'what' kinds of probing questions were also raised by the household survey questionnaire based on the households' responses. In addition, the quantitative results which needed further reasoning from officials of both governmental and non-governmental agencies and farming households were also treated through these qualitative data collection methods.

Focus group discussions (FGDs): The survey data was checked through group discussions with farming households. Focus group discussants included the elderly, the priests and the former school dropouts, who now became farmers, and *kebele* leaders. They were carefully selected based on age and experience in farming and adaptation practices in consultation with key informants (research assistants, development agents, model farmers, and woreda and kebele officials). The number of participants in each focus group ranges from six to nine. One FGD with nine participants and one with eight participants were contacted in *kola* site. While two FGDs, one with six members and one with nine members were contacted both in *dega* and *woyna dega* sites. From this it is vivid that because of information saturation, the FGDs undertaken had only six sessions (2 for each agro-ecology). The discussions were administered in and around church compounds and kebele offices.

In-depth Interviews: In-depth interviews were conducted with farmers progressively, before and after the questionnaire survey period. Attempts were made to develop a rapport with the community through short informal interviews. These discussions took place in the public meeting places, villages, and church compounds. Discussions with woreda and kebele office heads, kebele leaders, project managers, experts, and extension agents at various levels were held using guiding questions in the topic areas in their offices. A total of 15 officials and 6 Office heads from *Woreda* Administration, Office of Agriculture, Disaster Prevention and Food Security, Health, and Organization for Rehabilitation of Amhara (ORDA) were approached for in-depth interviews. Informal discussions were also held with police men to acquire basic information about the sources of conflict among the households in the respective communities. People who were assumed to have rich information were chosen. Creswell (2012) confirmed the importance of contacting these people by expressing his stand as "The standard for choosing the participants is whether they are information rich". Similar to FGDs participant selection process, key informants such as research assistants, extension agents, *kebele* managers, and respected figures of each *kebele* played important roles for identifying participants in in-depth interviews.

Field observation: Field observations were conducted in all the study areas in order to gain better insights into the selected study sites. The first contact was made with the heads and experts of the Departments of Agriculture at Zone Administrations to acquire basic information about the *woredas*, followed by visits to *woredas* and then *kebele* offices. During these visits, discussions were held with office heads and experts to learn more about the agrarian systems, climatic hazards and types of interventions, which provided the general picture of the biophysical, economic, social and institutional features of the *woredas*. By doing so, I was acquainted with the specific agro-ecological zones included in the study.

Although visits were undertaken before, during and after the household survey, the actual field observation was conducted after the survey data collection was completed. Visits at an early stage of the fieldwork to different villages were found to be a good opportunity to meet the community members. In the process, I introduced myself to the community and the grassroots workers. The observation focused on physical features, flood and erosion-prone areas, flood displaced people, crop patterns, settlement patterns, land management structures, water schemes, vegetation, grazing lands, protected areas, and market places. Moreover, pictures were taken in the field to portray more vivid features of the study sites and to support the quantitative and qualitative works of the study.

The uses of these qualitative data gathering methods are recognized by Creswell (2012) by stating that qualitative inquirers triangulate among different data sources to enhance the accuracy of a study. Triangulation is the process of corroborating evidence from different individuals (e.g., a principal and a student), types of data (e.g., observational field notes and interviews), or methods of data collection (e.g., documents and interviews) in descriptions and themes in qualitative research. The researcher examines each information source and finds evidence to support a theme. This ensures that the study will be accurate because the information draws on multiple sources of information, individuals, or processes. In this way, it encourages me to develop a report that is both accurate and credible.

3.4. Quantitative methods of data analysis

After the acquisition of data through different data collection methods, analysis was made using both quantitative and qualitative methods to address the research questions. After being completed by the enumerators, I verified the data to ensure whether or not the interview schedule had been filled up properly and accurately. Then the data was coded, entered, and analyzed using statistical package for social sciences (SPSS) 16.0 version. In the analysis process, Microsoft Excel worksheet, pcpSTAT, instat, and GIS software were used, in addition to SPSS.

3.4.1. Measures of trend and variability

Exploration of a range of biophysical and socio-economic contexts and processes demand various quantitative data analysis methods anchored with qualitative analysis. The data collected through mainly the third and partially the fourth data sources presented in sub-section 3.3 above were used for addressing these issues. Each of the quantitative methods is depicted in the discussions to come.

3.4.1.1. Temperature and rainfall trend analysis

Trend is a change over time exhibited by random variables, detectable by statistical parametric and non-parametric procedures (Longobardi & Villani, 2009). Temperature and precipitation trend analysis, on different spatial and temporal scales, has been of great concern during the past century because of the attention given to global climate change by the scientific community. According to some recent studies, Ethiopia has been suffering from precipitation decrease especially the northern areas seem to be more affected. Based on Longobardi & Villani (2009) argument with the aim of trend detection, parametric statistical procedure was applied to the temperature and precipitation time series aggregated in the annual time series.

(1) Simple regression: When we are examining the relationship between a quantitative outcome and a single quantitative explanatory variable, simple linear regression is the most commonly considered analysis method. This method was used so as to detect and characterize the long-term trend and variability of temperature and rainfall values collected from NMA and Global weather data for SWAT at annual time scale. The parametric test considers the simple linear regression of the random variable Y on time X. The regression coefficient a (or the Pearson correlation coefficient) is the interpolated regression line slope coefficient computed from the data. It is known that the statistic

$$Y = \beta x + c \qquad (3.4.1A)$$

where, Y = Physical factor (changes in rainfall and temperature) during the period; β = slope of the regression equation; x = number of years from 1979 to 2010; c = regression constant (Mongi et al., 2010).

(2) Standardized precipitation index (SPI): SPI was used to assess drought duration, magnitude and intensity across the years using yearly rainfall data. It can be calculated as:

$$SPI = \frac{x-\bar{x}}{\sigma} \qquad (3.4.1B)$$

SPI refers to rainfall anomaly (variance, irregularity and precipitation deficit) on multiple time scales; X represents annual rainfall in the year t; $\overline{X}$ is the long-term mean annual rainfall; and σ represents the standard deviation of rainfall over the period of observation (McKee et al., 1993; Agnew and Chappel, 1999; cited in Woldeamlak, 2009). Accordingly, the drought severity classes are:

extreme drought (SPI < -1.65);
severe drought (-1.28 > S > -1.65);
moderate drought (-0.84 > S > -1.28),
no drought (S > -0.84).

After quantifying the SPI values, drought duration, magnitude, and intensity were analyzed. Drought duration is the period between drought starts and ends expressed in months or years. Drought magnitude (DM) is the sum of the negative SPI values for all the months or years within the period of drought (McKee et al., 1993). Mathematically it can be expressed as:

$$DM = \sum_{j=1}^{x} -(SPI\ ij) \qquad 3.4.1C$$

where, j starts with the first month/year of a drought and continues to increase until the end of the drought (x) for any of the i time scales. Drought intensity (DI) is the ratio of the drought magnitude of the duration event, which can be expressed as Mi/Li where Mi is drought magnitude and Li is the drought duration calculated from the SPI. Although most drought analysis used the monthly time scale, the yearly scale was selected for the purpose of this study because of the comparative nature of the study. If the monthly scale was used, the presentation would be complicated and would make the result much bulky.

3.4.1.2. Spatial and temporal measures of rainfall variability

The spatial and temporal climate variability was assessed using aridity index, precipitation concentration index, and coefficient of variation.

Aridity Index (AI): aridity index was calculated to understand monthly dry and wet variations in terms of moisture demand for agriculture in each agro-ecology using temperature and rainfall data. The aim was to identify the months that need irrigation. So, according to Zhang et al. (2009), irrigation is necessary when AI<20. The aridity index can be computed as:

$$AI = \frac{12P_i}{T_i+10} \qquad (3.4.1D)$$

where, P_i and T_i represent the monthly precipitation amount and monthly mean temperature respectively.

Precipitation Concentration Index (PCI): It is very essential to indicate the monthly distribution of rainfall which can be calculated using rainfall data as:

$$PCI = \frac{\Sigma Pi^2}{\Sigma(Pi)^2} x100 \quad (3.4.1E)$$

where Pi is the rainfall amount of the i^{th} month; and Σ = summation over the 12 months. PCI values of less than 10 indicate uniform monthly distribution of rainfall, values between 11 and 20 indicate high concentration, and values of 21 and above indicate very high concentration (Oliver 1980, cited in Woldeamlak, 2009).

3.4.1.3. *Measures of other trends and variations*

One-way Analysis of Variance (ANOVA) was employed to test the mean differences in crop yields that the farmers produce per hectare of farmland and the number of livestock units died due to climate related hazards in the three study sites. These data sets were collected through household survey and analyzed using SPSS.

The stability of crop yield and wood supply trend was analyzed by constructing indices of trend of yield (ITY) based on farmers' responses to a question related to supply and productivity trend since the past 20 years or so using household survey data as (Ahmad et al., 2003): Microsoft excel was the most important tool for analyzing crop yield stability trend by employing the household survey data.

$$\text{ITY} = (\text{fi} * 1 + \text{fd} * -1 + \text{fc} * 0/\text{N}) \quad (3.4.1F)$$

where, ITY = index of the trend of yield

fi = frequency of responses indicating increasing yield

fd = frequency of responses indicating decreasing yield

fc = frequency of responses indicating constant

N = total number of responses

3.4.2. Livelihood vulnerability index using functional relationships

An assessment of the vulnerability levels of the farmers was done using the livelihood vulnerability index (LVI) based on the household survey data. The indices were constructed using weighted average approach to measure households' access to a set of livelihood assets and climate change exposures (Hahn et al., 2009). On the basis of the conceptual framework, indicators were selected for five capitals and climatic factors using expert judgment, observation, and previous studies. The indicators were changed into standardized index using the following equation (Sudarshan, 1981; Sullivan et al., 2002; ICRISAT, 2006; UNDP, 2010):

$$Standardized\ \text{index value} = \frac{\text{Observed (average) values} - \text{Minimum values}}{\text{Maximum values} - \text{Minimum values}} \quad (3.4.2A)$$

This method of normalization takes the functional relationship between the predictor variable and vulnerability (Refer to Annex 2). ICRISAT (2006) identified two types of relationship: vulnerability increases with the increase (decrease) in the value of the indicator. In this type of relationship the higher the value of the indicators, the more is the vulnerability. For example, the larger the change in temperature, rainfall, and distance indicators, the more will be the vulnerability of the place or the community to climate change impacts. In this case, the variables have a positive functional relationship with vulnerability and hence the normalization was done using equation 3.4.2A. For these types of variables, the average values are taken as observed values. For variables that measure frequencies of events, the minimum value is set at 0 and the maximum at 100.

For indicators which assumed to have an inverse relationship (adaptive capacity indicators) with vulnerability, the inverse scoring technique was applied in the standardization of values for each indicator by equation 3.4.2B based on ICRISAT (2006) and NMA (2007).

$$\text{Index values} = \frac{\text{Maximun values} - \text{Observed (average) values}}{\text{Maximum values} - \text{Minimum values}} \quad (3.4.2B)$$

In this case, let us consider farm income of households, a high value of this variable implies better off households in the agro-ecology. So the rural households will have more capacities to cope with climate change impacts. Put differently, the vulnerability levels will be lower and farm income has an inverse functional relationship with vulnerability.

Other indicators having inverse functional relationships and can be directly calculated by their own formula such as crop diversification and livelihood diversification indices (refer to Annex 6b) were inversed by the following formula:

$$\text{Index value} = \frac{1}{1+\text{index}} \quad (3.4.2C)$$

According to equation 3.4.2B and 3.4.2C, an indicator with the least value will have the highest standardized value. By taking the inverse of the value of the indicator, one can create a number that assigns higher values to households with a lower number of livelihood activities and vice-versa. Normalizing vulnerability indices for each indicator on a scale of 0 to 1 allows calculating mean scores for each major component using formula 3.4.2D (Hahn et al., 2009):

$$MCVI = \frac{\sum_{i=1}^{n} \text{Index}}{n} \qquad (3.4.2Di)$$

where, MCVI = one of the seven main components for social capital (S), financial capital (F), human capital (H), physical capital (P) natural capital (N), climatic factors (CF); Index refers to the sub-components, represented by i, which make up each principal component, and n is the number of sub-components in each major component. For example, the average index of the health (H) component can be calculated as:

$$\frac{H_1 + H_2 + H_3 \ldots + H_n}{N} \qquad (3.4.2Dii)$$

By applying the same procedure, composite indices were computed for other sub-and major components and then for the overall vulnerability levels of households across the three agro-ecologies. Once the index values for each major component were calculated, the composite index was computed using the weighted average with the following equation to obtain the livelihood vulnerability index (LVI) (Hahn et al., 2009):

$$\text{LVI} = \frac{\sum_{i=1}^{7} \text{Ni NCi}}{\sum_{i=1}^{7} \text{Ni}} \qquad (3.4.2E)$$

where, LVI = Vulnerability Index equals the weighted average of the seven important components; the weights of each main component, Ni is the number of indicators in sub-components that make up each major component (NCi).

3.4.3. Index of adoption and logistic regression

Adaptation assessment was made using descriptive statistics (percentage, minimum, and maximum), index of adoption and logistic regression. The composite index of adoption (CIA) reflects the range of adaptation strategies used and it helps to understand the variation in technology adoption (Barungi & Maonga, 2011). The CIA is computed as:

$$CIA = \sum_{t=1}^{t=n} \frac{\frac{T_{tA}}{T}}{n} \qquad (3.4.3A)$$

where; T_{tA} = the total number of adaptation strategies adopted by the household,

T = the total numbers of adaptation strategies available for adoption,

n = the sample size, and $^{T_{tA}}/_{T}$ = the index of adoption for the household.

Model and variable description for logistic regression: Econometric analysis was also done to examine the factors influencing adaptation strategies. The logistic regression model, the natural logarithm of an odds ratio, has been used to analyze the data. Since the probability of an event must lie between 0 and 1, it is impractical to model probabilities with linear regression techniques, because the linear regression model allows the dependent variable to take values greater than 1 or less than 0. The logistic regression model is a type of generalized linear model that extends the linear regression model by linking the range of real numbers to the 0-1 range (SPSS16). This model is well suited for describing the relationships between categorical response variables (adoption) and one or more categorical or continuous predictor variables (Tarling, 2009; SPSS16). This condition calls for the use of logistic regression model by identifying both dependent and independent variables from the literature.

Table 6: Description of dependent and independent variables for model estimation

Dependent variables (binary) (1=Yes/adopt,0=No/not adopt)	Independent variables (for all independent variables)	Description of independent variables used for each dependent variable
Manure-compost [No (0), yes (1)]	Age of the household head	Continuous (in years)
Modern fertilizers	Gender of the household head	Took 1 if male and 0 if female
Use of improved seeds	Family size in the household	Continuous (No. people in a hh)
Diversifying livelihoods	Education of the hh head	No. of activities hhs engaged in
Diversifying crops	farmland fertility level	Took 1 if good& 0 otherwise
Change of planting dates	Farm size households own	Farm size owned by hhs in hect
Replanting crops	Access to water for irrigation	Dum: took 1 if yes;& 0 otherwise
Application of irrigation	Livestock and oxen ownership	No. of livestock owned by a hh
Water harvesting	Farm income in Ethiopian Birr	Amount of Birr hhs gain
Digging wells	Non-farm income in Birr	Amount of Birr hhs gain
Diversifying livestock species	Amount of Birr hhs borrowed	Amount of Birr hhs borrowed
Use of improved livestock	Access to input & output markets	Time to reach market centers
Adoption of terraces	Number of relatives in a village	Number of relatives in a village
Planting trees	Farmer-to-farmer extension	Dum: take 1 if yes;& 0 otherwise
Change to cheaper food items	Extension services	Dum: take 1 if yes;& 0 otherwise
Seasonal migration	Access to training & climate info.	Dum: took 1 if yes& 0 otherwise
	Perceived temperature change	Dum: took 1 if yes;& 0 otherwise
	Perceived rainfall change	Dum: took 1 if yes;& 0 otherwise
	Agro-ecology	took 1= *dega*, 2= *w/dega*, 3=*kola*

Source: The researcher's compilation **Note**: For all dummy variables 0 stands for 'No' and 1 stands for 'Yes'

Explanations on how the independent variables influence alternative adaptation strategies to climate change are presented in the literature review, section 2.7.3 of *Chapter Two.*

(a) Dependent variables: The dependent variables for various adaptation options of each agro-ecology were created for this study. The dependent variables are dummy variables equal to 1 if the farmer adopted that particular adaptation option and 0 otherwise.

(b) Independent variables: I have analyzed whether a household adopted any adaptation strategy or not using dummy variables. Different social, economic, and physical factors were included as independent variables in the estimation procedure. The choice was based on experience and previous studies (Maddison, 2006; Yesuf et al., 2008; Temesgen et al., 2010). Analysis of these dependent variables requires a binary response model as:

$$\text{Logit (y)} = \text{In (odds)} = \text{In}\left(\frac{P}{1-P}\right) = B_0 + B_1x_{i1} + B_2x_{i2} \ldots. + B_px_{ip} \qquad (3.4.3B)$$

where, y is the binary response variable (adaptation),

B_1 is the constant or the intercept of y,

$B_0 + B_1x_{i1} + B_2x_{i2}$ are regression coefficients,

P is the predicted probability to adopt which is coded with 1,

1−P is predicted probability of the decision to adopt a particular adaptation option,

$x_{i1}+x_{i2}+x_{ip}$ are the predictor variables included in the model.

Note that, in the binary logistic regression if the Exp(B) also known as odds ratio is less than one, the independent and dependent variables have negative relationships and if it is greater than one their relationship is positive (SPSS 16).

3.5. Qualitative data analysis methods

The quantitative analysis was anchored with qualitative data analysis methods. The collected qualitative text or word information through in-depth interview, FGDs and by writing field notes during observations was analyzed. Before directly getting into analysis, these collected information need to be converted into word processing documents and field notes were read to begin the process of analysis. Because qualitative data collection takes long time and funds, I have taken only some interviews and observational notes transcribed. Creswell (2012) defined the term transcription as the process of converting interview, discussion and field notes into text data. Then they were translated from local language (Amharic) to English and analyzed through narrating and interpreting the issues at hand. The qualitative data collection and analysis used triangulation, member checking and auditing as is suggested by Creswell (2012).

Intensive process of validation activities were undertaken with farmers and government and non-government officials at *woreda*, regional and national levels whenever significant differences across the three study sites were obtained in the quantitative works. In this regard scholars advise that throughout the process of data collection and analysis, researchers need to make sure that their findings and interpretations are accurate (Creswell, 2012; Johnson & Onwuegbuzie, 2004). Validating findings means that the researcher determined the accuracy or credibility of the findings through strategies such as member checking, triangulation and auditing. Creswell (2012) explains on the need for checking the research findings with different participants in the study as: Researchers may check their findings with participants in the study to determine if their findings are accurate. Member checking is a process in which the researcher asks one or more participants in the study to check the accuracy of the account. This check involves taking the findings back to participants and asking them about the accuracy of the result. I did many things in this regard by asking experts and managers about the findings that need further justifications. In addition, I asked people about many aspects of the study, such as whether the description is complete and realistic, if the themes are accurate to include, and if the interpretations are fair and representative (Creswell, 2012: 259).

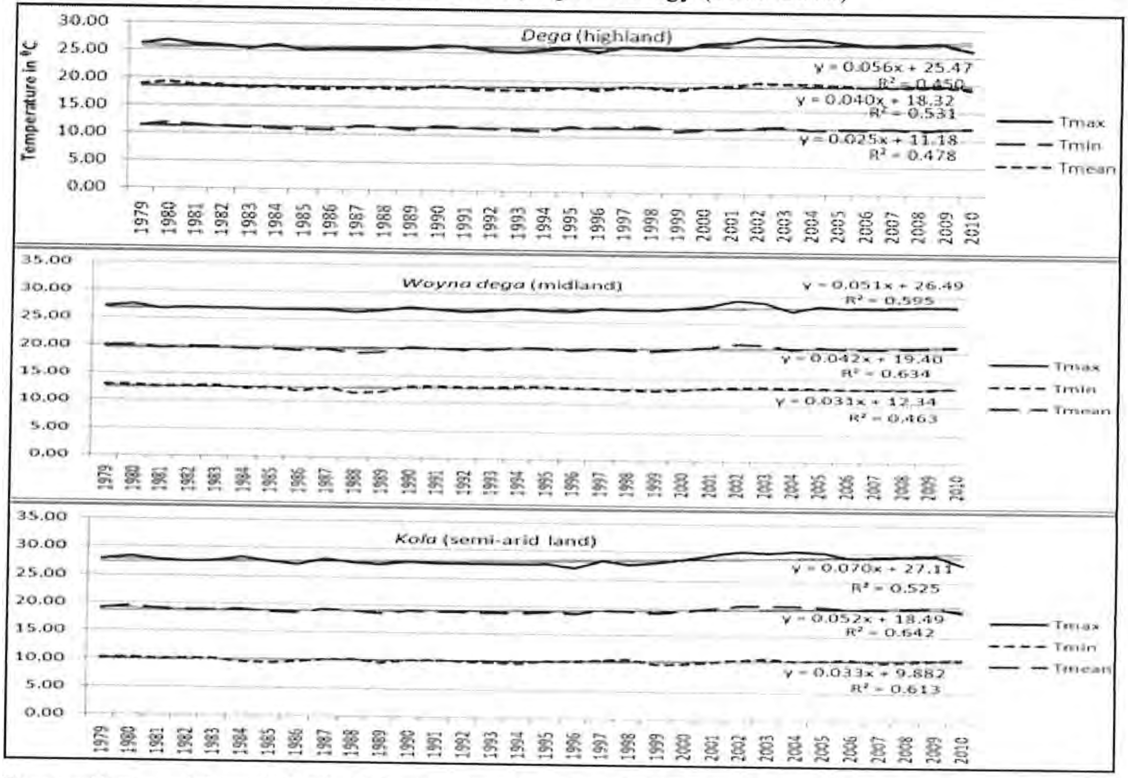
I also provided my thesis for persons to conduct a thorough review of the study and report back in writing the strengths and weaknesses of the project during and after conclusion based on the advice of Creswell (2012). In this regard Creswell argues that researchers may also ask a person to conduct a thorough review of the study and report back, in writing, the strengths and weaknesses of the research work. This is the process of conducting an external audit, in which a researcher hires or obtains the services of an individual outside the study to review different aspects of the research. The auditor reviews the report and writes or communicates an evaluation of the study. This audit may occur both during and at the conclusion of a study. Accordingly, I provided my draft thesis for people working in Amhara agricultural Research Institute, Organization for Rehabilitation and Development of Amhara, Staff members of University of Gondar, PhD students of Social work and Linguistic and communication through which I received important feedback mostly in the written form. Amendments were made based on the comments obtained from people who have different academic background.

concentration index, and aridity index based on the equations depicted from 3.4.1A – 3.4.1E. The period of study was chosen as long as possible in function of the data availability. The thesis has realized a data quality check and interpolation of monthly missing data for the selected stations. The monthly missed values for NMA data were filled with linear interpolation method using SPSS 16 whilst no missed values were detected for the Global weather data for SWAT. The two data sets for temperature were integrated using arithmetic mean method based on FAO (1998) and Silva et al. (2007) and equations 3.3.1A and 3.3.1B for rainfall as advised by Garg (2005) and Silva et al. (2007). Tests were undertaken for linear trend in annual means of temperature and rainfall for the three study sites as was used by Gbetibouo (2009), Mongi et al. (2010) and IPCC (2013). Quantitative results were also triangulated and checked with information obtained through FDGs, in-depth interviews, field observation and field photos.

4.1.1. Long-term temperature distribution and deviation (1979—2010)

The results of the meteorological data showed that annual temperature in the study area had been in increasing trends for the last three decades in *dega*, *woyna dega* and *kola* study sites.

Figure 13: Long-term temperature trends by agro-ecology (1979-2010)



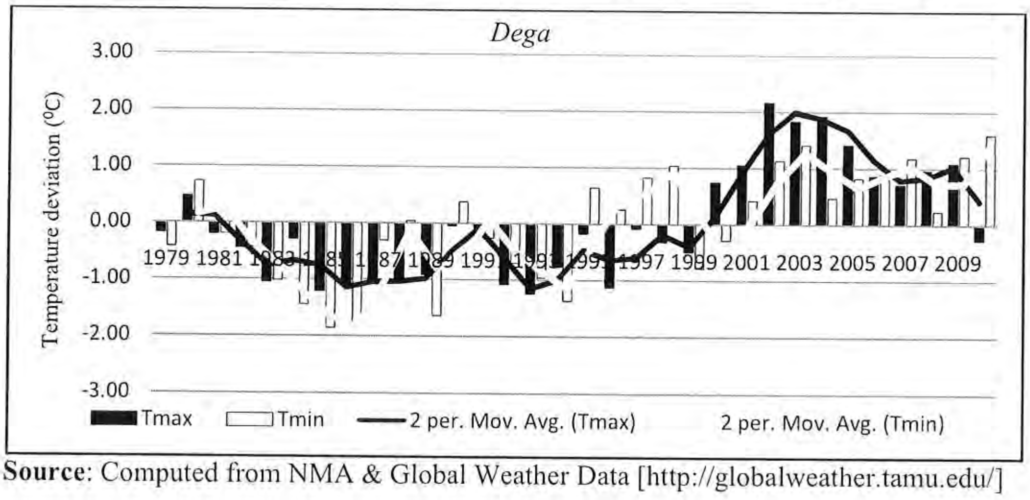
Source: Computed from NMA & Global Weather Data [http://globalweather.tamu.edu/]
*Tmax, Tmin and Tmean represent maximum, minimum and mean temperature respectively

temperature increased by 2.17^{0}C and the minimum rose by 1.02^{0}C in the same period (0.68^{0}C and 0.32^{0}C per decade respectively). In *kola* site, the rate of temperature change was found faster than in *dega, woyna dega,* and national level rate of increase (NMA, 2001, 2007). While maximum temperature in *woyna dega* site was somewhat lower than those of in *dega* and *kola* sites. Only 4.2% of the households in *kola* noticed the contrary, a decrease in temperature while only 6.1% of them have not noticed any change in temperature.

The direction of the temperature trend in the three study sites was found to be consistent with the findings of Mongi et al. (2010) for Tanzania which found out those both minimum and maximum temperatures showed increasing trends. However, in Tabora Urban and Uyui Districts of Tanzania minimum temperature increased faster while maximum temperature increased gradually. This increasing temperature trends in the three sites has paramount impact on water, land and vegetation resources through exacerbating evapo-transpiration with negative consequences on the productive capacities of these valuable resources.

In addition to the increasing trend of long-term temperature, greater temporal variability was also observed in the three sites over the same period (1979-2010). The deviation was calculated using the SPI formula based on Mongi et al. (2010). Figure 14 demonstrates the maximum and minimum temperature anomalies (deviation) from the long term average temperature in *dega* from the period 1979 to 2010 average temperature. It is clear from the figure that around 1981 there was no much deviation both in maximum and minimum temperatures from the long-term average temperature.

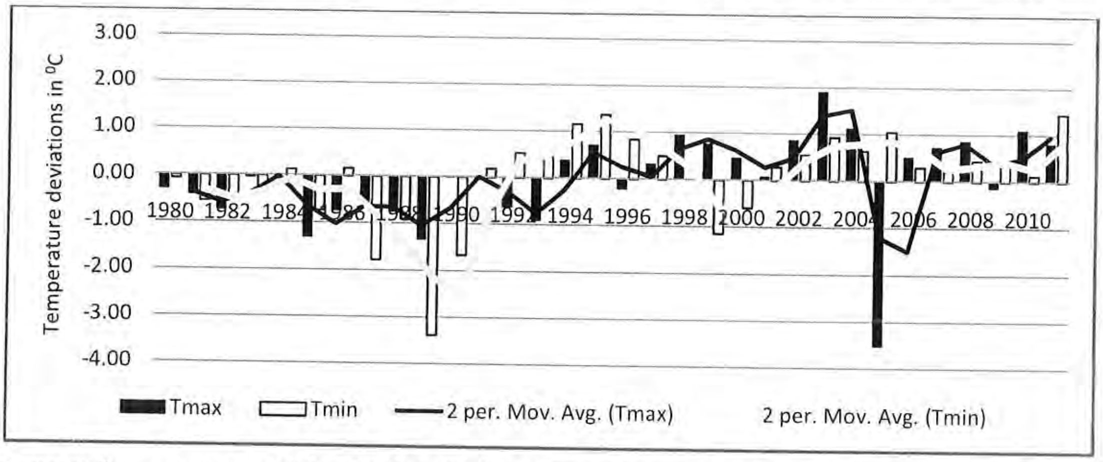
Figure 14: Long-term Tmax & Tmin deviations in *dega* (2 years moving average)



Source: Computed from NMA & Global Weather Data [http://globalweather.tamu.edu/]

Since then both maximum and minimum temperature deviations went down until 1986 while increased until 1992. In 1994 equal deviation was detected in maximum and minimum temperature with certain decline as compared with the previous years. Since 1995 both the maximum and the minimum temperatures increased with greater fluctuations over time. While the minimum temperature continued its increment, the maximum temperature decreased after 2003 though after 2001 both the maximum and minimum temperature deviations were above the long-term average temperature.

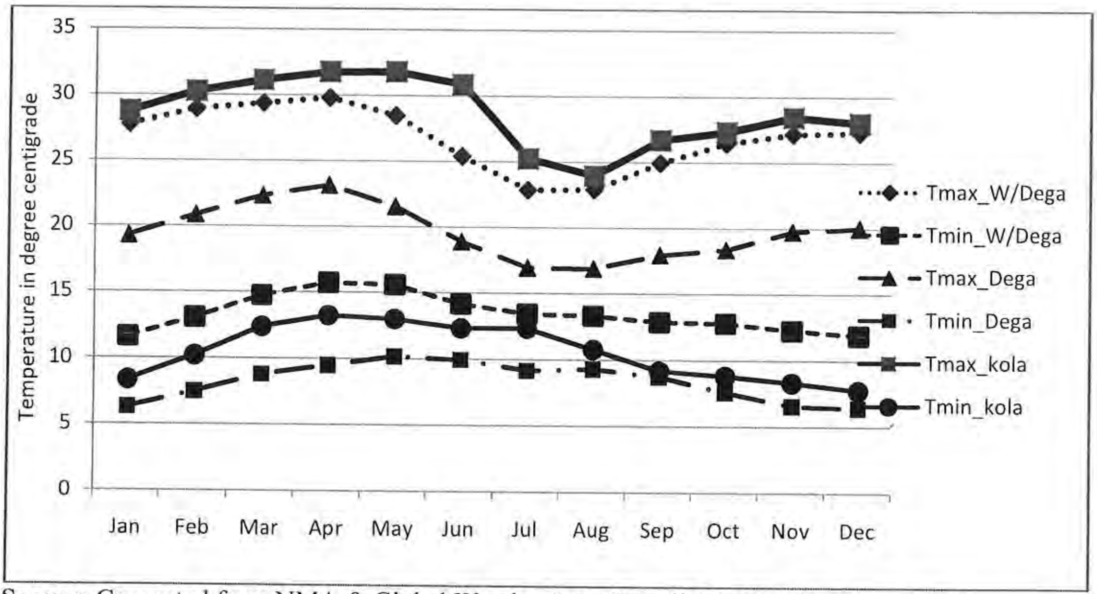
Figure 15: Long-term Tmax & Tmin deviations in *woyna dega* (2 years moving average)



Source: Computed from NMA, 2012 & Global Weather Data [http://globalweather.tamu.edu/]

Figure 15 demonstrates the maximum and minimum temperature deviations from the long-term average temperatures for *woyna dega* study site. It is clear from the figure that until 1984 the deviation between maximum and minimum temperatures was almost similar. After 1984, increasing trend of deviations were detected both in the minimum and maximum temperatures with greater fluctuations over time. Analysis of temperature trend showed similar trends as the one reported by IPCC (2007) and Mongi et al. (2010). The IPCC reports pointed out that climate change have added difficult situations to the tropical and sub-tropical regions of the world where the temperature is already very high (IPCC, 2007).

Figure 17: Average monthly maximum and minimum temperature by agro-ecology



Source: Computed from NMA & Global Weather Data [http://globalweather.tamu.edu/]

From Figure 17 it is very clear that the lowest maximum temperature was recorded in July and August in the three study sites whilst the highest maximum temperature was observed in April and May. The effect of cloud cover is the reason for having lowest maximum temperature in July and August in the three sites. In terms of minimum temperature, the highest was observed in April and May, whereas the lowest was from November to January in the three sites.

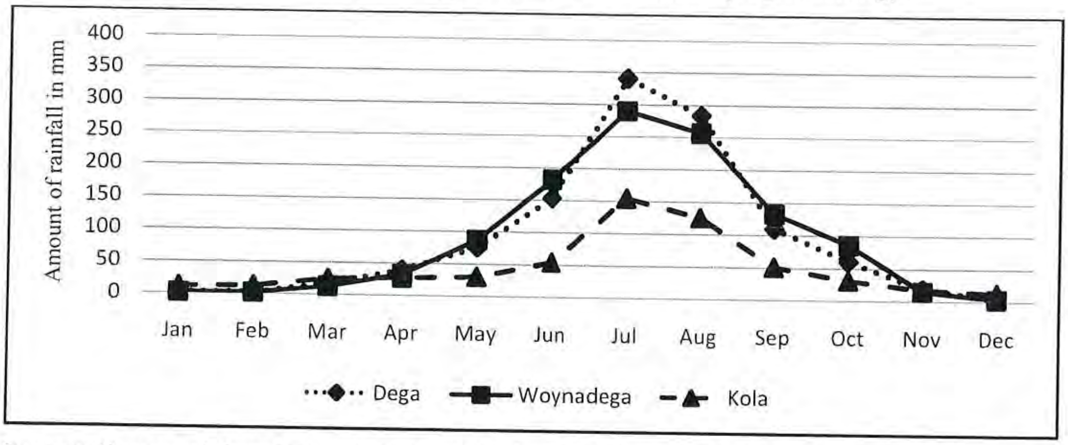
4.1.2. Rainfall variability and changes

4.1.2.1. Seasonal rainfall variability

The meteorology data for the period 1979 to 2010 indicated that the overall rainfall amount and distribution was varying in time across the three study sites. The *dega* site receives rainfall amount ranging from 732 to 1787mm. The range of total annual rainfall in *woyna dega* study site has become lower (870 – 1394mm) than the rainfall recorded in *dega* site. The site has experienced unimodal (*Meher*) rainfall pattern usually from Mid-June to Mid-September. Much lower total annual rainfall (554 to 847 mm) was detected in *kola* site of Abay-Beshilo Basin than in *dega* and *woyna dega* study sites. In addition, rainfall is erratic in the lowlands below 1500 m and averages below 600 mm.

The most important feature observed in the rainfall data is the greater inter-seasonal variation in the three study sites. It is clear from figure 18 that the highest rainfall in all the study sites was observed in the month of July followed by August. June ranks third in getting the highest rainfall in *woyna dega* (181.54 mm) and in *dega* (152.91 mm) followed by September with an average record of 132.44 mm and 109.5 mm respectively. December, January and February are very dry months in *woyna dega* and *kola* while *dega* site has received at least 22 mm average rainfall amount.

Figure 18: Long-term monthly average rainfall distribution by agro-ecology



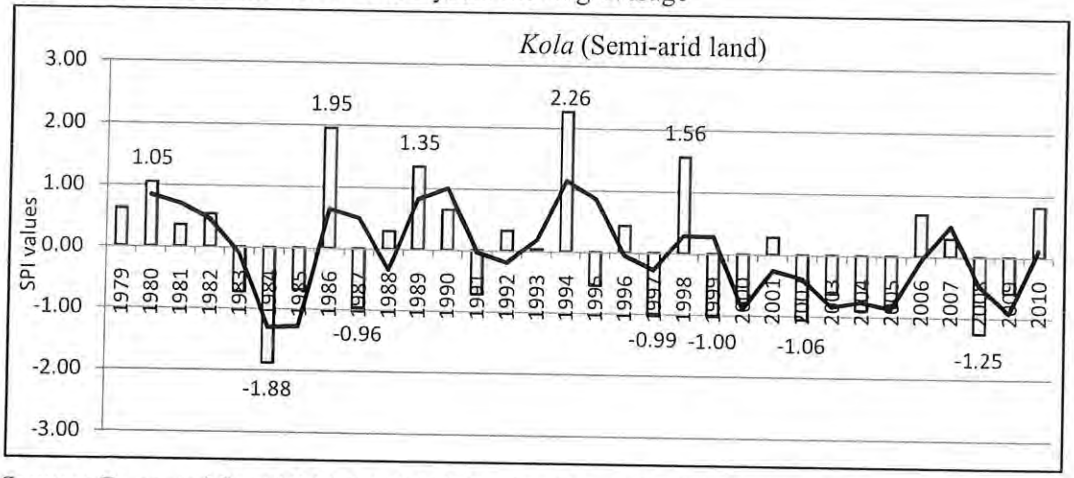
Source: Computed from NMA & Global Weather Data [http://globalweather.tamu.edu/]

The monthly mean rainfall pattern in the period 1979 to 2010 ranges from 2.08 mm in February to 340.32 mm in July in the *dega* site, from 1.73 mm in January to 289.51 mm in July in the *woyna dega* site, and 0.49 mm in September to 154.09 mm in July in the *kola* site. The average annual rainfall for the same period was 1106.18 mm in *dega*, 1096.7 mm in *woyna dega,* and 686.95 mm in *kola* sites. The rainfall occurs mostly during the summer season (usually from Mid-June to Mid-September), often falling as intense storms. About 80.11% of the annual total rain in *dega*, 78.15% of *woyna dega*, and 70% of *kola* was received from June to September.

Precipitation concentration index (PCI): In order to characterize the monthly distribution of rainfall, PCI was calculated by applying formula 3.4.1E presented in Chapter Three. The PCI values showed that rainfall in the three study sites is mainly characterized by high concentration in a few months. These PCI values indicate greater variability of monthly rainfall distribution in the study sites. As can be seen from Table 8 below, the rainfall concentration in *dega* and *woyna dega* areas range from 19 – 33 and 17.22 – 30.36 (high to very high concentration) respectively and 8 – 15 (uniform to high concentration) in the *kola* sites. This means, the rainy days with very high rainfall amount range from 8 – 15 in *kola* and vice-versa in *dega* and *woyna dega* study sites.

The standardized precipitation index (rainfall anomaly) for the *woyna dega* site is shown in figure 21. Similar to the *dega* site, the rainfall is described by alteration of wet and dry years in a periodic pattern. Out of 32 years, 14 years (43.75%) recorded below the long-term average annual rainfall amount while 17 (53.13%) years recorded above-average. Only the year 1999 received equal rainfall amount with the long-term average rainfall. Most of the positive SPI values occurred before 1990 (9 out of 12 years). Consecutive negative SPI values occurred from 1990 to 1995 and 2002 to 2004. The 2002 rainfall amount was the lowest record in the observation period with SPI value 2.67. According to the drought assessment method by Agnew and Chappel (1999) referred by Woldeamlak (2009), there were seven drought years in the period spanning from 1979 to 2010 in the site, with varying severity. There were one extreme (2002), and four moderate (1990, 1991, 1992 and 2008) drought years, and one severe drought, which together account for 21.88% of the total number of observations. In contrast, 1998 was the wettest year in the period followed by the year 1996 (almost consistent with the anomalies of Amhara region by Woldeamlak). This wettest year may be associated with the probability of flood incidences with SPI values of 1.87 and 1.45 in 1998 and 1996 respectively.

Figure 22: SPI for *kola* zone with 2 years moving average



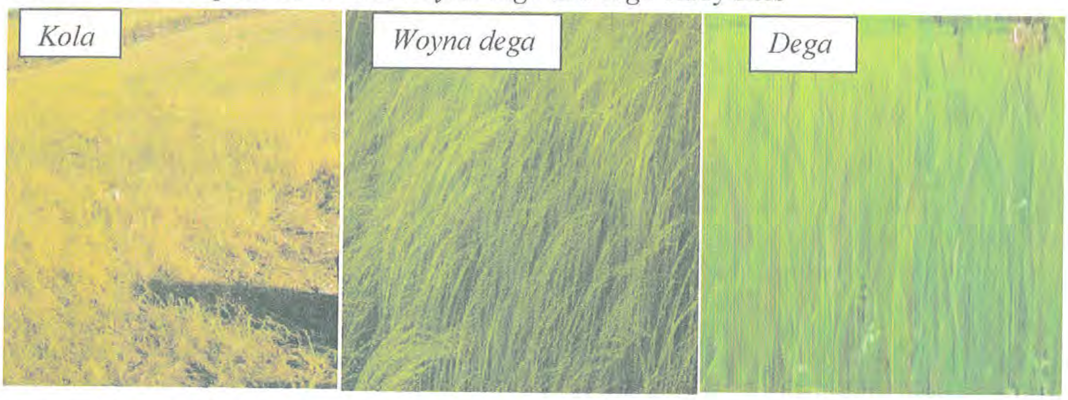
Source: Computed from NMA & Global Weather Data [http://globalweather.tamu.edu/]

Figure 22 demonstrates the standardized precipitation index for *kola* study site (1979 – 2010). It is clear from the figure that rainfall is characterized by periodic fluctuation of wet and dry years. Out of 32 years of observation, 15 years (46.88%) recorded below the long-term average annual rainfall and the rest 15 years recorded above the long-term average. Only one year received nearly normal rainfall in the period. Before 1983, the rainfall was above the long-term average whilst from 1983 to 1995, it was below the long-term annual rainfall. Again, in 1986 positive SPI value was detected in spite of its

The previous quantitative results and discussion were based mainly on secondary data generated from NMA and Global Weather Data for SWAT. This sub-chapter also needs to triangulate and check the quantitative results with some qualitative information extracted from surveys, FGDs, in-depth interviews and field observation. The results indicated that one of the major hazards is found frequent drought in the three sites with varied duration, magnitude, and severity. It is found the most frequent shock particularly in *kola* and *dega* sites while it ranked fourth in *woyna dega* study site (See Annex 6a).

The three snapshots in photo 1 demonstrate the field crops in *kola*, *woyna dega* and *dega* study sites. *Teff* crop in the left showed very poor growth in *kola* site in the year 2012/13 due to early cessation of summer rainfall. Better *teff* crop growth was observed in *woyna dega* site, and wheat in *dega* site, with a relatively good growth status. The experts and the communities from the study sites asserted that drought frequency, particularly in *kola* site used to occur in every 5-8 years, but now it occurs every 2-3 years and perhaps every year in the deeper parts of the Abay-Beshilo Basin.

Photo 1: Field crop status in *kola*, *woyna dega* and *dega* study sites



Source: Own field photo and by assistants in 2012 cropping season

The informants strongly complained the delayed onset and/or early cessation of summer rains. These situations were confirmed by interview and discussion results in *woyna dega* and *kola* study sites as:

> In the previous time, the rain started in March interspersed with certain dry periods to continue up to October with no severe erosion on the land resources and less damage to crops and grazing lands. However, nowadays the situation significantly changes. The rain usually starts at the end of June/beginning of July and stops at the end of August/early September in the flowering and fruit-bearing stages of most cultivated crops. Later, it comes again in November and December causing tremendous shocks on matured and harvested crops in the field. This untimely rainfall event sometimes has come being accompanied with heavy storms and snowfalls to make the matters even worse.

Other studies also confirm that severe drought ravaged Ethiopia for many of the last 40 years due to the failure of main rainy seasons in the summer that accounted for 65–95% of the total annual rainfall (Devereux, 2000; Dercon, 2004; Dercon et al., 2005; Segele & Lamb, 2005).

Aridity Index: For a given region, the annual mean evapo-transpiration rate is governed primarily by the amount of available energy and precipitation. The primary control of energy (net-radiation) and precipitation in determining annual evapo-transpiration rate has been long recognized. It has been observed that annual evapo-transpiration approaches annual precipitation in regions where the available energy greatly exceeds the amount required for evaporating annual precipitation. Conversely, in regions where available energy is a fraction of the amount required to evaporate the entire annual precipitation, the annual evapo-transpiration approaches potential evaporation (Arora, 2002).

To understand further dry and wet conditions of the year in terms of moisture demand for agriculture, the aridity index was computed using equation 3.4.1D presented in Chapter Three. The main purpose of calculating the aridity index is to identify the months which need irrigation for crop production. According to Zhang et al. (2009), irrigation is needed when the aridity index (AI) is less than 20.

Table 9: Long-term average monthly aridity index (AI) by agro-ecology

Month	Aridity Index		
	Dega	*Woyna dega*	*Kola*
January	1.32	0.70	7.99
February	1.03	0.84	8.58
March	8.05	4.83	15.05
April	18.11	11.86	16.57
May	35.16	32.69	18.40
June	75.13	73.17	32.38
July	177.12	123.47	86.22
August	147.18	109.26	72.70
September	56.30	55.00	35.92
October	31.40	34.74	22.23
November	9.55	5.95	12.87
December	2.22	1.39	9.20

Source: Computed from NMA, 2012 & Global Weather Data [http://globalweather.tamu.edu/]

Table 9 shows the long-term average monthly aridity index (AI) (1979-2010). Aridity index in the *kola* site is found to be much lower in July (86.22) and August (72.7) than in *dega* and *woyna dega* study sites. According to the standard set by Zhang et al. (2009), it

Untimely rainfall: Untimely rainfall in crop harvesting and threshing seasons (October to December/January) was also reported by interviewees and discussants in *kola* and *woyna dega* study sites. This event damages matured crops and spoils gathered crops in the farmers' farmlands. When the field work was conducted in October and November 2012 there was untimely rainfall in *kola*. To save crops from damages, the farmers were collecting crops through traditional helping mechanisms (*'debo'*), which is part of the social capital. During the same time, *woyna dega* and *dega* crops were in the growing, flowering and fruit bearing stages. Therefore, the October and November rainfalls is advantageous to some crops particularly in *dega* site but it becomes devastating when it fails after Mid-November to January/February. In the *woyna dega* study site untimely rainfall has both positive (for flood recession agriculture) and negative (for flood free areas) effects. During the field work for observation and in-depth interviews in January 2012 and February 2013 there were crops in the field. Accordingly, the farmers seriously complained the adverse effects of untimely rains in *woyna dega* sites particularly in flood free areas.

Flood and soil erosion: Flood is the major climate-related extreme event reported by the farmers of the three study sites. In *kola*, flash floods associated with severe soil erosion are the devastating extreme events as it receives higher rainfall for only July and August with less or no rainfall during the other months of the year. When the rain comes, it falls hard followed by intense flooding without recharging underground water, removing away soils, devastating agricultural production, and beating down the cultivated crops. Soil erosion is found to be relatively less in the dega site because it is situated in the relatively flat highland topography as compared with the undulating *kola* site.

The advancing of water from Lake Tana and overflows of river waters from Megech, Dirma, and others exceptionally affect the people of *woyna dega* sites in nine *kebeles* (See photo 2). Intense rainfalls in July and August accompanied with forceful run-off and silting up of riverbeds has led to further flooding of the surrounding areas including residential compounds. Soil erosion has created rills, fractures, and deep gulley in the thicker, fertile lands of the *dega* site and farmland and rangeland fertility have been gradually going down. However, unlike Dembia (*woyna dega*) households, *dega* households are less likely to be affected by intense flooding because the sites are located in a relatively flat topography. In this regard, FAO (2003) and UNESCO (2004) underlined that slopes are one of the parameters of the terrain to worsen soil erosion.

Photo 2: Flood and displaced people in temporary shelter in Dembia, July-August 2012

Source: Field photo by assistants July, 2012

Photo 2 demonstrates the flood incidence in the *woyna dega* site from July to August 2012 and the people in temporary shelter. The data obtained from the *Woreda* Office of Agriculture indicated that 189, 981 people in the nine *kebeles* have been exposed to flood incidences and many of whom have been displaced and resettled in the temporary shelters with the support of governmental and non-governmental organizations in most summer seasons of the years. By the incidence, the agricultural lands, the schools, the health institutions, the residential houses, the roads and the bridges have been flooded and damaged.

Crop pests: Farmers' livelihood activities are also affected by different weeds, pests and insects. Interviewed farmers reported that they have lost a lot of crops in the past as a result of pest infestation in all the three sites. However, the impact varies across the three study sites. For example, crop pests ranked as the first problem in the *woyna dega* site, 4th in *kola* and 3rd in the *dega* site, marking it as the frequently occurring extreme event in the *woyna dega* site. The flat, warm, and humid nature of the area enhances the infestation of different crop pests. According to the information obtained from interviews with agricultural experts and managers, the common crop pests are African ball-worm and aphids in all the three study sites while stalk borer, shoot fly, Wollo bush cricket, army worm, and cutworm are more in *kola* and *woyna dega* sites. It was also reported that the African ball-worm and aphids can damage mostly peas, beans, and chickpeas. Although bird infestations on cereals were reported in all the three study sites, it was extreme in *dega*, affecting highland fruits and vegetables. When extreme pest infestations occur, treatment has been available from the Bureau of Agriculture on sale and for free. However, controllable infestations have been encouraged by local protection mechanisms in order to prevent the adverse environmental effects of sprayed chemicals.

Crop diseases: By crop diseases, the *woyna dega* and *kola* sites are reported to be the most affected areas ranking 1st and 4th respectively. Interview reports from agricultural supervisors and project managers indicated that the common crop diseases are found to be yellow rust, smut, and root-rot in *kola* and *woyna dega* sites. Powdery-mildew and root-rot were also reported in the *dega* site to damage highland fruits and vegetables. According to the agricultural supervisor, these crop diseases have usually occurred around the end of August when the relative humidity increases. Farmers, local leaders, experts and extension officers recognized the link between climate variability and increased incidences of crop pests and diseases. Other reports in Ethiopia and Tanzania also indicated that the changing temperature regimes will affect not only growing seasons, but also the prevalence of pests and disease that attack the cultivated crops. These impacts are anticipated to have very significant implications for the livelihood bases of the poorest farmers (Mongi et al., 2010; Leulseged et al., 2013).

Human diseases: According to the survey results, increased trend of human disease were reported in the *kola* and *woyna dega* study sites, particularly during warmer periods and drought years. The *woyna dega* site was found to be most affected site by prevalence of human diseases, mainly malaria and water borne diseases ranking as the 3rd problem by the interviewed households. For example, the water logging and flood affected flatland of the *woyna dega* site (Dembia *woreda*) is suited for malaria breading. Like other shocks, its incidence is rare in *dega* as it ranked to be the 6th extreme weather-related event. In line with this finding, McSweeney (2010) also noted that the most common climate change-induced human diseases in Ethiopia are malaria, dengue fever and diarrhea.

Livestock diseases: climate-induced livestock diseases have also created health shocks in the study sites. The survey results indicated that it ranked 3rd both in *kola* and *woyna dega* sites whilst it was reported as the 7th extreme event in the *dega* sites. In other words, livestock disease is a less frequently occurring weather-related extreme event in the *dega* study site. However, when livestock diseases occur, the threat to the farmers' livestock production is found to be much severe in all the three study sites.

Although efforts have been made in the form of medical treatments, the incidence of livestock disease in the study sites is prevalent. In *kola*, the veterinary technician (May 2012 and November 2012) noted that the livestock species are weak in resisting disease, partly due to decreasing pasture availability and quality as well as increasing water stress. He recognized anthrax and black leg as the major catastrophic livestock disease in the dry periods of the *kola* sites. The technician also added that almost all other animal diseases are prevalent nowadays, usually at the beginning and end of the short and main rainy reasons. This result is supported by Liu (2007) who asserts that unusual periods of rain-free weeks result in high livestock mortality rates by increasing the likelihood of food and water shortages in the Asian and Pacific Regions. During the field work from April-June and in November 2012, in the *kola* site, farmers were reporting the incidence of livestock disease and they were also asking the veterinary technician for vaccination campaign. I also personally observed in the field that the nearby farmers were bringing their cattle to the veterinary clinics for medical purpose (Photo 3).

Photo 3: Diseased cow in veterinary clinic in *kola* and hungry one in *dega*

Source: Own field photo November, 2012

Photo 3 shows the thinner cattle as they have been affected by feed shortage and the resultant livestock diseases. This implies that livestock keeping has become a serious problem from time to time. In the light of this situation, Leulseged et al. (2013) recognized that in recent years a complex set of factors such as increased rainfall variability, rising temperatures, invasive species, conflict and overgrazing are forcing huge changes within farming communities in Ethiopia. The farmers usually feed their livestock by collecting and preserving and/or purchasing straw and hay throughout the year. The problem was expressed by participants in in-depth interview in *kola* study site as:

> In the previous times, there was plenty of grass and vegetation in our surroundings. We simply released our animals into the field to feed them with more abundant grass and vegetation species. Now we do not release our animals the way we used to because there is no grass and vegetation cover. Furthermore, the officials introduced a new strategy of feeding animals by keeping in sheds, and thus numbers of animals we have owned are becoming far fewer. Some people buy straw/hay to overcome the feed problem; some send to relatives in the very deep gorges of Abay and Beshilo. However, this latter solution is also becoming in trouble as these gorge areas are severely degrading and are unable to grow sufficient grasses and bushes. Nevertheless we are getting poorer because of severe environmental degradation, recurrent drought, low productivity of agricultural lands and fewer numbers of animals we have owned.

Woyna dega and *dega* households also reported similar livestock health and feed problems. The survey results indicated that 54.1% of the *woyna dega* and 41.4% of the *kola* households have used free grazing on common lands while only 12.4% of them have used it in *dega* site. This result is quite consistent with the reported strict control over common forest resources in *dega*. Almost all households have used crop remnants (straw) and hay to feed their animals which may have negative implications on land fertility management activities, however. The field observation in 2012 summer and 2013 winter confirmed the seriousness of livestock feed shortage in three study sites. Accordingly, the death of many livestock was reported by the surveyed households in three study sites. However, the maximum death of animals was reported in *kola* (20.3 Tropical/Total Livestock Unit/TLU) than the maximum average of 12.43 TLU and it is 12.2 TLU in *woyna dega* which is almost similar to the maximum average. The lowest TLU died was reported in *dega (*4.8 TLU).

Table 10: Comparisons of the mean TLU died by climate hazards in the past 5 years

(I) Agro-ecology	(J) Agro-eology	Mean d/nce (I-J)	SE	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Dega	*W/dega*	-.66278	.30711	.080	-1.3846	.0591
	Kola	-2.28105*	.26631	.000	-2.9070	-1.6551
Woyna dega	*Dega*	.66278	.30711	.080	-.0591	1.3846
	Kola	-1.61827*	.26562	.000	-2.2426	-.9939
Kola	*Dega*	2.28105*	.26631	.000	1.6551	2.9070
	W/dega	1.61827*	.26562	.000	.9939	2.2426

*The mean difference is significant at 0.05. **Source**: Household survey, March – September 2012

Table 10 illustrates the comparisons of the mean TLU died by climate-related hazards in the past 5 years by agro-ecology. It is clear from the table that the average number of tropical livestock unit (TLU) died was higher in *kola* (3.1 TLU) than *woyna dega* (1.5 TLU) and *dega* (0.8 TLU). This means that the number of tropical/total livestock unit (TLU) died is by 52% higher in *kola* than in *woyna dega*. Similarly, *woyna dega* area is by 46% higher than *dega* site (Refer to Table 10 above). This indicated that the vulnerability context of the households to climate change impact by number of livestock death is much higher in *kola* than in *dega* and *woyna dega* study sites. Studies also confirm that changes in temperature, precipitation and wind patterns affect pathogen and vector habitat suitability, affecting human health and livestock resources. Heat stress and drought are likely to have further negative impact on people's and livestock health and disease-resistance (IPCC, 2007).

4.2. Land and forest resources degradation

Another important biophysical vulnerability context depicted in the conceptual framework is land and forest degradation. The topographic characteristics, the households' farmland locations, erosion intensity and fertility levels and forest supply situations are the fundamental characteristics (contexts) to predict the sensitivity of the households to the impacts of climate change and extreme events.

The basic data types used in this sub-chapter are household survey data and qualitative information. The data were used for analyzing farmland topographic characteristics, erosion intensity and farmland fertility status; and for measuring households' access to forest resources supply trend. Similar to other sub-chapters, the quantitative results were also triangulated and checked through FGDs with selected participants, in-depth interview with experts, office heads, and farming households. Field observations were also conducted including taking images which can support the quantitative and qualitative results and comparing the biophysical and socio-economic contexts across the three agro-ecological zones. The results and discussions are presented in the next sub-sections.

4.2.1. Farmland erosion and fertility levels

Farmland erosion severity and fertility levels are powerful vulnerability contexts in influencing the total production and productive capacities of farming households who have already settled and done their economic activities in the fragile environments. The surveyed data was analyzed using descriptive statistics, namely percentages. The results found out that farmlands situated in the dissected landscapes such as rugged terrain, deep valleys and mountain ridges as well as flood-prone areas, are highly sensitive to soil erosion, mass movement, landslide, flooding, and consequently to poor soil fertility and to fast productivity decline – as a result leading the farming households to higher vulnerability levels to climate change and variability.

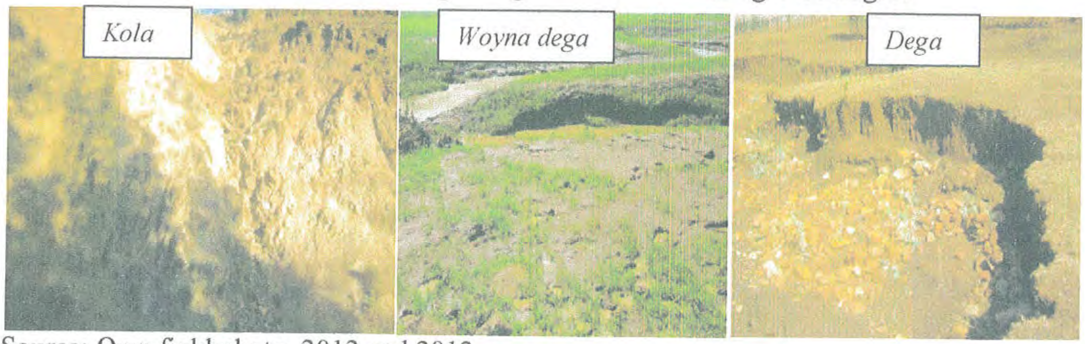
Table 11, depicting the survey results, show the percentage of households by farmland location, intensity of reported soil erosion, and farmland fertility level in the three study sites. The results indicated that higher proportion of *kola* (65.4%) households have owned farmlands located in a very rough topography which has made the farmlands most susceptible to severe soil erosion, accelerated soil fertility decline, and in turn agricultural production to go down than the *dega (*36.4%) and *woyna dega* (22.6) households. The reasons are as presented in sub-section 4.1.4 under the discussion of flooding and soil erosion. Field photos depicted below show this worst biophysical vulnerability context.

located. Only 7% of the households in *dega* (relatively flat highland area) and nearly 4% in *woyna dega* reported the same. The majority of the respondents (82%) in *woyna dega* and nearly 74% in *dega* rated their farmland fertility level as medium while 34.2% in *kola* reported the same fertility level. This farmland fertility level has in turn great implications on agricultural productivity and food security situations of the studied households.

The results are mostly associated with the hazard-of-place model as these topographic contexts help to measure the farmers' degree of exposure and sensitivity to climatic hazards (Cutter, 1996; Cutter et al., 2003). This model noted that the hazard potential is influenced by a geographic exposure such as site, situation, and proximity to the sources of hazards, and the socio-economic conditions of places such as the ability to respond, to cope up with, to recover from, and to adapt to such hazards. Other studies also argue that the parameter of sensitivity is strongly linked to location and is evaluated by the inherent characteristics of places, considering human-environmental relationship, where both social and biophysical characteristics influence this relationship (Turner II et al., 2003; Gallopin, 2006). Places having infertile land continue to suffer from low rates of economic growth and pervasive poverty. This situation is evident in the *kola* site of Abay-Beshilo Basin. The fragile environment dominated by undulating topography in the *kola* site exposed the area to severe soil erosion resulting in poor farmland fertility and lamentable agricultural production. In the light of this result, FAO (2003) and UNESCO (2004) again underlined that slopes are one of the parameters of the terrain to worsen land degradation and soil erosion.

Land degradation can be both an impact and an amplifier of changing weather patterns. When the field survey was carried out from March to the end of June 2012, large areas in *kola* areas are completely devoid of green cover even during the rainy seasons, except cropped areas. Most areas have no soil cover left, bore soils and bedrocks can be seen over extensive areas; grazing lands are already over-stocked, and crop residues are used to feed animals. These and other contexts have worsened the vulnerability level of the studied households and the ecological systems as a whole (See Photo 5).

Photo 5: Observable bedrocks and degrading lands in the three agro-ecologies



Source: Own field photo, 2012 and 2013

Photo 5 shows the already observable bedrocks in *kola*, flood plains area in *woyna dega* and deep soils but severely degrading in *dega* study sites. With increasing population pressure, the intensively cultivated areas are heavily used and grazing lands are now under increasing stress. The result is cracked land leading to deep gulley and rills (Photo 6). Gullies and rills are indicators of considerable topsoil loss in the slope depressions. The very low vegetation cover has fostered the erosion process affecting farmlands and grazing lands, which in turn have worsened the situations of the study sites.

Photo 6: Pressure on grazing land in *dega* study site

Source: ACCRA, 2011(the first) and own field photo (the right), 2012

As it can be seen in snapshot 6, overgrazing is a severe trouble in the over-populated places of the studied areas. Rangelands are under pressure due to overgrazing and encroachment of crop farming. In addition to the widespread degradation of land resources, the increase in invasive alien species has been a recent-onset phenomenon from the early 1990s onwards in Ethiopia (Leulseged et al., 2013). Invasive weed species are usually characterized by rapid growth, and they typically replace other, more desirable indigenous plants. These species usually damage cultivated plants by competing with them for sunlight, water, and mineral nutrients. The spreading of the invasive alien plant species has also invaded vast areas in the Lake Tana shore of Dembia (*woyna dega*) sites (Photo 7).

Photo 7: Invasive species around Lake Tana and the practice of weeding by the people

Source: Own field photo November, 2012

These invasive alien species are called '*hyacinth*' or locally known as '*emboch*'. Experts working in the area stated that these plant species are evading vast swampy areas with devastating impact on indigenous plants. The areal coverage of these species has rapidly increased. In addition to harming the plants, this weed can poison livestock when eaten and spoil the flavor of the milk produced by cows that consume this weed. Fishing, one of the sources of income for the local community, are also now in danger. In the light of this, Leulseged et al. (2013) also recognized the impacts of invasive species in Ethiopia as one of the complex sets of factors in forcing huge change within the lives of the community in recent years. To alleviate the problems of these invasive species the local government bodies have undertaken massive clearing campaign through community mobilization in the last winter (2012/13), but the plants have been spreading quickly to the vast water bodies and swamp areas (Photo 7) which have called for further integrated actions in order to curb the problems and to save the Lake Tana water from drying.

4.2.2. Forest resources and fuel-wood trend stability

As the forest resources are other measures of the vulnerability contexts in the rural households, forest availability and situations related to common forest resources protection using the survey data were examined. The analysis was done by calculating an index based on households' response[4] for the question "What was the forest supply trend for fuel-wood over the past 20 years or so? The households were expected to answer one of the three alternatives: increased, decreased, and no change (See Table 12 below).

[4] Equation 3.4.1F, *Chapter Three*

Table 12: Firewood supply trend stability over time by the three study sites

Agro-	Increased		Decreased		Constant		
ecology	Frequen.	%age	Frequen.	%age	Frequen.	%age	Index
Dega	111	86	9	7	9	7	0.79
W/dega	25	18.8	104	78.2	3	2.3	-0.60
Kola	4	1.5	258	98.1	1	0.4	-0.97
Total	140	26 .7	371	70.7	13	2.5	-0.44

Source: Household survey, March – September 2012

It is very clear from Table 12 that, the index of fuel-wood stability index discloses negative trend for *kola* (−0. 97) and *woyna dega* (−0. 60 index value) study sites indicating a considerably higher declining trend in forest resources. Exceptionally, positive trend was detected in *dega* (0.79 index value) which is most consistent with the temperate households of Othaya district of Kenya from which the households most often have practiced tree planting and nursery as compared with arid and semi-arid districts (Bryan et al., 2011). Field observation confirmed that in *kola* and *woyna dega* study sites, except in a few remote areas and around churches, there was no visible vegetation (Neither man grown nor natural). The expansion of settlements and croplands up onto steeper slopes further put immense pressure on the limited woodland resources in the *kola* study sites.

The positive index value (0.79) in the *dega* site implies improvement experienced in the supply of forest products to rural households as compared with the past decades. Interview reports identified three reasons. The first was that farmers have changed their farmlands to eucalyptus trees as the benefits from them in the long-run outweigh that of crop production. Nearly 87% of the surveyed households reported they had planted at least a few trees in the past wet season as compared with the *kola* (62%) and the *woyna dega* (44.4%) study sites. Relatively higher survival rates of the trees also encourage the farmers to do so. Therefore, the positive trend of forest resource supplies and the interview reports is found to be consistent with the households' response of tree planting practices. Eucalyptus trees are needed for fuel-wood, construction purpose, and recently to generate income. Trees help households to earn income and to cope up with food shortage. The sample households accounted selling of eucalyptus trees as a key coping strategy of food shortage that may serve as another impetus for planting more trees in the *dega* sites (Photo 8).

Photo 8: Seedlings and well protected man-grown forest areas in *dega* site

Source: Field photo by assistants (the left) and the researcher (the right), 2012

The interviewees also mentioned the practice of strictly coordinated control over producing and selling of charcoal and cutting of trees as the second reason for the positive trend of forest resources supply in the *dega* study site. Over 47% of the households in the *dega* site reported that there is strict control over common forest resources by government bodies followed by 27.8% of them in the *woyna dega* site. But only 6.8% of the *kola* households reported the same. The rest reported that there is weak forest control practice which has allowed open access to everyone and has led to serious damage to the remnant forest species. The third reason was attributed to the expansion of area closure practice through integrated programs of the Dabat *woreda* Agriculture Office, Organization for Rehabilitation and Development of Amhara (ORDA), and North Gondar Zone Sustainable Natural Resources Program Office. Now vast areas have been protected from encroachments of people and animals and hence the areas are being rehabilitated within short time, even in a year. Trees have started to grow, and tall grasses and wild animals have reappeared in the protected areas.

Although the percentage of households who reported planting trees cannot be undermined in the *kola* and *woyna dega* study sites, very low survival rates of the planted trees were observed during the field works. The focus group discussants and field observations also asserted low survival rates of planted trees, particularly in the *kola* site mostly because of recurrent drought and expansion of desertification. In this *kola* area, most landless poor households have also engaged in selling of firewood and charcoal with tremendous impact on remnant bushes and shrub-lands. In line with this, the strict control over forests was reported only by 6.8% of the households in *kola*. On the contrary, the awareness creation education on forest management in the households' locality was found to be more in the *kola* (69.2%) followed by in the *woyna dega* (nearly 59%) study sites. Only 48.1% of households in *dega* have got an awareness creation education on forest management. This implies that environmental conditions can dictate more participation of households in planting trees rather than educating them. Education may nothing to do without suitable environmental conditions that can determine survival rates of the tree species.

4.3. Economic situations of the three agro-ecologies

The conceptual framework depicted in Chapter 1incorporated the economic situations of households under vulnerability context. In deeded, the type of economic sectors the people engaged in are essential in determining their vulnerability level. Therefore, the economic situations of the surveyed households in the three sites were described in this sub-chapter. The office documents from *woreda* Offices of Agriculture, household survey, in-depth interviews and field observations are the main data sources for this sub-chapter. The detailed results and discussions for each sub-section including the respective types of data and sources are presented in the sections to come.

4.3.1. Crop production and livestock rearing

This sub-section presents the qualitative information obtained from office documents and interview reports. The information obtained from the World Vision Ethiopia, Dembia Area Development Program (ADP) document and Offices of Agriculture in Simada and Dabat woredas indicated that all the people living in the three study sites are dependent on rain-fed mixed farming (cultivation and animal rearing) like elsewhere in sedentary farming areas of Ethiopia. The major crops grown in *kola* environment are sorghum, haricot bean, maize, and *teff*; whereas the dominant crops in *dega* are barley, wheat and beans while the main livestock in *kola* are cattle, goats, equine, and in *dega* they are sheep, cattle and equines (ADP, 2012). Local agricultural wage labor along with sesame weeding and harvesting opportunities in Metema, Humera, and Quara are important income sources for the poor and very poor and for many people who are dependent on PSNP and firewood sales to meet their food needs (ACCRA, 2011). Trade across the river valleys is minimal in the dry season and impossible in summer. The Amhara Regional Government classified *kola* and *dega* study sites among the low-potential, food-insecure areas.

The *woyna dega* site of Dembia *woreda* is entirely situated in the Tana zuria livelihood zone where almost all the population groups are assumed to enjoy relatively good agricultural production. However, it is found to be more vulnerable to the impact of climate change and extreme events. The major crops grown are *teff*, maize, and red-highland sorghum. Pulses such as, chickpeas and cow peas are produced and some cash crops like paper, Niger seed, and fenugreek are also grown with limited farmlands. Livestock holdings such as sheep and cattle are relatively in modest condition. Livestock and butter sales make a substantial compliment to the dominant crop sales. Sheep are sold more often to earn income for regular expenses through the year. During religious festivals in April (Easter), September (New Year) and January (Christmas and Epiphany), when community members individually or collectively purchase animals for slaughter, there is higher demand in town markets. Cattle are high value assets mostly owned by middle and better-off households and they are sold sparingly, especially fertile females. Livestock condition is promoted by the relatively good availability of pasture and water. Pasture is supplemented by the purchase of crop residues after the harvest season. The information obtained from the *woreda* Office of Agriculture (OoA) indicated that the main hazards to livestock are anthrax, trypanosomiasis, pasteurellosis and black leg.

Paid work gives a supplement to crop sales in the income of poorer households, especially for weeding and harvesting. Nevertheless, local men also travel to Metemma and Humera to work, for being attracted by the high wages during the sesame and cotton harvesting seasons. Fishing in Lake Tana using nets and hooks is an additional income source for those living in the nearby areas of Lake Tana, peaking in February and March. Fish are also coming to the surrounding lands of Lake Tana together with flooding in July and August and hence collected by the fisher-men (Photo 9).

Photo 9: Fish catch by the surrounding farmers of Lake Tana during flooding

Source: Field photo by the field assistant, August 2012

The interview contacts with an expert working in the Area Development Program of World Vision, indicated that there 108 people organized under one cooperative to prepare fish products for internal and external markets to Sudan. However, there is no sufficient market link created so far.

Climate-related hazards discussed in sub-section 4.1.4 are major threats to food production in the study sites like elsewhere in Ethiopia. The majority of the households reported decreasing food crop and livestock production, which is not sufficient to cover household expenses. Although households from all sites reported food shortage, the problem is much severe in *kola* areas. Most of the poverty stricken *kola* areas have suffered from chronic food insecurity resulting from erratic distribution of rainfall, snowfalls, degraded farmlands, pests and diseases infestations, livestock disease, malaria and other human diseases, and small landholdings among other factors. This has left the population dependent on food-aid, particularly in the kola site.

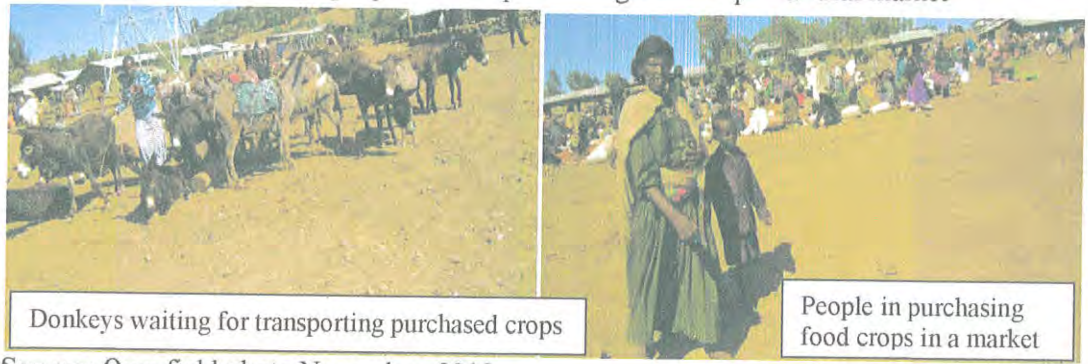
Table 13: Average number of months and households faced with food shortage

Indicators	Unit	*Dega*	*W/dega*	*Kola*
Average months with food shortage in a year	Months	3	2.6	4
Households faced with food shortage in a year	Percent	83	79	91
Household members who take less than 3 food items/day	"	54.3	66.7	90.7
Household members who take less than 3 meals/day	"	20.2	14.3	66.2
Households unable to save food crops for future use	"	89.1	88.6	96.2
Households unable to save seeds for the next sowing season	"	31.8	14.3	31.2

Source: Household survey, March – September 2012

It is clear from Table 13 that 91% of the households in *kola*, nearly 83% in *dega*, and 79% in *woyna dega* reported to have faced with food shortage at least a month in the drought and snowfall years. The average maximum number of months in which they faced food shortage was reported to be 3 in *dega*, 2.6 in *woyna dega* and 4 in *kola* sites. Consequently, there have been people who receive food aid ranging from 3 to 9 months in *kola* and *dega* sites. There is no food aid program in the *woyna dega* site. The surveyed households were asked about the coping mechanisms they use in times of food shortage. Their report indicated that the major coping strategy in all the study sites was selling livestock (89.1 of the *dega*, 78.2 of the *woyna dega*, and 77.7 of the *kola* households) to purchase food in rural markets (see Photo 10). Other studies also identified that selling of livestock has been the most common coping mechanism to climatic shocks, informing that in addition to serving as source of power for farming and manure for maintaining farmland fertility, livestock serves as a store of wealth providing insurance against climatic shocks (Temesgen, 2010, Barungi & Maonga, 2011).

Photo 10: Drought affected people in *kola* purchasing food crop in a rural market



Source: Own field photo November, 2012

4.3.2. Crop productivity and trend of yield stability

Crop productivity per hectare and trend of crop yield stability are the most important contexts for measuring land quality and livelihood security of the surveyed households. To measure the quality of land, crop yield was analyzed based on the data collected from a household survey. In the survey questionnaire the households were asked to give the amount of major crops produced in quintal in drought and non-drought conditions. For analyzing crop productivity, the average yields of the drought and non-drought years were calculated to obtain annual crop yield per hectare for different crops. Then the average of the major crops of the three study sites were taken for analysis using One-way analysis of variance (ANOVA). The mean yield of major crops for individual households was also presented in a scatter plot for making comparison across the three agro-ecologies. The households were also asked about the trends of their major crops' productivity per hectare (yield) over the last 20 years or so with the alternative responses of: 'increased', 'decreased' and 'constant'. The responses were analyzed using descriptive statistics and an equation depicted in 3.4.1F. The results are demonstrated, interpreted and discussed in the next sub-sections, under 'a' and 'b'.

(a) Crop productivity: The survey results indicated that crop production deviates over space and time due to variation in the quality of farmland and climatic conditions besides to other factors. There is considerable variation in the average productivity of cereals, pulses and other major crops by agro-ecology. Although it seems underestimated, average productivity was found to be five quintals per hectare in *dega* (maximum = 19.3, minimum = 1.4, and standard deviation = 2.77), 4.32 in *woyna dega* (maximum = 13.6, minimum = 1, and standard deviation = 1.82), and 2.77 in *kola* (maximum = 10, minimum = 0.5, and standard deviation = 1.41) which is found to be much lower than the national average of one tone per hectare for cereals. This simply implies how agriculture in general and crop production in particular is performing differently in the three study sites against the national level average crop productivity/yield.

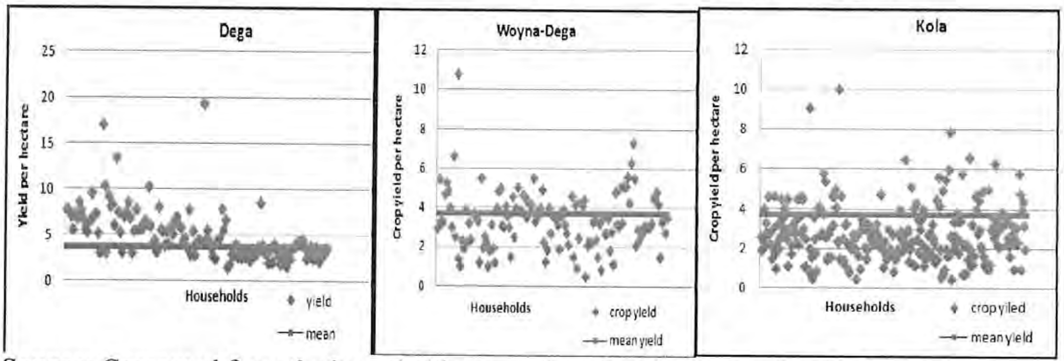
Table 14: Mean difference in crop productivity between agro-ecologies

(I)Agro-ecology	(J) Agro-ecology	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Dega	*Woyna dega*	0.68440*	.23848	.012	0.1239	1.2449
	Kola	2.24136*	.20718	.000	1.7544	2.7283
Woyna dega	*Dega*	-0.68440*	.23848	.012	-1.2449	-0.1239
	Kola	1.55697*	.20560	.000	1.0737	2.0402
Kola	*Dega*	-2.24136*	.20718	.000	-2.7283	-1.7544
	Woyna dega	-1.55697*	.20560	.000	-2.0402	-1.0737

*The mean difference is significant at 0.05. **Source**: Household survey, March – September 2012

Table 14 shows the mean variation in crop yield between the three study sites. The Analysis of one-way Variance (ANOVA) significant at 0.05 level indicated that crop productivity in the *dega* site is found to be higher by 0.68 quintal than in *woyna dega* and by 2.24 in the *kola* site. In *woyna dega,* crop yield is higher by 1.56 quintals than in *kola*. The degraded *kola* site provided very low crop production consistent with the hazard of place model.

Figure 23: Yield of major crops against mean yield of the three agro-ecologies



Source: Computed from the household survey data, March – September 2012

As the scatter diagram demonstrates (Figure 23), the majority of the households in the *dega* site are concentrated above or around the mean yield of the three study sites. The great majority of *kola* and *woyna dega* households are concentrated under the mean yield. The reasons are attributed to the factors mentioned in sub-chapters 4.1(4.1.3, 4.1.4) and 4.2. The result is supported by the findings of the IPCC (2007) that crop production was projected to increase slightly in the cooler regions for local mean temperature which rose up to 1-3°C. This may be due to the beneficial opportunities that climate change has brought by increasing growing seasons for crops despite climate change aggravates land degradation.

reported figures. I triangulated this report taking it to older household heads. They absolutely rejected the experts' reports even before 40 and 50 years ago when there was surplus production there. Information provided by the households does justify that crop yields are gradually going down in their locality though it seems somewhat deflated for outside observers and general national observers. In addition, as I was born, grew up, and worked in the farming households, crop yield is going down in the fragile landscape of northern Ethiopia. Triangulation was also done through visiting the households when they harvested and threshed their crops in the field which further justified the households' responses.

The above results does not mean that there is no growth in total production of the country as this is observed in its total agricultural production and in some households living in modest environmental conditions for new technology packages, good land management practices and irrigation justified reported increasing crop productivity over time. However, some scholars also related the effectiveness of new technology packages (at least partially) in boosting crop production with good weather conditions (Taffesse et al., 2011). They also argued that rather than technology adoption, the major factor behind the growth of total production in Ethiopia has been expansion of cultivated land area. For example, grain production has registered a growth of 74%, with yield growing by only 18% and area cultivated by 51% between 1989/90 and 2003/04. From 1994 to 2002, 70% of cereal production increases resulted from expansion of cultivated land area (Taffesse et al., 2011) and it is in an increasing trend in recent years. However, cultivable lands are already exhausted in the study sites so that there is no possibility of expanding agricultural land by households. Hence, the results seem logical for the fragile landscapes of northern Ethiopia where rain-fed crops are more sensitive to climatic anomalies. Rainfall variability is important determinant contexts of livelihoods of the community in Ethiopia. Good climate is needed to keep sustainable agricultural production for having better livelihoods of households.

CHAPTER FIVE

VULNERABILITY LEVELS OF FARMERS TO CLIMATE CHANGE

The results of objective two (second research question), assessment of vulnerability levels of households by agro-ecology, is presented in this chapter. As it was clearly discussed in chapter two, vulnerability is the combined effect of natural and socio-economic dimensions of the affected system. This chapter analyzed the vulnerability levels of the rural households to climate change impacts in terms of five capitals, climatic factors and adaptive capacities in *dega*, *woyna dega*, and *kola* study sites guided by integrated vulnerability assessment framework of sustainable livelihood approach. Analysis of the vulnerability levels of households was done by integrating multiple indicators using the livelihood vulnerability index. To address the second objective of the thesis, this chapter is organized into three main sections: vulnerability levels of households by climatic exposure, five capitals (human, natural, economic, physical and social and institutional capitals) and adaptation practices.

5.1. Doing livelihood vulnerability index (LVI) and statistical tests on LVI

Both secondary and primary data were used in this chapter based on Hahn et al. (2000). These authors strongly argue that both primary and secondary data can be used to construct the livelihood vulnerability index so that it helps avoid the problems of relying on a single data source and dependence on climate models, which need advanced skill and are uncertain to give correct projections for local conditions (Hahn et al., 2009). Accordingly, the data used in this chapter were generated mainly through household survey on the five livelihood assets/capitals, hazards frequencies and adaptation strategies applied by the surveyed households. In addition, for calculating exposure indices monthly standard deviations of temperature and rainfall were computed from interpolated meteorological data (See Annex 3). For calculating crop diversification index (inverse) using equation depicted in Annex 6b, the secondary data obtained from Offices of Agriculture was used

Before proceeding to the analyses of vulnerability and its determinants, it looks necessary to detect the non-response rate of survey questionnaire from the sample households. To begin with, from the total of 576 sample households, 525 (91.15%) surveys were fully completed and inserted into SPSS for analysis. By doing so input data for LVI analysis, namely percentage, average, maximum, and minimum values for each indicator were processed through SPSS 16. The SPSS results were presented in excel sheet (See Annex 3) to calculate livelihood vulnerability indices (LVIs) for each indicator and then to compute average LVI for sub-components and composite LVI for major components across the three agro-ecological zones.

After identifying and tabulating the input data mentioned above, LVIs were calculated by employing the selected formulae depicted from 3.4.2B – 3.4.2Di/ii). The computation was considering functional relationships of indicators with vulnerability (See functional relationships of indicators with vulnerability presented in Annex 2). When the indicators have direct relationship with vulnerability, the LVI was computed using equation 3.4.2A. Let us see the distance household heads travel to reach to the nearest hospital by agro-ecological setting. It is too long in *kola* with a value of 252km, and it has the shortest distance of 8km in *dega*. The observed (average) value in *kola* was found to be 164.29km (Refer to Annex 3). Hence, the normalization for *kola* agro-ecology was achieved by:

$$\text{Normalized value} = \frac{164.29 - 8}{252 - 8} = 0.65.$$

In this way, the standardized vulnerability scores for similar indicators were computed for each site by considering the functional relationships of indicators with vulnerability.

When the variables have inverse relationship with vulnerability, the normalized scores were computed using equation 3.4.2B. For example, farm income has inverse functional relationship with vulnerability; that is, as farm income increases vulnerability decreases and vice-versa. So, farm income was found to be higher in *dega* with a value of 60,500 Birr per year, while it has a lower value of 0 in all the three sites. The observed value (represented by average income) was found to be 5917.36 in *dega*, 9814.29 in *woyna dega*, and 3379.90 in *kola*. Thus, the standardized score for *kola* agro-ecology is:

$$\text{Normalized value} = \frac{60{,}500 - 3379.90}{60500 - 0} = 0.94.$$

In this way, the normalized scores for each indicator were computed for each study site.

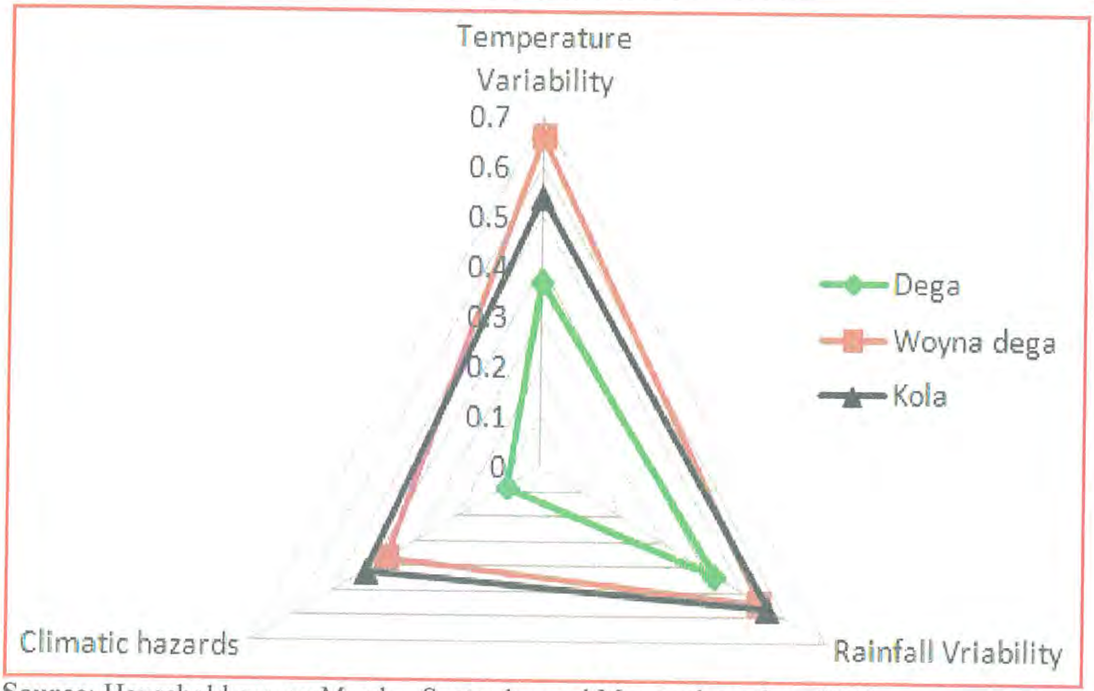
Other indicators which can be directly calculated by their own mathematical formula such as crop diversification and livelihood diversification indices were inversed using equation 3.4.2C. In this case, for example, the constructed crop diversification index is found to be 0.043 for *kola*, 0.071 for *dega*, and 0.12 for *woyna dega*. Then the normalized vulnerability index for *kola* is calculated as:

$$\frac{1}{1+0.043} = 0.96.$$

In a similar way, the vulnerability scores for these types of indicators were computed for the three study sites. After standardization of all indicators, average LVI was calculated using

(0.37). In sharp contrast, very low vulnerability index for climatic extreme events (0.08) was observed in *dega* study site. This result is consistent with the IPCC report in that vulnerability to climate change and variability is more severe in the tropical (arid and semi-arid) areas as compared with the cool temperate and cold regions of the world.

Figure 24: Vulnerability radar of climate elements and extreme events



Source: Household survey March – September and Meteorology data, 2012

Note: index value of 0 means no or very low vulnerability and vulnerability increases as LVI values increase in the radar diagram outwards from the center.

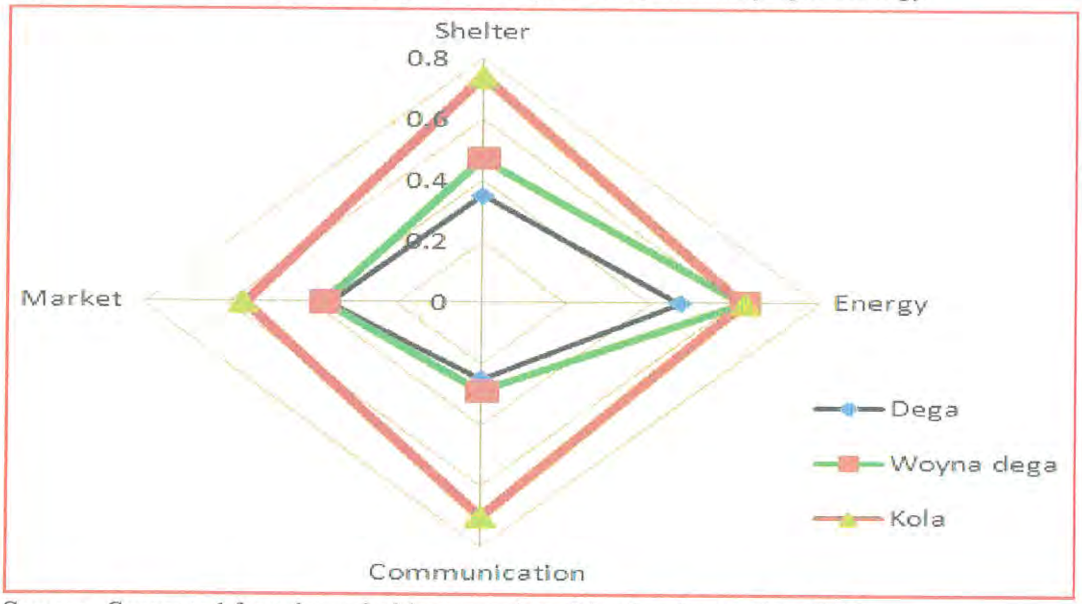
The vulnerability levels of the households by climatic exposure indicators are summarized in the following radar diagram (Figure 24). It is clear from the diagram that there are three main indicators: temperature, rainfall and climate related extreme events. In terms of aggregate climate exposure indices, *woyna dega* (0.54) and *kola* (0.51) are found to be more exposed to climate change and variability while only a relatively low exposure level was detected in the *dega* site with 0.31 normalized index value. The reason is attributed to the fact that climate extreme events are relatively lower in dega than the *dega* and *woyna dega* and *kola* sites. In addition, the temperature increase in *dega* has created optimum conditions by reducing frost actions and hence changing unproductive lands to productive ones. In line with this assessment IPCC (2007) report underlined that the exposure of a system is determined by the amount of stress that impacts the unit of analysis. Exposure can be represented by a change in magnitude, frequency and duration of an extreme climatic event (such as droughts, floods, By and large, the households who account for nearly 84% in *dega*, only 24.1% in *woyna dega* and 42.2% in *kola* traveled less than an hour to get public telephone services. It is clear that the households in *dega* sites were less sensitive than those from other sites in terms of access to public telephone services resulting in less vulnerable population to the impacts of climate variability, climate change and associated extreme events. The overall vulnerability scores were calculated and hence *kola* households (0.70) were found to be more sensitive to the impacts of climate change than *woyna dega* (0.29) and *dega* (0.25) households. It is also clear that *kola* ranks first in the overall vulnerability levels of households by transport and communication indicators.

Access to markets: Another factor worth considering, as a variable affecting productive, is proximity to factor markets. The hypothesis in this study is that households located near markets are expected to have lower sensitivity than those located in remote areas. The assumption is that proximity to markets increases farmers' access to agricultural inputs, credit facilities and income-generating activities. Accordingly, this section identified effective indicators for measuring the vulnerability levels of households to climate change impacts, namely average distance to agricultural inputs, quantity of modern fertilizers used by farmers, percentage of households who do not apply modern fertilizers, investment on agricultural inputs, and time needed to reach to input and output market centers.

The survey results indicated that the households in *kola* (0.56) are found to be more vulnerable than *dega* (0.36) and *woyna dega* (0.37) households who have almost similar livelihood vulnerability scores. In relation to this, studies argue that the long distance settlement of the households from input and output markets increases their degree of vulnerability to climate change related impacts through reducing coping and adaptive capacities (Hahn et al., 2009; Temesgen et al., 2009). Proximity to markets is an important determinant of adaptation because markets facilitate provision of agricultural inputs for adaptation and sale of products at a reasonable price. In addition, markets serve as the means of exchanging information with other farmers (Temesgen et al., 2009; Temsegen, 2010). Lower levels of investment on agricultural inputs (0.91 in *kola*, 0.85 in *dega*, and 0.82 in *woyna dega*) followed by limited application of modern fertilizers (0.91, 0.79, and 0.77 in *kola*, *dega* and *woyna dega* respectively) contribute much to higher vulnerability levels of households to climate change. Higher vulnerability scores were calculated in *kola* site by all indicators of market access.

After discussing the vulnerability situations of households measured by sub-component of physical capital (such as shelter, energy, communication and market related indicators), the composite indices were summarized (Fig.32) and discussed for it.

Figure 32: Vulnerability index of physical capital components by agro-ecology



Source: Computed from household survey data, March – September 2012

From Figure 32, it is clear that *kola* households are more sensitive to climate change impacts in terms of shelter (0.74), market (0.56), and communication (0.70), distantly followed by *woyna dega* households (0.47, 0.37 and 0.29 respectively). But similar level of vulnerability level was determined in terms of energy supply (0.62). The dissected and difficult nature of the landscape has made the *kola* households more vulnerable to environmental and climate change risks than those in *dega* and *woyna dega* sites. The reasons for the most vulnerability situations of these areas are poor capacity to apply inputs in time as they are far from transport services, markets and institutions coupled with limited attention on investment of these basic infrastructure facilities.

5.3.5. Social and institutional capital

Vulnerability is associated with social and institutional capital which can facilitate coordination and cooperation in times of crisis for material gain, or resolve disputes (Nyangena & Sterner, 2008; Barungi & Maonga, 2011). In this thesis, the households' social and institutional capital was assessed by networks and relationships, organizational affiliations, policies and strategies, as well as decision-making and service delivery components. See Annex 3 for detail results for each indicator and Figure 33 for summary of the sub-components of social and institutional capital.

Networks and relationships: The forms of social networks and relationships that were examined are the number of relatives in a village (kinship), degree of attachment with relatives and neighbors (friendship), farmer-to-farmer extension, helps received from relatives or neighbors, and borrow from and lend to relatives. The survey results indicate that many of the respondents were involved in many social activities and networking with relatives and non-relatives that involved resource, work, and information sharing. However, they are not free from being vulnerable by these indicators. By the number of relatives in a village, the households had almost similar vulnerability in the three study sites, that is, 0.95 in *dega*, 0.94 in *kola*, and 0.91 in *woyna dega*. The reason is that the number of relatives in a '*got*' (village) was 7.51 persons on average in *dega*, 8.79 in *kola* and 15.19 in *woyna dega*.

Number of relatives is not sufficient condition to measure the vulnerability levels of the households without supporting it with degree of attachment, because a person with a large number of relatives may be in conflict with them as opposed to a person who has strong attachments to his/her few numbers of relatives and non-relatives. Thus, the latter may have better adaptive capacity than the former who is with higher vulnerability level. The results on the degree of attachments of households with relatives and neighbors indicate that *kola* (0.62) and *woyna dega* (0.55) households had higher LVI than those of *dega (*0.23). This means weak ties of households with their relatives and neighbors were detected in *kola* followed by *woyna dega,* indicating greater vulnerability to climate change impacts. From this we can infer that poor attachment of households with their relatives and neighbors has strong association with natural resource depletion and poverty.

Concerning the cooperative tradition of the society, *woyna dega* and *kola* households have more limited capacity than those households in *dega*. Over 75% of *woyna dega* and 74% of *kola* households reported that the cooperative tradition of the society has been in a decreasing and worsening conditions through time. But only 32% of the *dega* households reported the same. Although better access to livelihood assets and people's good attachment with relatives and neighbors have positive influences, inverse relation is obtained in the more vulnerable *kola* sites. The results also show that by borrowing money from relatives and non-relatives, the *kola* households (0.81) were more vulnerable than both *dega* and *woyna dega* households (0.74). In fact, the households of all the agro-ecologies have higher vulnerability index. Again, *kola* households (0.85) were more vulnerable than *woyna dega* (0.70) and *dega* (0.68) households with regard to lending money to relatives and non-relatives. *Dega* and *woyna dega* households borrowed and lent money more frequently than those *kola* households in relative terms.

Different forms of supports the households have gained from relatives and non-relatives provided relatively little contribution for the households' livelihood vulnerability index value in all the three study sites. In deeded, *kola (*0.35) and *woyna dega (*0.3) households had higher LVI value than those *dega* (0.19) households. Although the cooperative and support culture of the society was reported to be on a decreasing situation, the respondents involved on some social and economic activities such as in farming, harvesting, threshing, keeping livestock, marketing, taking sick family members to health institutions, house construction, and sharing useful information to mention a few (e.g. Photo 14).

Photo 14: Farmers cooperation in agricultural activities, July & November, 2012

Source: Own field Photo (the right) and assistants' (the left), 2012

Photo 14 illustrates rural people's cooperation in sowing crops by forming a line (on the left and middle) in July and harvesting *teff* (locally known as *Debo)* (on the right) during untimely rain in November 2012. The results from the interview, group discussion, and observation confirm that those give-and-take types of co-operations are still working to some extent, but sharing crops, some amount of money, and animals for different agricultural and marketing purposes have been greatly decreasing with negative implications on the adaptive capacity of the studied households.

In the aggregated vulnerability indices, *kola* (0.68) and *woyna dega* (0.61) households were more vulnerable than *dega* (0.46) households by the networks and relationships component of social capital. By almost all the indicators, *kola* households have limited capacity in terms of networks and relationships to undertake adaptation/coping activities against the impact of climate change. This may be resulted from the very high level of vulnerability of households in terms of other livelihood resources in the *kola* site. From this one can infer that there is strong network and relationship among people in the places where there is relatively better access to different livelihood resources while the reverse is true in the areas where there is limited/no access to such resources. As Temesgen (2010) argued, in the vulnerability and adaptation studies networks and relationships can play a significant role in information exchange and in facilitating help and support within the people during the climatic hazards – by reducing vulnerability to climate change impact. Other studies noted that networks and relationships are assets which exist in the networked relationships to cope up with the impacts of climate change and related issues (Adger, 2003; Luk, 2011). Wisner et al. (2004) also argue that households that have access to social networks are less vulnerable to natural hazards. These represent social safety nets and a form of informal grass-roots insurance available to the household during climate-related crisis (Vincent, 2007).

Organizational affiliations: Farming household's organizational affiliation in this study was examined based on membership status of households in farmers' cooperatives, saving and credit groups, religious groups, traditional help associations *(Edir& Equib)*, and relatives holding *kebele* positions. The survey results indicated that the households of all agro-ecologies were highly vulnerable by traditional help associations because about 99% of the households in *kola*, 96% in *dega*, and 91% in *woyna dega* had no membership status in traditional help associations. In terms of membership status in saving and credit groups, the households were found to be vulnerable at 93% in *woyna dega*, 91% in *kola*, and 70% in *dega*. By farmers' cooperatives, they were found vulnerable to 81% in *woyna dega*, 75% in *kola*, and 72% in *dega*. Over 62% of the respondents in *woyna dega*, nearly 68% in *kola*, and over 50% in *dega* had not any relative holding position in the *kebele* administration. *Woyna dega* households (46.6%) followed by those of *kola* (63%) households were more vulnerable than *dega* (81%) households by membership status in religious groups. The results imply higher degree of vulnerability of the households by membership in religious groups. *Woyna dega* (0.76) and *kola* (0.74) households were more vulnerable than *dega* (0.59) households by organizational affiliations, indicating limited capacity and in turn greater vulnerability level of households to climate change impact (Refer to Table 27). Other studies argue that as vulnerability and adaptation are dynamic social processes, the ability of societies to adapt is determined, in part by the ability to act collectively. Being members of any association or group is crucial for reducing vulnerability through enhancing adaptive capacity of farming households through information exchange, experience sharing, material and financial support in times of climatic disasters (Adger, 2003; Luk, 2011). In the light of this argument, other scholars also argue that associations can build trust, confidence, and moral values and provide information (Nyangena & Sterner, 2008).

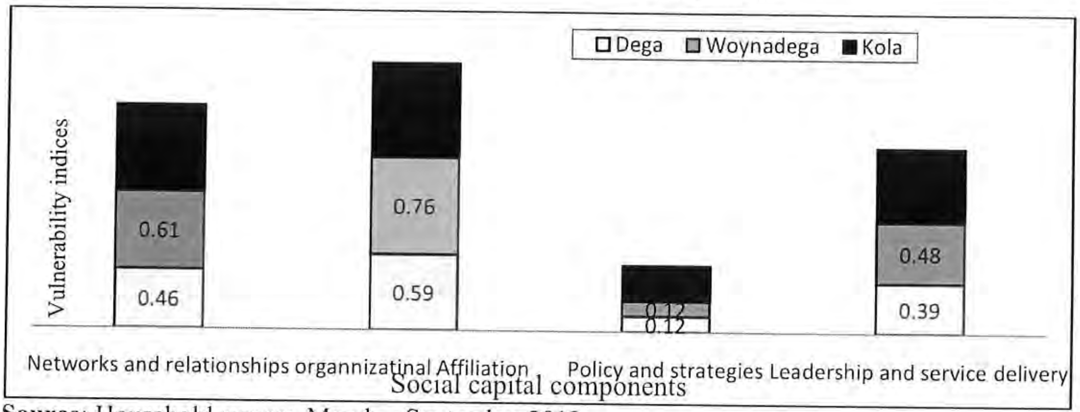
Policy issues: Policy processes are important determinants of vulnerability and adaptation to climate change. Accordingly, land tenure security, land certification, flow of policy information, and the benefits the households acquire from the current policies were examined under this issue. The results indicated that *kola* households (0.28) were more vulnerable than *dega* and *woyna dega* households by policy issues with similar LVI of 0.12. *Kola* households (0.36) were more vulnerable in terms of access to current policy information while *dega* (0.02) and *woyna dega* (0.08) households had lower vulnerability levels. By levels of improvement in living standards by the current policies, *kola* households (0.34) were also more vulnerable than *dega* (0.06) and *woyna dega* (0.11) households. In terms of the role of NGOs in supporting local development efforts, *kola* (0.34) and *dega* (0.33) households were more vulnerable than those of *woyna dega* (0.12) households. Due to its accessibility and being located in the Lake Tana watershed area, many NGOs have been involved recently in the development efforts of several sectors in Dembia. World Vision, Plan Ethiopia, Organization for Rehabilitation and Development of Amhara (ORDA), Ethiopian Orthodox Church, Tana Beles Integrated Watershed Development project and others are doing different activities. But limited NGOs in *kola* and *dega* environments have focused on relief provision and Safety Net Programs. The isolated and inaccessible nature of the *kola* site due to difficult terrain arrangement has made it one of the least preferred areas for intervention by most NGOS which has in turn made it to gain limited/no benefits from these kinds of intervention.

Although *kola* households were more vulnerable than those in *dega* and *woyna dega* in terms of policy indicators, the households of all the three study sites had low levels of vulnerability to climate change impacts when compared with other vulnerability indicators. In addition to be the least preferred area for development interventions, the inaccessible nature of the *kola* setting has made the households more vulnerable in terms of information flow on potential hazards, new technology options and actual implementations of policies and strategies.

Leadership and service delivery: Different levels of government institutions play crucial role in helping communities by enhancing their adaptive capacity. All levels of government, such as federal, regional, zonal, *woreda*, and *kebele* are involved in administering the community and in initiating other development activities. In this context, households' level of satisfaction with the decisions and services provided by their local leaders, households' participation in their leaders' election processes, number of households who have been visited by development agents in the past cropping season and frequencies of visits per cropping season were taken as indicators to assess vulnerability levels of rural households to climate change impact. The results indicated that *kola* (0.58) followed by *woyna dega* (0.48) households were more vulnerable than *dega* (0.39) households in terms of leadership and service delivery. Consequently, in terms of levels of satisfaction from the services and decisions provided by local leaders, *kola* (0.75) followed distantly by *woyna dega* (0.51) households were more vulnerable than those in *dega (0.23)*.This may be attributed to the fact that again the inaccessible nature of the *kola* site has posed difficulty for the zonal and woreda officials to undertake continuous follow-ups on the grass-root-level decision-makers and service providers so that some bias and discriminations were reported by in-depth interviewed households.

Another important indicator considered in vulnerability analysis was access to extension services (whether the households accessed extension services or not and how often). The inverse scoring technique depicted in equation 3.4.2A indicated that by the frequency of visits to households by Development Agents (DAs) in the past cropping season, the three sites were highly vulnerable (0.91 in *kola*, 0.89 in *woyna dega*, and 0.85 in *dega),* indicating limited extension services provided to the households. Even 46% of the surveyed households in *kola*, 40% in *dega* and 37% in *woyna dega* reported that they had never got any visit from DAs in the season considered. From this we can infer that neither extension visits nor visits and trainings have not brought significant capacity increment in terms of skill, knowledge and attitudinal changes in adopting new adaptation technologies. In fact, development agents remain at the edge, never reaching the farmer and that the service packages may not fit the agro-ecological settings.

Figure 33: Vulnerability of households by social capital components



Source: Household survey, March – September 2012

Figure 33 presented the average vulnerability score for the sub-components of social capital. It clear from the figure that in terms of organizational affiliations, *woyna dega* (0.76) and *kola* (0.74) households were found to be more vulnerable than *dega* (0.69) households implying very limited affiliations to different formal and informal organizations. Again, in terms of networks and relationships, *kola* households (0.62) were more vulnerable than those in *dega* (0.44) and *woyna dega* (0.43), and by leadership and service delivery, *kola* (0.48) and *woyna dega* (0.37) households were more vulnerable than *dega* (0.28) households. Despite the challenges to identify the indicators that reflect the local social assets, including them in climate vulnerability assessment is essential as many adaptation behaviors rely on collective insurance mechanisms such as religious groups, agricultural cooperatives, credit groups, and traditional help associations. Although the households were less vulnerable in terms of government policy issues, *kola (0.28)* households were found to be more vulnerable than those of *woyna dega* and *dega* (0.12 for each) households. However, the data gathered from the household surveys across the three study sites doesn't show what farmers have experienced. Such a lack of congruence between the survey data and what people actually experienced is understandable. In the interview sessions, people complain more for little/no benefits obtained from the policy interventions, particularly in the *kola* study site.

5.3. Vulnerability by inverse of adoption indices

Kelly and Adger (2000) argue that according to the IPCC approach, vulnerability is contingent not only on estimates of the potential climate change but also adaptive responses of the communities. In other words, the level of vulnerability is determined by the adverse consequences that remain after the process of adaptation has taken place. These expressions of vulnerability and adaptation have implications for assessments of vulnerability to climate change. In one case, vulnerability depends on adaptation that has taken place by households; in the other, vulnerability is defined in terms of capacity to adapt, and capacity to respond to stress is a starting point for impact analysis.

Based on this background, the composite index of adoption of different adaptation measures employed by the rural households reside in the three agro-ecological settings was calculated[5]. Then by considering the functional relationships between adaptive capacity and vulnerability to measure their capacity to adapt to the impact of climate change (See Annex 7a-c), the indices were inversed[6] to measure the households' degree of vulnerability by the number of adaptation options they have used against the impact of climate change and associated

[5] Using equation 3.4.3A, *Chapter Three*
[6] Using equation 3.4.2C, *Chapter Three*

extreme events. The inverse scoring technique was used considering the functional relationships between number of adaptation and vulnerability because an increase in the crude indicator, in this case, the number of adaptation strategies undertaken by a household, decreases vulnerability (e.g., a household who adopts more adaptation strategies is less vulnerable than a household who only adopts lower number of strategies), so by taking the inverse of the crude indicator, I created a number that reflects this line of reasoning and assigns higher values to households with a lower number of adaptation strategies following Hahn et al. (2009) and Lamichhane (2010).

Table 20: Households' vulnerability level by inverse of adoption of adaptation measures

Agro-ecology	Vulnerability index by inverse of adoption		
	Average	Minimum	Maximum
Dega	0.67	0.56	0.91
Woyna dega	0.69	0.57	1.0
Kola	0.72	0.56	1.0
Average	0.70	0.56	0.97

Source: Household survey, March – September 2012, computed using equation 3.4.2C

Table 20 indicates the inversed vulnerability scores of households by adoption rate of different adaptation options in the three study sites. It is clear from the table that on average, almost similar vulnerability indices were detected in the three sites though it is somewhat higher in *kola* households (0.72) than those of *dega* (0.67) and *woyna dega* (0.69) households. The minimum vulnerability levels in terms of adoption index ranges from 0.56 to 0.57 whilst the maximum vulnerability index ranges from 0.97 to 1.0. This means that there are individual households with 97% to 100% probability of not adopting the available climate change adaptation strategies. This indicates the need for increasing the adaptive capacity of the rural households and communities better against the impacts of climatic variability and extremes in the future. To this end, strengthening innovative capacity take center stage in any development initiative, including the process of experimentation and exploration of practices, techniques, or new organizational forms.

5.4. Composite vulnerability level of households

After accomplishing the computation and discussions of the vulnerability indices of households for the seven major components, the composite vulnerability indices were calculated using equation 3.4.2A and compared across the three agro-ecologies. When we see component-wise, the vulnerability levels of the households vary significantly by agro-ecology. *Kola* households, for example, were the most vulnerable groups to climate change impact by all the five capital assets and inverse of adoption indices with normalized scores ranging from 0.51 to 0.72. Inverse of adoption indices (0.72 in *kola*, 0.69 in *woyna dega* and 0.67 in *dega*) ranks first. Economic capital ranks second in all the agro-ecologies while the ranks vary by other components (Refer to Table 21).

Table 21: Vulnerability levels and ranks of households by major components

Major components	*Dega*	Rank	*W/Dega*	Rank	*Kola*	Rank
Human capital	0.43	3	0.51	3	0.60	4
Natural capital	0.43	3	0.51	3	**0.67**	**2**
Economic capital	0.58	2	0.59	2	**0.67**	2
Physical capital	0.36	5	0.44	6	0.66	3
Social capital	0.40	4	0.50	5	0.58	5
Climatic exposure	0.31	6	0.54	4	0.51	6
Inverse of adoption index	**0.67**	1	**0.69**	1	**0.72**	1
Composite index	**0.45**	**3**	**0.54**	**2**	**0.63**	**1**

Source: Extracted from Annex 3

In *kola*, natural and economic capitals have equal ranks 2nd (0.67) closely followed by physical capital (0.66) ranking 3rd followed by human capital (4th) whereas natural and human capital assets stand 3rd both in *dega* and *woyna dega* agro-ecologies with LVI of 0.51. Again, *kola* (0.58) and *woyna dega* (0.5) households were more vulnerable than *dega* (0.4) households by the social capital component. By physical capital *woyna dega* (0.44) households were more vulnerable than *dega (*0.36) households. By climatic exposure index *woyna dega* (0.54) households had higher vulnerability level than *kola* and *dega* (0.31) households.

The final composite vulnerability indices calculated for each agro-ecology are consistent with other sub-component indices in indicating the very high vulnerability levels of *kola* households. When LVI values are compared with previous empirical findings, the vulnerability level of the three agro-ecologies is much higher than the vulnerability indices calculated in the two districts of Mozambique (Hahn et al., 2009) and Nepal (Lamichhane, 2010). The very high vulnerability levels of *kola* households is also consistent with Watson's et al. (1997) arguments who stated that vulnerability is highest where there is the greatest sensitivity to climate change and the least adaptability. They further stressed that vulnerability depends on the level of economic development and institutional capacities which inform the need for local context-specific adaptation interventions and community assistance programs.

Failure in securing one component of a capital asset such as knowledge and skill may lead to failure in securing another capital including income, material needs and capacity to bounce back and recover quickly from the impact of climatic hazards. This interrelationship is demonstrated by rural poverty in kola site where there is a lack of education combined with inadequate incomes or assets amongst households, poor-quality housing, and a lack of basic infrastructure for providing water, sanitation and toilet facilities to reduce negative effects on human health. The worst biophysical and economic contexts discussed in the *kola* site have made households more vulnerable to climate change impact than those in *dega* and *woyna dega*.

CHAPTER SIX
FARMERS' PERCEPTION AND ADAPTATION TO CLIMATE CHANGE

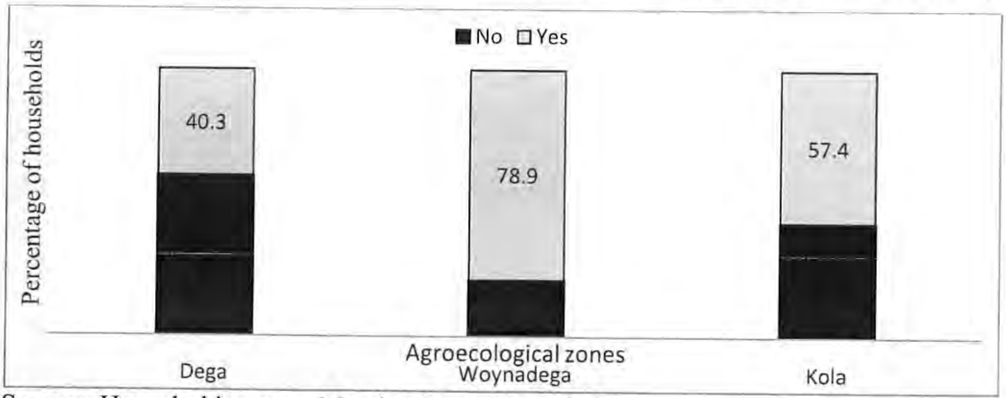
This chapter has tried to address the 3rd and 4th objectives/research questions presented in the first chapter of this thesis regarding households' perception and adaptation to climate change. The household survey was the main data sources checked with in-depth interviews with experts and farmers. In order to propose appropriate adaptation options to the specific localities , it is essential to understand the levels of perception of farmers to climate change impact and the kinds of adaptation options, including the difficulties faced to cope up with risk management at the micro-level. Perception has to be analyzed based on the observations of the local community as it is a prerequisite for adaptation. Therefore, this chapter is structured into three major sections: farmers' perception to climate change and variability, assessment of adaptation strategies used by the rural households, and analysis of the determinants of their adaptation choices.

6.1. Households' perception to climate change

6.1.1. Households' sources of climate information

Timely, reliable information is essential to inform people about the adverse impact of climate change, to get them ready, and to suggest possible adaptation measures. This study tries to explore whether or not farmers have information about climate change, its impact and response measures, including the strategies to be taken to protect their livelihood resources from being damaged. The results indicate that higher percentage of the households in *woyna dega* (78.9%) reported that they have received climate change information than *dega* (40.3%) and *kola* (57%) households (See Fig. 34). This is because, during each flood incidence in the *woyna dega* sites, development agents have provided advice for the people about climate change and its consequences. This implies that climate information from concerned bodies is very limited in *dega* and *kola* sites. Thus, this study suggests strengthening of the early warning information dissemination system as it may help the community to design preparedness plans for climatic variability and extreme events.

Figure 34: Percentage of households who heard about climate change before this survey



Source: Household survey, March – September 2012

Households who have received information about climate change so far mentioned different sources of information. These were training and education, radio, family members, development agents, friends and *kebele* administrators (See Table 22).

Table 22: Sources of climate information for farming households by agro-ecology

Sources	*Dega*		*Woyna dega*		*Kola*	
	Frequen.	Percent	Frequency	Percent	Frequen.	Percent
Education and training	24	45.3%	46	*24.1%*	34	19.7%
Radio broadcast	10	18.9%	48	*25.1%*	27	15.6%
Family members	14	*26.4%*	18	9.4%	24	13.9%
Development agents	5	9.4%	54	28.3%	78	45.1%
Friends	-	-	19	9.9%	6	3.5%
Other sources	-	-	6	3.1%	4	2.3%
Total households	53	100%	191	100.0%	173	100.0%

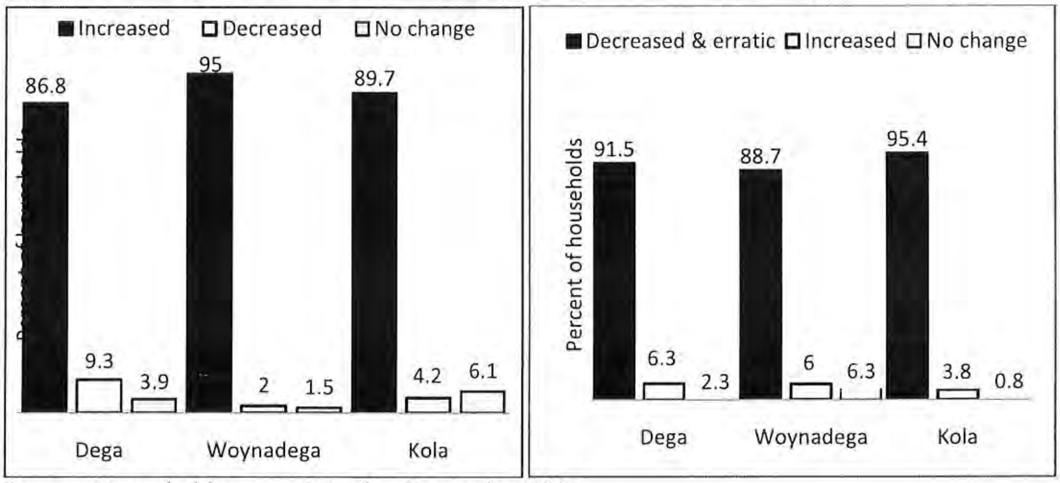
Source: Household survey, March – September 2012
* Other sources = *kebele* leaders, other public leaders

Table 22 indicated the respondents' sources of information about climate change and associated impacts. It is clear that education and training was the first source of information for the higher proportion of *dega* households (45.3%) than those in *woyna dega* (24.1%) and *kola* (19.7%) while the second source for *dega* households was family members (26.4%) followed by radio broadcasts (nearly 19%). Although the overall information and vulnerability levels in the *dega* site were lower than *kola* and *woyna dega* study sites, a higher percentage of households who heard about climate change had obtained information through education and training. The interview results also supported the finding, attributing it to the fact that the African Climate Change Resilience Alliance (ACCRA) has provided training and awareness creation sessions for managers, experts, and community workers in the *dega* sites. Before that, climate change was not a concern there. Following that session, the trainees have started to provide information about climate change, its impact and adaptation options for the rural community. The first source of information about climate change for *kola* (45.1%) and *woyna dega* (28.3%) households was advice from Development Agents (DAs) because the *kola* sites are more drought-prone coupled with severe soil erosion and the resultant food insecurity while the *woyna dega* sites are more sensitive to recurrent flooding. As a result of these problems, the DAs and other concerned bodies have provided advice for the people about climate change and the consequences of droughts and flooding. The second source for *woyna dega* households (25.1%) was radio broadcasts against 15.6% for *kola* households.

6.1.2. Perception to temperature and rainfall changes

Adopting any adaptation measure requires an understanding of how much the climate has already changed and how variable it is. This section presented evidence of climate change and variability from the perception of the surveyed households, including the observations of officials.

Figure 35: Perception of households to temperature and rainfall changes



Source: Household survey, March – September 2012

Figure 35 presents the details of the survey results about temperature variation and change in *dega*, *woyna dega* and *kola* agro-ecologies. The results showed that climate change is a reality and has become so variable over space and time. Increasing temperatures, decreased/erratic and unpredictable rains, but more intense episodes were reported to be the serious problems in the rural households' livelihoods. It is clear from figure 35 that the majority of the surveyed households reported that temperature has increased through time with some differences in perception by agro-ecology (95% in *woyna dega*, nearly 90% in *kola*, and 86.8% in *dega*). However, very few households have perceived in the contrary, a decreasing trend of temperature (i.e., 9.3% in *dega*, 4.2% in *kola*, and 0.8% in *woyna* *dega*). In the *kola* sites, only 6.1% of the farmers have not noticed any change in the temperature. The majority of the farmers' perceptions were consistent across the surveyed sites. Moreover, these perceptions appear to be in accordance with the results of similar study conducted in Kenya (Bryan et al., 2011) and with the records of the meteorological stations.

Figure 35 also demonstrates the percentage of the households in terms of levels of perception on rainfall changes in the three study sites. The results show an opposite trend of temperature change in the period similar to the meteorology data. Almost similar pattern of perception of change in rainfall was observed across the three research sites. In total, 91.5% of the respondents in *dega*, 88.7% in *woyna dega*, and 95.4% in *kola* observed changes in rainfall patterns over the past 20 or so years. When decreases and changes in timing disaggregated into two, the proportion of the households who perceived rainfall changes varied with agro-ecology which is also similar to the study findings in Kenya (Bryan et al., 2011). For example, nearly 80% in *kola* perceived rainfall to be decreasing through time with shorter rainy seasons while only 41.1% in *dega* and 27.1% in *woyna dega* perceived the same. Almost 79% of the households in the *woyna dega* site noticed the erratic nature of the rainfall–a change in the timing of the rains, coming either earlier or (mostly) later than expected time. About 56% of the surveyed households in *dega* and 31% of them in *kola* reported the same. Bryan and colleagues (2011) suggested that the farmer's perceptions of long-term decreases in rainfall from the household survey are actually based on their experiences with rainfall variability, and particularly changes in timing and distribution of rainfall.

The same pattern of perception of climate change was detected within the different social groups of the community such as age, education, gender, farmers, and government and non-government officials. However, this is quite different from the study conducted in semi-arid Tanzania by Mongi et al. (2010) as it pointed out different perceptions among social groups in terms of level of education, location, age and gender. Interview and discussion results confirmed that there is no varied understanding on the trends of temperature and rainfall by level of education, agro-ecology, age and gender in the study sites. In terms of perception, the local communities unanimously agreed that the climate is continually changing and getting worse and worse from time to time. In all the sites, it is commonly agreed that the temperature is getting much hotter across times. Such a situation therefore results in poor performance in agriculture and food security efforts.

storms, etc), climate variability or long-term climate patterns such as increasing temperature and decreasing, or erratic precipitation to which farmers' livelihood assets are more exposed (IPCC, 2007).

5.3. Farmers' vulnerability to climate change by livelihood assets

The conceptual framework (Fig.1) depicts that the households' five livelihood assets are influenced by the exposure created through vulnerability contexts. Therefore, the major components for measuring rural households' levels of vulnerability to climate change are the five livelihood assets. These are important to inform the need for local context-specific adaptation interventions and community assistance programs which can enhance these asset entitlements to the rural households. When we see component-wise, the vulnerability levels of the households vary significantly by agro-ecological setting. The *kola* households, for example, were the most vulnerable groups to climate change impacts by all the five capital assets. The details of each capital asset indicators are discussed in the sub-sections to come.

5.3.1. Human capital

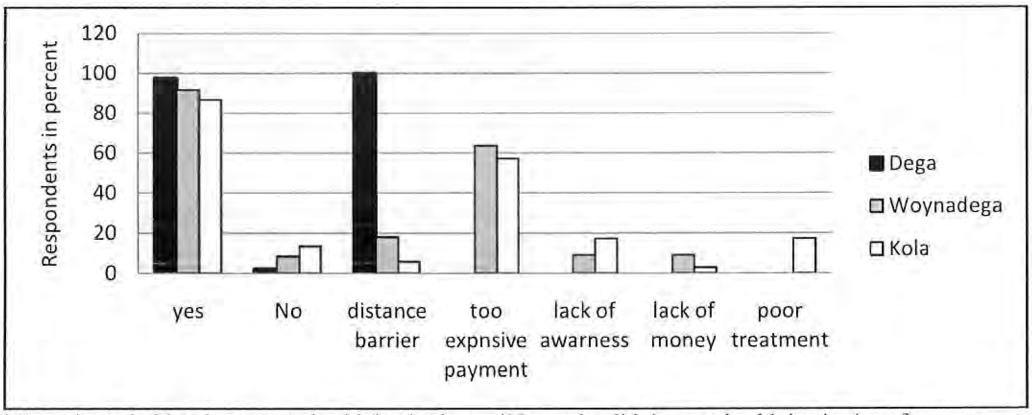
The indicators for human capital are depicted in the conceptual framework (Fig.1) and Annex 2 including their functional relationships with vulnerability. In the context of this study, human capital entitlements were measured by four components: health, knowledge and skill, food situation, and demographics which have been measured by several indicators. The quantitative analyses of human capital indicators are presented in Annex 3 and the detail of each major component is presented in the discussions to come.

Households' sensitivity to climate change in terms of health: This study examined health vulnerability levels of the households as part of analysis of sensitivity to climate change impacts. The important indicators for this analysis are: distance taken by households to reach the nearest health facilities, chronic illness, injury and death in the family, and missing work or school by a family member, malaria incidence in the respondents' locality, health package services, and toilet facilities with their functional relationships with vulnerability.

The results are comparable with indicators by agro-ecology. In the composite health vulnerability scores, *kola* (0.46) and *woyna dega* (0.44) households were highly sensitive to climate change impacts whilst the lowest health sensitivity was constructed for *dega* (0.16) households. When compared in terms of indicator wise, absence of toilet facilities took the lion's share for the health sensitivity in *woyna dega* (0.92), in *dega* (0.88) and in *kola* (0.68). *Woyna dega* (0.91) and *kola* (0.74) households were more sensitive to malaria incidence while no malaria infection was reported by the *dega* households. This result is consistent with the report regarding to incidences of different tropical diseases in *kola* and *woyna dega* sites while no or less diseases prevalence in the dega site. It is also supported by the IPCC (2007) report which states that human diseases are prevalent in the hot regions against the cold environments.

Better access to different services reduces sensitivity to climate change and increase adaptive capacities of a household. By the distance to health facilities, particularly to hospitals, *kola* (0.65) households were highly sensitive than *woyna dega* (0.18) and *dega* (0.08) households. By the remaining health sensitivity indicators, *kola* households were more sensitive followed by *woyna dega* households while *dega* households had lower sensitivity score than *woyna dega* and *kola* households. Households of the three agro-ecologies had almost similar sensitivity levels for the sources of health care. This is because, almost 98% of *dega*, 92.5% of *woyna dega*, and 87.1% of *kola* households indicated that their primary sources of health care were public health institutions, such as health posts, health centers and hospitals. A very small percentage of *dega* (2.3%), *woyna dega* (3.8%), and *kola* (4.2%) households went to traditional health healers. Only 3.8% of the households in *woyna dega* and 8.7% of them in *kola* claimed they never sought out health care. The reasons are depicted in Figure 25.

Figure 25: Households treatment in case of illness and reasons for not using institutions



*Yes = households who went to health institutions *No = who didn't go to health institutions for treatments

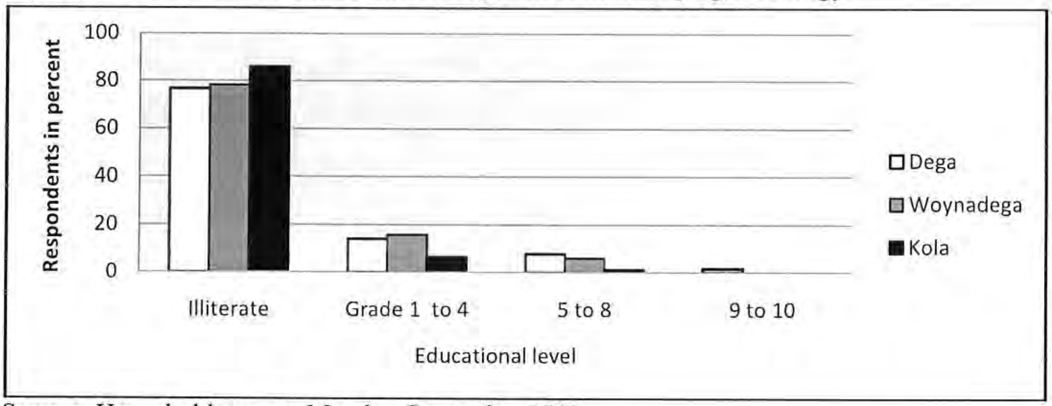
Source: Computed from household survey data, March – September 2012

All the households who didn't get treatment from health institutions in the *dega* site explained distance factor as the only reason. About 63.6% of *woyna dega* and 57.1% of the *kola* households reported high treatment cost requested by health institutions as the first reason. This capacity issue for accessing services is associated with deep-rooted poverty in the *kola* and *woyna dega* sites. The rest 9.1% in *woyna dega* and 17.1% in *kola* sites mentioned lack of money while 9.1% of the respondents in *woyna dega* and nearly 3% in the *kola* site reported lack of awareness about modern medication. Exceptionally, 17.1% of the *kola* households claimed lack of skilled medical staff in the health institutions as the major reason for not going to public health institutions. Skilled employees are not working voluntarily due to the fragility and isolated nature of places and poor access to infrastructure facilities, and hence human resource turnover is very high and has continued as a serious problem in many sector offices.

The different health indicators have contributed to lower human capital, particularly in the *kola* and *woyna dega* study sites. The reason would be explained to the fact that the areas have limited access to health institutions, health package services and prevailing of different diseases like maralia and other waterbore diseases. These in turn affect productive labor force and divert productive resources to health treatments. In line with this, Barungi and Maonga (2011) argue that households with health problems have lower human capital as they may allocate their scarce resources to treating illnesses and household daily consumptions, thereby reducing their capacity to withstand the impact of climate change.

Households' adaptive capacity in terms of knowledge and skill: This study analyzed the vulnerability levels of rural households in terms of knowledge and skills using indicators presented in Annex 2 (variables with their functional relationships with vulnerability) and 3 (raw data and calculated vulnerability indices). The most significant contributing factor to the households' vulnerability level by knowledge and skill in all the three sites is very limited years spent on education with vulnerability scores of 0.94 in *kola*, 0.92 in *woyna dega*, and 0.91 in *dega).*

Figure 26: Educational levels of the surveyed households by agro-ecology



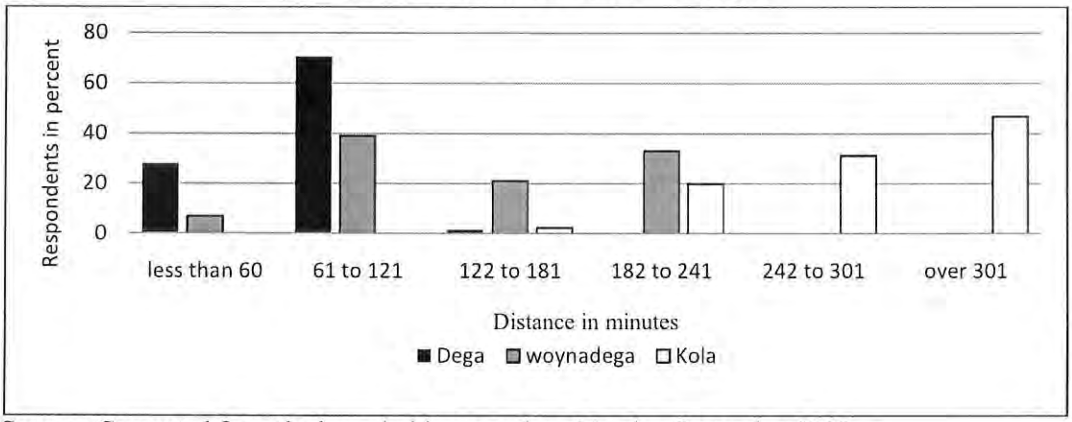
Source: Household survey, March – September 2012

Another significant reason for the higher vulnerability index value for knowledge and skills component was greater proportion of respondents who had never received formal education

(0.77 in *dega*, 0.78 in *woyna dega*, and 0.86 in *kola*). Most respondents do not read and write as only slightly over one-fifth (23.3%) in *dega*, 21.8% in *woyna dega*, and less than one-seventh (14.1%) of them in *kola* had formal education, ranging from 1 to 10 years spent in schools (See Figure 26).

Long distance to education institutions is one of the contributors to the vulnerability levels of the households to climate change impact which is higher in *kola* (0.52) than in *woyna dega* (0.21) and *dega (*0.14) sites. This reduces school enrollment rate and increases dropouts of children in the sample households. Figure 27 presents the average distance children travel to get primary, secondary, preparatory and technical vocational training services across the three study sites. It is clear that the *dega* children followed by those of the *woyna dega* travel relatively short distances as compared to those children in the *kola* sites. In the *dega* site, over 98% of children travel for 18 minutes to 2 hours, but only 45.9% in the *woyna dega* and no one in the *kola* sites have access to education facilities within this range. In *kola* sites, nearly 47% of children travel over 5 hours and 31.2% of them travel from 4 to 5 hours walking on foot. Only nearly 10% of them travel from 3 to 4 hours and the rest 2.3% from 2 to 3 hours.

Figure 27: Time taken by children to reach to education institutions



Source: Computed from the household survey data, March – September 2012

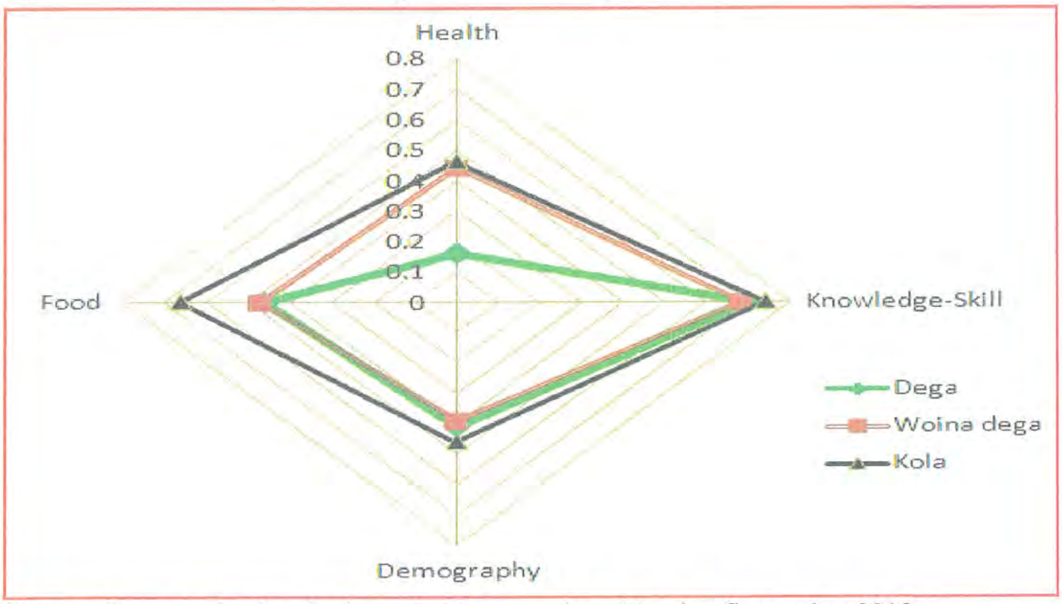
Lack of information about climate change and adaptation options in the *dega* site scores 0.6 while it was 0.43 in *kola* and 0.21 in *woyna dega* sites contributing to the vulnerability levels of households in terms of knowledge and skill which is similar to the findings of other studies in Africa (Eriksen et al., 2004). In addition, the survey results indicated that the households in all the three study sites have limited/no access to vocational trainings (0.90 in *woyna dega*, 0.89 in *kola,* and 0.87 in *dega).* Thus, the farmers cannot have alternative job opportunities for coping up with the adverse impacts of climate change and associated extreme events.

dependency in *kola* and *dega* had contributed to have limited adaptive capacity as compared with *woyna dega* households. This is because households with large dependent family size are forced to divert their meager resources to household consumption than investing on other productive and income generating activities (Temesgen, 2010; Barungi & Maonga, 2011). Thus, this has paramount contribution to the vulnerability levels of the households to climate change and associated extreme events.

Food supply: This study examined the vulnerability levels of the households in terms of food, based on the number of food insufficient months, proportion of people who have faced food shortage per year, food varieties, number of meals per day, ability to store food crops for contingency, and distance taken by the households to travel to food markets. The results indicated that the households in *kola* are more vulnerable to a score of 0.66 while those in *dega* and *woyna dega* have almost the same vulnerability level (0.47 and 0.46 respectively). Around 91% of the households in *kola*, 83% in *dega*, and 79% in *woyna dega* reported that they have faced food shortages at least a month in a year. The households confirmed this reality, as for example, 96% of them in *kola*, 89% in *dega* and *woyna dega* together reported that they are unable to store crops for future times of food gaps. In terms of meals per day, the surveyed household in the *kola (0.91)*, *woyna dega (*0.67) and *dega* (0.54) sites were found to be highly sensitive to climate-induced adverse effects. By food diversification per day, the respondents in *kola* (0.50), *woyna dega* (0.42) and *dega* (0.41) study sites were also found to be vulnerable to the negative effects of climate change.

The average LVI results for food and its indicators indicated that *kola* followed by *woyna dega* households are found to be more sensitive to climate change impact. The households may be easily exposed to climate related health problems which have in turn affect productive labor and divert resources toward health treatments. In relation to this explanation, Robit and colleagues (1996) argue that increased food insecurity and malnutrition is likely to decrease labor productivity through increasing illness, reducing resistance to disease, and weakening the ability to undertake livelihood activities. Access to, availability, and use of food and nutritious diets are the most pertinent measures of human capital.

Figure 28: Vulnerability radar diagram of human capital components



Source: Computed using the household survey data, March – September 2012

5.3.2. Natural capital

Obviously natural capitals are providers of goods and services for the humans and other life form though these assets have experienced persistent pressure and stresses from a range of direct and indirect socio-economic driving forces. These conditions in turn have increased the vulnerability situations of natural resource dependent communities to climate change and other stresses. Having this in mind, in this study three components have been used to analyze the vulnerability levels of the rural households to climate change impact by natural capital: farmland, forest and water resources. The detail findings of each indicator and the sub-components are presented in Annex 3 and hence refer to it for all discussions to come.

Farmland: An assessment of farmers' levels of vulnerability in terms of farmland was carried out based on land size, terrain characteristics of farmlands, soil erosion severity, land fertility level, and crop yield based on households response. The total LVI result contributed by different indicators indicated that the vulnerability levels of households measured by farmland was found 0.76 in *kola*, 0.57 in *dega* and 0.51 in *woyna dega* sites. Instability of crop yield trend contributes greatly to the vulnerability levels of households in terms of farmland in *dega* (0.94) and in *kola* (0.92) while it is the third contributor in *woyna dega* (0.80). Inverse scores of yield per hectare were 0.83 for *woyna dega*, 0.89 for *kola* and 0.81 for *dega* sites implying very low yield per hectare.

The vulnerability scores for total farm size was higher in the three study sites (0.82 in *woyna dega* and equally 0.88 in *kola* and *dega*) which might be explained by the fact that the per capita farmland was found to be 0.46 hectare in *dega* and *kola*, and 0.77 in *woyna dega*. The maximum per capita land holding size was almost the same ranging from 3–3.5 hectares while the minimum ranged from 0 in *kola* and *woyna dega* to 0.05 hectares in *dega*. Farmland location, poor soil fertility level, and intense soil erosion also contribute more to the vulnerability levels of households in terms of farmland in *kola (0.45)* than *dega* (0.06) and *woyna dega* (0.16). By farmland topography, *kola* (0.65) households are more sensitive to climate change impact than *dega* (0.36) and *woyna dega* (0.23) households.

The land resource indicators are valuable to measure farmland quality and hence levels of vulnerability of households. The vulnerability assessment result indicated that the composite vulnerability score for land vulnerability was found much higher in *kola* site followed by *dega* and *woyna dega* sites. Crop yield per hectare including its long-term declining trend is an important measure of farmland quality and vulnerability to climatic risks. The results on these indicators indicated that the surveyed households are highly vulnerable to climate change impacts by crop yield, particularly in the *kola* site. The reasons are severe soil erosion resulting from undulating topography, intense rainfall with short duration and poor quality land management practices. Some authors argued that soil erosion is a major problem with the estimated erosion rates of 16–50 tones/hectare per year in Amhara Region accounting for more than 50% of estimated annual soil loss in Ethiopia (Desta et al., 2000). Interview reports also supported this explanation. One government official in the Office of Agriculture in *kola* agro-ecology noted the problem as: 'The production potential of the land is going down due to shorter rainy seasons, recurrent droughts, and intense rainfall events in shorter time which cause severe erosion.' This situation has increased vulnerability levels of rural households to the impact of climate change and associated extreme events in the region.

The results on land size indicators also showed that the total vulnerability level of the households to climate change impact in terms of farm size was higher in the three study sites. The reason could be explained by the fact that the average land holding was found to be 1.62 hectares per household in *woyna dega*, 0.79 in *kola,* and 0.78 in *dega* sites. Several empirical works indicated that owning larger farmlands provide more opportunities to cultivate more crops and yield though it is noted that labor availability and financial capital affect the reality of how much land can be cultivated. Barungi and Maonga (2011) found out that less farmland area is often attributed to increased vulnerability of farming households to climatic risks.

Location of farmlands in a very rugged terrain with the resultant accelerated intense soil erosion and poor soil fertility level has created significant differences in vulnerability levels of households across the three study sites. This has led to more vulnerability levels of the *kola* households than *dega* and *woyna dega* households. The reasons might be attributed to the fact that *kola* area with the very undulating topography has led households to become more sensitive to climate change impact. This result is line with the hazard-of-place model that argues that places located nearer to sources of a natural hazard are more vulnerable to hazard impacts (Cutter et al., 2003).

Vulnerability in terms of forest: Assessment of the vulnerability levels of the households in terms of forest resource supply was made in the study sites. Firewood supply trend and ownership of private trees around homesteads or elsewhere, distance to reach the sources of firewood and protection of forest resources were indicators to construct the livelihood vulnerability indices. The data was obtained through household survey triangulated with other qualitative data collection methods. The results revealed that limited ownership of the trees and severe damage in common forests provided households' vulnerability score of 0.20 and 0.53 respectively in *dega* while less vulnerable score was calculated for firewood trend stability (0.07) and distance to source of firewood (0.02). In *woyna dega*, the vulnerability scores for firewood supply trend and for severe damage to common vegetation were 0.78 and 0.69 respectively while the score was found to be 0.33 for tree ownership of households. Exceptionally, *kola* households were found to be more vulnerable by firewood supply trend (0.98), severe damage to common vegetated areas (0.93) and the status of trees ownership (0.79). In terms of distance to sources of firewood, *kola* (0.22) households were more vulnerable than *dega* (0.02) and *woyna dega* (0.05) households (Refer to Annex 3).

The densely populated, severely degraded *kola* environment was found to have greater vulnerability indices for almost all of the forest resource indicators as compared with *dega* and *woyna dega* study sites. As such, the efforts exerted for planting trees and other land conservation practices in the *kola* site are not promising as it is evidenced by the experiences observed over the last 25 years or so. Little effort in planting trees and land management practices has been exerted in the *woyna dega* study area. Still, low survival rate of seedlings was reported in both *kola* and *woyna dega* sites. In the dega site, eucalyptus is increasingly planted on the farmlands to overcome shortage of wood for construction and fuel uses. It is also used for both consumption and generating income.

Water resources: water is the basic natural resource for all forms of life on earth, without adequate supply of which there is no sustainable development and environmental functions. Rural household's degree of vulnerability in terms of access to water resources was examined based on farmers' observation. Responses from the survey indicated that 92% of households in *kola* have no access to piped water for domestic use against only 7% in *dega* and 7.5% in *woyna dega*. Hence, they are forced to utilize water from unprotected sources (wells, streams, rivers, ponds), indicating water-born health problems. Photo 11 demonstrated people waiting for fetching water for domestic purpose in *dega* study site. From this photo we can infer that let alone in *dega* site where there is a relatively abundant water resource, it indicated how much water shortage is more severe in the *kola* site where there is harsh climatic and environmental condition.

Photo 11: People waiting for water in *dega* agro-ecology

Source: Own field photo, February 2013

The survey results in *dega* indicated that 57.4% of the households spent 4 to 15 minutes to obtain their water supplies, 32% spent 16 minutes up to half an hour and 10.2% of them required 35 up to 53 minutes. Only one household took two hours to reach to water sources. In the *woyna dega* site, nearly half of the households (49%) travel from 3 to 15 minutes; 42.2% from 16 to half an hour and 7% from 31 up to 53 minutes. The rest, 2.3% of the households traveled between 70 and 75 minutes to obtain sufficient water in *dega*. In sharp contrast, less than 20% of the households in *kola* reported traveling from 3 to 15 minutes to fetch water for domestic purposes while 40.1% were required to travel from about 16 minutes to half an hour. Around 26% of them were traveling between 35 minutes and an hour while 12.3% of them between one and two hours, and the remaining 2% were traveling longer than 2 hours to obtain water.

The surveyed households have very limited access to irrigation with a vulnerability score of 0.94 in *kola*, 0.76 in *dega*, and 0.74 in *woyna dega*. The application of irrigation both from the users and area coverage perspectives in *kola* was only 4.6 hectares of land was irrigated by 6.5% of surveyed households. It was 8.5 hectares of land irrigated by 26.3% of surveyed households in *woyna dega* followed by 6.24 hectares irrigated by 24% of households in *dega*.

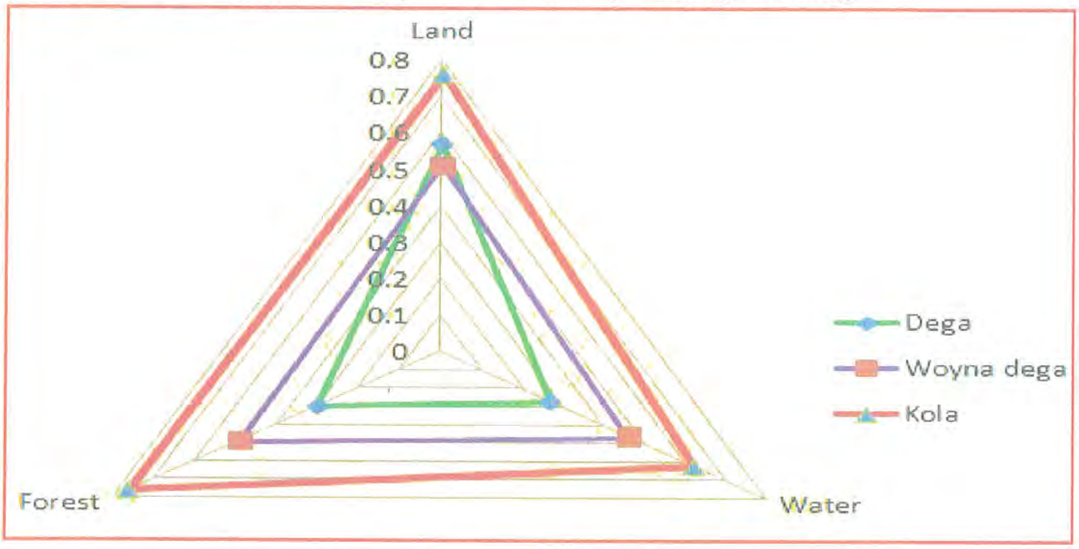
Average liters of water the households consume per day (0.80), lack of access to regular water supply (0.75), and conflict over water resources (0.51) contribute much to the vulnerability levels of the *kola* households in term of water resources. The amount of water consumed by a household per day (0.84), conflict over water (0.78), and absence of regular water supply (0.58) are making the households more vulnerable to climate change impacts in the *woyna dega* site. Low level of the households' water consumption per day (0.82) is the dominant contributor of water vulnerability levels of the households while conflict over water resources has lower contribution (0.17) to climate change vulnerability for *dega* households.

Corresponding to adverse climatic and environmental conditions experienced in the *kola* site, exceptionally 92% of the surveyed households have no access to piped water for domestic purposes as compared with de*ga* and *woyna dega* households (<=7.5%). Distance to water points is also an important measurement of vulnerability levels of households to climate change risks. The results indicated that *kola* households are traveling longer distances to fetch water and hence they are more sensitive to climate change impact calling for intervention through alternative mechanisms. While 89.4% of *dega* and 92.2% of *woyna dega* households travel from 4 minutes to half an hour, only 60.1% of *kola* households travel the same time to reach to water points. The remaining proportions of households in *kola* are expected to travel from 35 minutes to 2 hours with negative implications on time allocation for other productive and income generating activities.

Although irrigation is often identified as an effective adaptive strategy to cope with drought in rain-fed agriculture dependent households in the dry seasons, the surveyed households have very limited access to irrigation with very high vulnerability scores of 0.94 in *kola*, 0.76 in *dega*, and 0.74 in *woyna dega*. This is because the application of irrigation both from the users and area coverage perspectives was very low indicating that farming households are more vulnerable to drought and associated extreme events. In the light of this, the FGD discussants and in-depth interviewees in *kola* site strongly complained the problem of water shortage for different purposes. The increasing run-off which has affected underground water potential through reducing infiltration of rainwater and intense evaporation from surface water bodies are major cause of water scarcity in the study sites.

The cumulative effects of very low access to pure water and long distance to water points forced the households to utilize water from unprotected sources with implications for commonness of water-born human health problems, conflict among households over scarce water resources, and low water consumption for domestic and irrigation purposes thereby aggravating vulnerability situations of the community. The finding is consistent with other studies which report that water is variable in space, limited in availability, highly sensitive to climate change and one of the most critically stressed resources (Sullivan, 2002; IPCC, 2007; Sullivan & Huntingford, 2009). Nearly every country faces water shortage during certain times of the year. Poverty itself is now recognized as a lack of access to different livelihood capitals like water (Sullivan & Meigh, 2006). Having access to a reliable source of water for domestic and production use is indicative of levels of natural capital for households (Barungi & Maonga, 2011) and can clearly be linked to most of the human capabilities against climate change related risks (Sullivan et al., 2002).

Figure 29: Vulnerability radar diagram of natural capital by agro-ecology



Source: Computed form the household survey data, March – September 2012

Figure 29 and Annex 3 illustrate that by natural capital, the households are found to be vulnerable at 0.67 in *kola*, 0.51 in *woyna dega* and 0.43 in *dega* sites. The biophysical contexts have already made *kola* households more vulnerable in terms of this livelihood resource. Farmers and officials of both governmental and non-governmental offices are observing massive impact of drought and extreme weather-related events on natural resources such as farmlands, pastureland, water sources, and vegetation. They reported the depletion of these resources and in turn the subsequent declining levels of agricultural productivity and the resulting food insecurity. In relation to this, Wisner et al. (2004) argue that although they may experience greater losses (in absolute terms) than the poor, resource-rich households are more resilient in that they can recover more quickly from a climatic stress/stimulus.

Although natural capitals are known providers of goods and services which are highly valued by the society, these valuable natural assets have experienced persistent pressure and stresses from a range of direct and indirect socio-economic driving forces. Indeed, they are severely affected by climatic and environmental changes, leading the studied households dependent on these resources more vulnerable to poverty and food insecurity. The impacts of future changes will be felt particularly by these communities given that our environment has faced with risks from climate change.

5.3.3. Economic/Financial capital

One of the major components of vulnerability assessment depicted in the conceptual framework of this thesis (Fig.1) is economic/financial capital. The main economic resources upon which the study communities depend include, farm and non-farm income, livestock, credit, and livelihood activities based on entitlements for which this study examined the vulnerability levels of the households. The contributions of each component indicators to the composite vulnerability indices of economic capital are presented in detail in the coming sections. The indicators with their functional relationships and tabulated quantitative data for major components with their respective indicators are presented in Appendices 2 and 3 respectively. The data used in this sub-chapter is mainly obtained from the household survey triangulated and checked with information gathered through FGDs, in-depth interviews, field observations and previous study results.

Income: refers to cash generated from different sources to household consumptions and agricultural expenses. Households' financial assets were examined based on the average farm income, non-farm income, non-farm income diversification, remittance received by the household and non-farm employment opportunities.

The survey results indicated that households in the three sites showed greater vulnerability levels by income component with average vulnerability scores of 0.92 in *kola*, 0.87 in *woyna dega* and 0.86 in *dega* sites. Average farm income vulnerability was the worst situation in all the three sites (0.94 in *kola*, 0.94 in *dega*, and 0.84 in *woyna dega*). Almost 100% of the households in *kola*, 97% in *dega*, and 94% in the *woyna dega* sites do not have access to any remittances from relatives and friends from abroad or inside. Very low farm income diversification, in the *woyna dega* (0.91), in *dega* (0.86) and in *kola* (0.82) sites contributed to vulnerability levels of households in terms of income source diversification indicating very low adaptive capacity of households against climate change risks. In terms of non-farm income level, the households were more vulnerable to 0.98 in *kola* and 0.97 in *woyna dega* and *dega* equally. Even those households who reported to have non-farm job opportunities earned on average 1204.40 Ethiopian Birr per year in *dega*, 1407.20 Birr in *woyna dega* and 867.21 Birr in the *kola* sites. Moreover, non-farm job opportunities were limited in diversification, in *kola* (0.56), in *dega* (0.55) and in *woyna dega* (0.53) study sites.

The LVI results from the household survey indicated that households in the three study sites were found to be highly vulnerability by income component indicators. The reason is attributed to the fact that the households are very poor in terms of income as the majority of them are subsistence farmers. Although the three sites are highly vulnerable to climate change risks, the vulnerability scores have decreased when we move from *kola* (0.92) to *woyna dega* (0.87) and *dega* (0.86) sites. The income of *kola* households from their farms was even very low with an average of 1080.50 Ethiopian Birr, equivalent to $60, per year as compared with the farm income of farmers living along the Blue Nile of Ethiopia (4356.30 ET Birr) (Temesgen, 2010). The average farm income of the households in *woyna dega* was 9814.30 ($545.23), and 5917.40 ($328.74) per year in *dega*, which is larger by 55.61% than farm income of the households reported by the same author. As Chapter Four provided detail accounts, the harsh climatic anomalies coupled with fragile environmental conditions in the *kola* site have contributed much to the lowest farm income levels of the surveyed households, through affecting their crop and livestock production processes.

Additional income generated by other household members, who engage in non-farm employment, can more than compensate for the constraints caused by reduced farm labor availability. However, diversification of both farm and non-farm incomes and access to remittances were found very low in three study sites. The results point out very limited source of income for households indicating lower adaptive capacity against climate change impact. Temesgen (2010) and Barungi and Maonga (2011) argue that in the rural agriculture-dependent communities, diversified sources of income and remittances from family and friends play a crucial role in helping farmers cope up with the livelihood impact resulting from climate change.

Credit facility: Availability of credit institutions and the times taken to reach to them is different among the three study sites. Less than 4% of all the surveyed households in *dega*, 16% in *woyna dega* and 43% in *kola* reported absence of credit institutions around their localities. However, slightly more than two-third of the surveyed households in *kola*, but less than two-third in *dega* and *woyna dega* did not get money through credit in the past half decade. Those households who had borrowed money from formal/informal credit providers had taken on average 747.21 Birr in *dega*, 1104.48 in *woyna dega*, and 561.15 in *kola*, giving vulnerability index values of 0.94 in *kola*, 0.92 in *dega*, and 0.88 in *woyna dega* which implies very high vulnerability levels of households in all the study sites. In addition, in terms of time the households taken to reach to credit facilities have LVI values of 0.35 in *kola*, 0.12 in *woyna dega*, and 0.05 in *dega* sites.

The composite vulnerability index of the households by credit access is found to be higher in *kola* (0.62) than those in *dega* (0.44) and in *woyna dega* (0.43). Access to credit institutions may influence adaptation to climate change through facilitating access to agricultural inputs in production such as improved cultivars of crops, oxen and modern fertilizers. However, there is quite a great deal of fungibility in the sense that most people use the loan for unintended purposes such as consumption smoothing. Hence, it is assumed that the households who have no access to credit and unable to use money gained from credit for production purposes will be more vulnerable to climate change impact than those who have access to it (Temesgen, 2010) which demands for affordable formal and informal credit schemes for the vulnerable rural community.

Livestock ownership: The survey results indicated that nearly 89% of the surveyed households in *dega*, 92.2% in *woyna dega*, and 87.4% in *kola* own livestock, at least a hen. However, in terms of livestock units, the households were more vulnerable to 0.85 in *dega*, 0.84 in *kola*, and 0.81 in *woyna dega*. The survey results also indicated that the livestock ownership measured in terms of tropical livestock units (TLU) ranges from 0 to 8.15 in *dega*, 0 to 17.54 in *woyna dega* and 0 to17 in *kola*. Nearly 18% of the households in *dega*, 17% in *woyna dega*, and 19% in *kola* have no draught power.

The LVI results computed from the survey data indicated that overwhelming majority of the surveyed households own livestock, at least a hen in all study sites. The reason is related to the fact that livestock rearing does not depend on land ownership as compared to crop farming. Thus, it gives some option for landless households who have the opportunity to use community grazing fields.

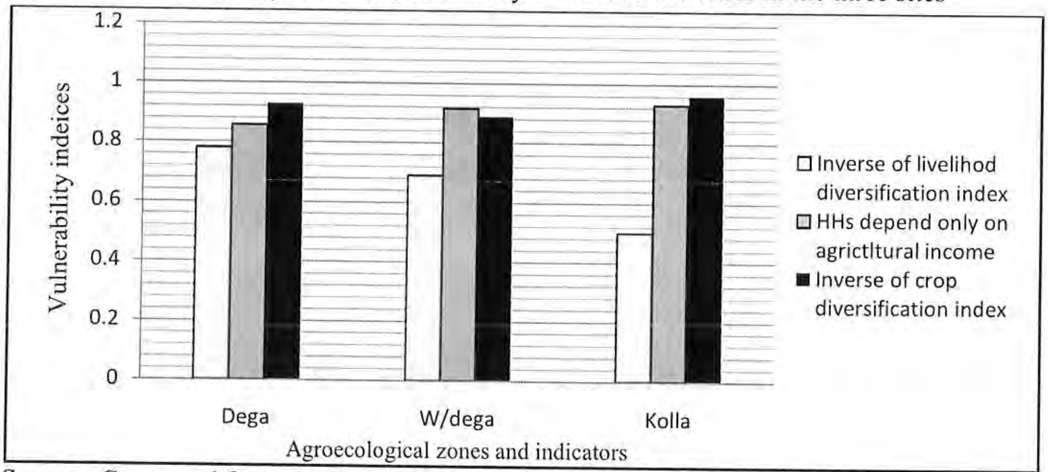
With regard to households' livestock ownership, the results in this study are in line with the findings of several other empirical works. Barungi and Maonga (2011) and Temesgen (2010) argued that households who have not draught power are more vulnerable to climate change risks as they are unable to cultivate their farmlands in the appropriate time, or for being forced to give their lands for share-cropping. In the farming season, oxen mark a big difference among farmers who own and who do not own livestock. Moreover, households who have no livestock cannot sale and buy fertilizers, unable smoothing their incomes and poorly nourish their families with animal products such as milk and meat. They also do not use dung cakes to fertilize homesteads. Besides, they cannot use pack animals for timely transportation of the crops to a threshing point. Since threshing is conducted using animal power, the availability of livestock especially during peak periods is vital. It helps reduce post harvest loses.

Livelihood activities: As livelihood diversification is one of the risk minimization measures; this sub-chapter assessed the extent of households' livelihoods activity diversification. The analysis based mainly on the data collected through household survey and secondary sources (areas coverage for different crops) to identify livelihood activities that the rural households engaged by counting their numbers undertaken, calculating their shares to the overall income, proportions of households solely depend on agriculture, and crop diversification level. Figure 30 and Annex 3 present raw data for indicators of livelihood diversification and the levels of adaptive capacity of the farmers to climate variability and change.

The LVI results indicated that the majority of the households in the three agro-ecologies were found only dependent on agriculture with LVI values of 0.93 in *kola*, 0.92 in *woyna dega*, and 0.86 in *dega* sites. The inverse of the calculated crop diversification index was 0.96 in *kola*, 0.93 in *dega* and 0.89 in *woyna dega*. By inverse of livelihood diversification, the households' vulnerability indices were 0.78 in *dega*, 0.69 in *woyna dega*, and 0.5 in *kola*. Working non-farm activities generates additional income only for 31%, 20.3% and 16.3% of the *dega*, *woyna dega*, and *kola* households respectively. Moreover, the contribution of non-farm income was calculated to be 20.42% of the total income collected by households in *dega*, 14.41% in *woyna dega*, and 28.23% in *kola* unlike that of reported in Barret et al. (2001), cited in Barungi & Maonga (2011) which was over 40% in rural parts of Africa.

In contrary to other indicators, the proportion of non-farm income was found somewhat high in *kola* followed by *dega* sites. This finding is similar to Ellis's (2000, 2004) argument which noted that because of the mixed nature of the rural poor people, multi-activity is common on a household level. The livelihoods of the poor are thus based on diversification of sources of food, income and security (Ellis, 2000, 2004). Multi-locality is also increasing for the poor – people living in several places and families splitting up to search for better jobs. These types of people are found to be common in the study areas though the proportion is estimated to be higher in *kola*, as people move to Mizan Tepi, Wollega, Metama and Quara areas as daily laborers.

Figure 30: Vulnerability of the households by livelihood activities in the three sites



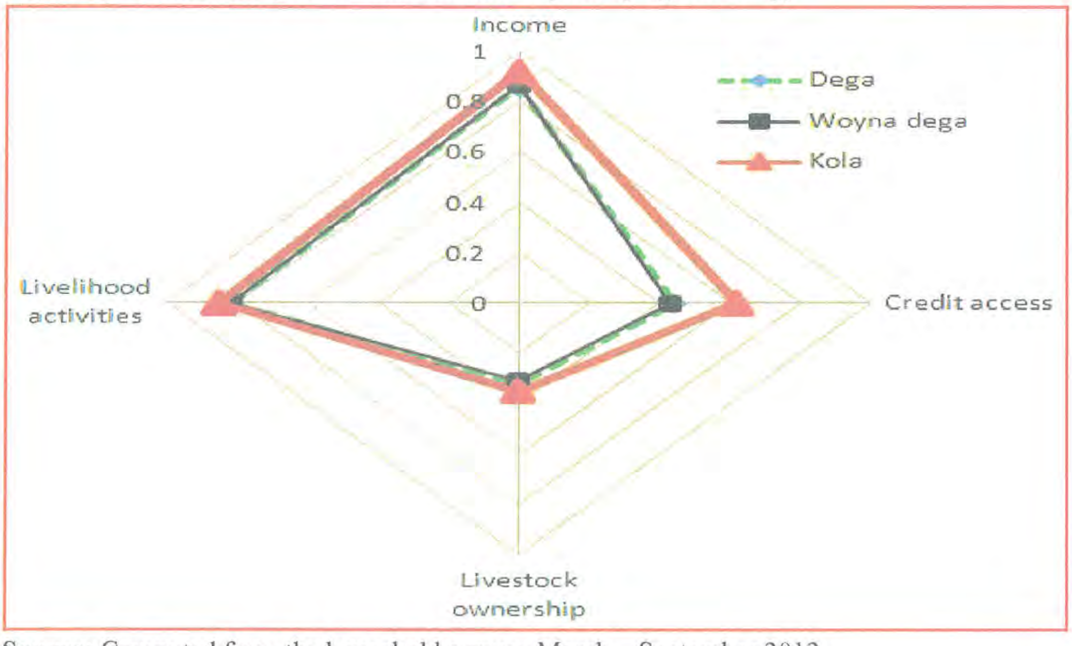
Source: Computed from the household survey, March – September 2012

Several studies unanimously confirmed that livelihoods diversification is the main strategy for reducing the vulnerability of households and for increasing options for the community in the face of climate change (Chambers & Conway, 1992; Ellis, 2000; Turner et al., 2003; Allison, 2004). The LVI results presented above indicated that the majority of the households in the three agro-ecologies were found only dependent on agriculture, cultivation of limited crops, and low access to non-farm activities which contributed much to the highest vulnerability levels of the surveyed households to climate change related risks.

With regards to livelihood diversification, the results in this thesis are in line with the findings of a number of other empirical findings which have already confirmed that people engaged less in the cultivation of different crops and livelihoods activities have greater vulnerability levels and the opposite is hold true for the people engaged more in diversification of crops and livelihood activities (Ellis, 2000, 2004; Barungi and Maonga 2011). Land shortage together with other factors could be explained as the main reason to have planted different crops in the field. Those other reasons could mainly be attributed to limited/no other job opportunities, lack of money, limited skill and knowledge, and lack of access to markets among other factors. Other more reasons can be speculated that the extension package has encouraged livelihood intensification through specialization with less/no emphasis on diversification. FAO (2003) and Leulseged et al. (2012) asserted that the current agricultural extension approach is focused on what is known as the Agricultural Development-Led Industrialization/ADLI 'intensified package' approach putting heavy attention on accelerating production through application of fertilizer and improved seeds without careful analysis of agro-ecological zones, markets, infrastructure, farmers' choice and other more sustainable development options. The current climate resilient green economy (CRGE) initiative also prioritize intensification of cultivation through improved inputs and better residue management to limit the soil-based emissions from agriculture and the pressure on forests from expansion of cultivated land area (Leulseged et al., 2012). However, there are some activities related to livelihood diversification and asset building haphazardly practiced in different parts of the country including the study areas.

After presenting the results and discussions for each sub-component of economic capital asset, the composite vulnerability levels of households were summarized in the radar diagram (Figure 31) namely income, access to credit, livestock ownership and livelihood diversification, across the three study sites.

Figure 31: Vulnerability radar for economic capital by agro-ecology



Source: Computed from the household survey, March – September 2012

From Annex 3 and Fig. 31 it is very clear that *kola* households (0.67) were highly vulnerable to climate change impacts than those in *woyna dega* (0.59) and *dega* (0.58) households. When disaggregated by major components of economic capital, households have limited adaptive capacity by income level (0.92) in *kola*, (0.87) in *woyna dega*, and (0.86) in *dega*, and livelihood diversification (0.86) in *dega*, (0.83) in *woyna dega*, and (0.80) in *kola* than by credit access (0.62) in *kola*, (0.44) in *dega*, and (0.43) in *woyna dega*), and by livestock ownership (0.32) in *dega*, (0.35) in *kola*, and (0.3) in *woyna dega*.

5.3.4. Physical capital

It is obvious that people's access to basic infrastructure services is fundamental to bring economic growth whereby play significant roles in enhancing public welfare and improving quality of life of the community. As such, level of access to infrastructure facilities is an important measure of the households' sensitivity to climate change risks. Hence, this sub-chapter analyzed the households' levels of sensitivity/vulnerability indices to measure the households' access to physical capital. The indicators considered in this capital asset included shelter quality including residential location, sources of household energy, access to road transport and telephone services, as well as access to input and output markets. The results for each indicator are presented in detail in the subsequent sections supported with Annex 3.

Housing quality and location: Housing quality and location can create variation in the households' levels of sensitivity and/or adaptive capacity to avert the risks posed by climate change and variability. Households' differentiation on house quality and safety can be observed through variation of wall building, roofing materials and location. The data was collected for these indicators using household survey and checked with field observation.

The findings revealed that 95% of the households in *dega*, 99.2% in *woyna dega*, and 75.3% in *kola* reported their dwelling houses' walls are made of wood and mud while insignificant proportions were constructed from stone and mud. The overwhelming majorities, 93% in *dega*, 92.5% in *woyna dega*, and only 14.1% of *kola* households reported that they used corrugated iron sheet roofing. With regard to settlement location, nearly 97% of *dega*, 67% of *woyna dega* and 60.1% of *kola* houses are located in the plain areas, which are almost free from flooding and severe erosion while the rest were reported to be located in the hazardous locations (See Table 17).

Table 17: Types of building materials for the residences of households

Indicators	Specific indicators	*Dega*	*Woyna dega*	*Kola*
Houses' walls made of	Wood and mud	95.3	99.2	75.3
	Mud and stone	4.7	0.8	24.7
Houses' roofs made of	Corrugated iron sheet	93	92.5	14.1
	Grass roofed	7	7.5	85.9
Houses' location	Plain - free from floods	96.9	66.9	39.9
	Plain - exposed to floods	2.3	13.5	10.3
	Mountainous and rugged terrain	0.8	17.3	45.2
	Near rivers – exposed to floods	-	2.3	4.6

Source: Household survey, March – September 2012

The indicators used and the results in this thesis are in line with the findings of other several empirical works. The quality of houses is an indicator of wealth status in most African countries (Temesgen, 2010). For example, a stone house is a key indicator of wealth in rural Tanzania (Barungi & Maonga, 2011). Similarly, the wall of houses made of stone and a roof of corrugated iron sheets are measures of wealth status in the study areas. Accordingly, the information obtained through the household survey indicated the types of building materials used by the surveyed households. The findings revealed that although the overwhelming majority of the households' houses' walls are made of wood and mud, their proportion increased when we move from *kola* to *dega*. As the *kola* environmental condition is not suitable for planting eucalyptus trees, wood shortage is a serious problem for different purposes. As a result, households have gradually shifted their construction of houses towards stone and mud. Therefore, it is vivid that the materials used to construct walls in all the three sites are highly sensitive to climate change impacts. Surprisingly, the wider variation was reported in the use of corrugated iron sheet roofing between *dega* and *woyna dega* together and *kola* households because only 85.9% of *kola* households reported that their houses are grass roofed with only 14. 1% of them used corrugated iron sheet roofing. This has made the community exceptionally most sensitive to climate change-induced risks.

On the one hand, it was reported that most of the *woyna dega* houses are located in the plain areas, which are almost free from flooding and severe erosion while the rest were reported to be located in the hazardous locations. On the other hand, about 60.1% of the houses in *kola* are located in the hazard prone topographies. Therefore, the dwelling houses of the *kola* households will be under increasing risk of damage and destruction like dwelling houses in other parts of Ethiopia, with the projected increase in heavy rainfall events, hailstorms, wind, and landslides. Correspondingly, the LVI scores signified variations in vulnerability levels of the households in terms of shelter by the agro-ecological setting. In fact, the overall scores indicated that the households in *kola* are found to be more sensitive to LVI score of 0.74 and decreased to 0.47 in *woyna dega* and 0.35 in *dega*. This means the households in *kola* have a 74% probability to be affected by climate change-induced extreme events while it is 47% in *woyna dega* and 35% in *dega* sites.

Location is an important determinant in the vulnerability situations of people and places to climate change-induced hazards. For example, the location of *woyna dega* site around the shore of Lake Tana and at the foot of the Semein highlands exposes it to recurrent flooding. Over-flowing of the channels of the minor and major rivers and an abnormal rise in the level of the Lake Tana has flooded agricultural fields and human settlements almost every year (Hassan, 2006) though the magnitude and intensity vary from year to year. Similarly, the location of the *kola* site in the fragile undulating landscape of Abay and Beshilo Valleys exposes it to severe land degradation, soil erosion and recurrent drought conditions.

Photo 12: Sensitive houses to weather-related events in *Woyna dega* & *kola* areas

Source: Field photo by the assistants, 2012

Photo 12 demonstrates the location and quality of the rural houses in *woyna dega* (the left) and *kola* (the right). Although they have relatively better quality, the left houses in the figure are more prone to flooding while the right houses are poorer in quality so that they are more sensitive even to simple weather-related events such as wind and flash floods. Although coordinated early-warning system and community-based preparedness plans should be given prior attention, particularly in *kola* and *woyna dega* agro-ecological settings, they are lacking.

Sources of energy: Access to energy source is one of the fundamental measures of households' climate change vulnerability as it can contribute to social and economic development, to energy access, to a sustainable energy supply, and to a reduction of negative impacts of energy provision on the environment and human health (IPCC, 2012). Accordingly, the vulnerability levels of rural households were examined using households entirely relying on firewood and battery/electricity for lighting and fuel saving stoves for cooking. In terms of the dependency on firewood for lighting, *dega* (0.54) and *kola* (0.48) households were vulnerable as compared with *woyna dega* households who had least LVI score (0.01). Exceptionally, few numbers of *woyna dega* households have used fuel saving stoves (0.96), which makes them more sensitive to climate change impacts while nearly half of the respondents in *dega* and *kola* sites have never used it for cooking. Different batteries become important sources of lighting for 64% of *dega* households in comparison to 12% of both *kola* and *woyna dega* households with no support from GOs and NGOs (Photo 13).

Photo 13: Sources of lighting in *dega* agro-ecology

Source: Field photo by the assistants, 2013

Distance to sources of services, firewood in this case, is another indicator of sensitivity of the community to climate change risks. Therefore, the households were asked how much time spent on travelling to reach to sources of firewood in hour/minute. The result for the three study sites is presented in Table 18 indicating differences on time the households travel to reach to sources of firewood. It is clear from the table that while 93% in *dega* and 78.2% of all the surveyed households from *woyna dega* took not more than 30 minutes, only 10.3% of them in *kola* travel the same length of time to collect firewood. On the other hand, while 42.2% of *kola* households have moved about 30 minutes to 1:00, against 11.3% in *woyna dega* as compared with only 6.2% in *dega* sites.

About 7.2% *kola* of households took about 1:00 to 1:30, and 19% from 1:30 to 2:00 to reach to sources of firewood. Over 21% of them travel longer than two hours to collect the same energy source. When we see the cumulative percentages, over 99% of the households in *dega*, 89.5% in *woyna dega* and 52.5% in *kola* have spent less than an hour to collect firewood implying higher degree of sensitivity of the later households to climate change and associated extreme weather events.

Table 18: Distance households travel to collect firewood by agro-ecology

Agro-ecology	Distance in minute	Frequency	Percent	Cumulative percent
Dega	0-30	120	93	93
	31-60	8	6.2	99.2
	61-90	1	0.8	100
	91-120	-	-	-
	Over 120	-	-	-
Woyna dega	0-30	104	78.2	78.2
	31-60	15	11.3	89.5
	61-90	-	-	-
	91-120	4	3	92.5
	Over 120	3	2.3	94.8
	Missing system	7	5.2	100
Kola	0-30	27	10.5	10.3
	31-60	111	42.2	52.5
	61-90	19	7.2	59.7
	91-120	50	19.0	78.7
	Over 120	56	21.3	100

Source: Household survey, March – September 2012

The cumulative effects of the above indicators namely: households entirely relying on firewood, non-users of battery/electricity for lighting and fuel saving stoves for cooking, and distance to source of firewood have resulted in overall energy vulnerability scores of 0.62 for *kola* and *woyna dega* and 0.47 for *dega* households. The heavy reliance of households on forests for energy consumption through increasing pressure on the already exhausted forest resources is the main reason. As such, this situation has put the environmental sustainability issues in question. The time rural households spent to collect forest products for household energy consumption can impact on the time available for other productive and income generating activities. Significant differences among the sites in terms of time a household traveled to collect firewood has created sensitivity variation among households settled in the three agro-ecological zones. By this indicator, *kola* households were found exceptionally more sensitive to firewood shortage than *dega* and *woyna dega* households. The results discussed in section 4.2.2 among other factors are the main reasons. In relation to this, several studies noted that longer distance to reach to different services centers increase the sensitivity of the community to climate change-related extreme events (Hahn et al., 2009; Lamichhane, 2010; Temesgen, 2010).

Larger proportion of *dega* and few *woyna dega* and *kola* households have used different batteries systems usually charged with sunlight and connected with thin wires as the most important adaptation technologies for lighting with no recognition and support from GOs and NGOs. The use of this renewable energy source has important implications for forest and land resources management and mitigation thereby enhance sustainable environmental and socio-economic development. This direction is in line with the IPCC (2012) ideas which viewed the relationship between renewable energy (RE) and sustainable development (SD) as a hierarchy of goals and constraints that involve both global and regional or local considerations. Though the exact contribution of RE to SD has to be evaluated in a country-specific context, RE offers the opportunity to contribute to a number of important SD goals: (1) social and economic development; (2) energy access; (3) energy security; and (4) climate change mitigation and the reduction of environmental and health impacts.

Communication: access to transport and telephone services are essential indicators of sensitivity to and/or adaptive capacity of households against climate change risks. Most specifically, time required for reaching to the nearest vehicle station/road network and public telephone centers, numbers of households who travel on foot to their *woreda* town were vital indicators of communication component of physical capital. This section considered these indicators as these can create variation in the vulnerability levels of households across the three sites.

The survey result revealed that the average time to reach to the nearest vehicle station or road network is nearly 8 hours (477 minutes) against less than 1 hour (59 minutes) and slightly over half an hour (35.5 minutes) respectively for *woyna dega* and *dega* households. About 68% and 37.6% of the households in *dega* and *woyna dega* sites respectively do not use a vehicle to travel to their *woreda* towns. In terms of availability of year-round transport, nearly 21% of the households in *dega* and 53.4% in *woyna dega* reported the absence.

Places located in isolated difficult topographies are found more sensitive to different climate-related hazard risks as it is difficult to construct roads. In the light of this, the survey result revealed that by transport indicators the *kola* site is found to be the most inaccessible area as it is located in Abay and Beshilo valleys. Inaccessibility is evident by absence of vehicle transport to all people and hence forms of transport to travel to their *woreda* town is limited to walking, head loading and traditional means of transport using pack animals, perhaps much more difficult than the situation at the national and regional level. As regards access to transport, the results in this study are in line with the findings of several other empirical works (Robit, 1996; Temesgen, 2010). These authors noted that transport can play an important role in adaptation to climate change by facilitating access to different resources. For instance, all-weather roads facilitate the distribution of necessary agricultural inputs for adapting to climate change, and the economic activities by increasing access to output markets. So, lack of this essential infrastructure influences human decision on adaption and the overall well-being of the society.

Communication through radio, television, fixed public telephone and mobile phone is effective tool for disseminating information on changing weather patterns and adaptation options to the rural community. However, all these communication tools were not included in the vulnerability computation because the initial field observations suggested that these physical assets did not significantly differ among the communities. But later on, it was asserted that mobile phones have been utilized by few *woyna dega* and *dega* households while it was rare in *kola*. Only access to fixed public telephone services was considered for analyzing households' sensitivity to climate change risks.

Table 19: Distance households travel to the public telephone center by agro-ecology

Agro-ecology	Time in minute	Frequency	Percent	Cumulative percent
Dega	0 – 30	38	29.5	29.5
	31 – 60	70	54.3	83.7
	61 – 90	12	9.3	93.0
	91 – 120	9	7.0	100.0
	Over 120	-	-	-
Woyna dega	0 – 30	23	17.3	17.3
	31 – 60	9	6.8	24.1
	61 – 90	23	17.3	41.4
	91 – 120	14	10.5	51.9
	Over 120	64	48.1	100.0
Kola	0 – 30	41	15.6	15.6
	31 – 60	70	26.6	42.2
	61 – 90	24	9.1	51.3
	91 – 120	52	19.8	71.1
	Over 120	76	28.9	100.0

Source: Household survey, March – September 2012

Table 19 presents the time taken by the households to reach to public telephone centers. The results indicated that the households travel on average nearly 53 minutes in *dega*, 2 hours in *woyna dega* and over 2 hours in *kola* site to reach to public telephone centers. Thus, *kola* and *woyna dega* households reported longer average time to reach to the nearest telephone centers, indicating limited information exchange in the areas. Nearly 30% of the *dega*, 17.3% of *woyna dega* and 16% of *kola* households have traveled up to 30 minutes to get pubic telephone services. From 31-60 minutes distance is traveled by 54.3, 24.1, and 26.6% of the households in *dega*, *woyna dega* and *kola* respectively. While 17.3% of the households in *woyna dega* have traveled from 1:00 to 1:30, 9.3% of them in *dega* and 9.1% in *kola* traveled the same. Similarly, nearly 20% of households in *kola*, 10.5% in *woyna dega,* and 7% in the *dega* site traveled from 1:30 to 2:00. Exceptionally, 48.1% in *woyna dega* and nearly 30% of the households in *kola* site traveled longer than 2 hours while no one travels this distance in *dega* site.

6.1.3. Farming households' perception to climate change impacts

The survey data and the meteorological records indicated increasing temperatures and decreasing and/or erratic rainfalls in the study sites over the past decades. The decreasing trend in precipitation is against the projections of climate models for East Africa as they predicted that except in very few places, rainfall is likely to increase (IPCC, 2007). The study in Kenya also indicated an increasing trend of rainfall (Bryan et al., 2011).

An assessment of climate change impact perception in the three agro-ecological settings indicated that a significant proportion of the households perceived its adverse effects of exacerbating extreme events on their livelihoods systems.

Table 23: Perceived impacts of climate variability by agro-ecology

	Perceived impacts identified by households	*Dega*		*Woyna dega*		*Kola*	
		Frequen.	%	Frequen.	%	Frequen.	%
Impact of temperature (Perceived)	Crop pests, diseases and weeds	24	18.6	81	60.9	165	62.7
	Animal and human diseases	64	49.6	99	74.4	142	54.0
	Change in cropping pattern	18	14.0	72	54.1	149	56.7
	Increased climate hazards	25	19.4	81	60.9	172	65.4
	Dried up water resources	55	42.6	92	69.2	178	67.7
	Pasturelands damaged	70	54.3	81	60.9	154	58.6
	Livelihoods changed	28	21.7	70	52.6	111	42.2
	Food shortage aggravated	77	59.7	97	72.9	180	68.4
	Negative effect on agriculture	78	60.5	101	75.9	124	47.1
Impact of rainfall (Perceived)	Change in cropping season	65	50.4	109	82.0	181	68.8
	Change in land use pattern	22	17.1	80	60.2	126	47.9
	Crop and animal product↓	71	55.0	101	75.9	168	63.9
	Crop pests & animal diseases↑	36	27.9	90	67.7	136	51.7
	Damage to pastureland ↑	50	38.8	84	63.2	159	60.5
	Rainfall intensity and erosion↑	42	32.6	96	72.2	138	52.5
	Climate related hazards↑	21	16.3	90	67.7	142	54.0
	Dried up water resources	53	41.1	90	67.7	165	62.7

Source: Household survey, March–September 2012; SPSS 16 output using multiple response command *Frequen. = Frequency

Table 23 presents the consequences of climatic shocks perceived by sampled households. The majority of the respondents (82% in *woyna dega*, 68.8% in *kola*, and 50.4% in *dega*) noticed that rainfall change results in changes in cropping patterns and changes in land use pattern (60.2%, in *woyna dega*, 48% in *kola*, and 17.1% in *dega*), decrease in crop and livestock products (76% in *woyna dega*, 64% in *kola*, and 55% in *dega*), increased crop pests, disease, weeds and animal diseases, pastureland deterioration, increased rainfall intensity which leads to severe soil erosion, increased climatic hazards, damage to water resources, increased food crisis, and harmful effects on total agricultural production.

While the FGD results do support the results of the household survey, farmers place greater emphasis on rainfall variability when making the plans for their farming activities. Their perception to climate change centered over long-term greater rainfall variability which hindered their ability to predict rainfall patterns and plan their farming activities accordingly. In addition, many farmers reported that the shortening of the rainy seasons have led to longer dry periods which result in greater pressure on food supplies. The farmers' concerns about rainfall variability are warranted given that rain-fed agriculture is the dominant source of staple food crop production and livelihood for the majority of the rural poor. Climate variability, in particular the occurrence of drought, is the strong determinant of agricultural performance as well as general economic development in the country (Devereux, 2000; NMA, 2001). Both of the survey and FGD participants also reported an increase in rainfall intensity has exacerbated the problem of flooding and soil erosion, particularly in *kola*.

As it was discussed in sections 4.2.1 and 4.3.2, the majority of the households reported a decreasing trend of food crop production from time to time in contrast to the 8.4% national level average production growth rate in the period 2005/2006 to 2009/2010 (MoFED, 2010). Although it seems contradictory for outsiders and generalists it is hold true for the context of my study sites, particularly for *kola* site. For example, during the survey period, Mid-March to the end of June 2012, there was no rainfall in all the three study sites. Particularly, *kola* households claimed late onset delayed planting of slow maturing crops like maize, sorghum and millet, and even other cereals followed by early cessation of rainfall has led to greater yield decline and in some cases total damage to crops. This was checked by the field observation during harvesting months in *kola* (October – December, 2012), *woyna dega* and *dega* (November – January). The case presented next also elaborates more the severity of the problem in *kola*.

> The rainy seasons are becoming shorter than the past 20 or so years. In the past, the main rainy season was four months long; now there is on average two months with decreasing rainy days over these two months. Last year (2012), the rains started to fall around 5th July and ended 1st September. Long maturing crops such as sorghum, maize and millet, the dominant food crops in our area, were not totally planted. Even the rain was not sufficient enough for the growth of cereals and pulses as well as for regenerating pasturelands for livestock at least in the rainy season. The streams, ponds, and reservoirs continue to be empty immediately after the rain has stopped falling. To make matters even worse, in these short rainy times, the rain has increased in intensity, causing landslide, severe soil erosion and pasture degradation. The overall effects of these problematic situations were crop failures; no harvesting was undertaken on *teff*, barley, wheat, beans, peas, and other crops. I don't know what would happen until the next harvest; people may migrate and die; theft and conflict over livelihood resources may increase unless the government could mitigate the problem through a wide range of interventions (Free Food Aid and Safety Net Programs). But there is a doubt that the government couldn't do so, as we are told that we are already graduated from a Safety Net Program after participation over the past six years. If the government fails to do so, I am eager to see the last fate of the people until the next harvest.

The majority of the households interviewed associated the decline of crop yield with the impact of drought, poor soil fertility, increased incidence of crop and animal pests and disease. Furthermore, other non-climatic factors like inadequate extension services and poor access to modern inputs or ineffectiveness of modern fertilizers; particularly in *kola* site were mentioned. In this regard, ACCRA (2011) noted that the impact of climate change is more pronounced when there is interaction with other non-climatic stresses. Farmers, experts, extension officers, and veterinarians iterated that drought, flood, pests, and diseases have increased in recent 10-20 years as compared to the previous decades. They also revealed the emergence of new pests, diseases, and invasive weed species.

The magnitude and rate of current climate variability, climate change, and other extreme events combined with environmental, social, and political factors are making many traditional coping strategies ineffective and/or unsustainable, amplifying land degradation and food insecurity which in turn forced households to find new strategies.

6.2. Farming households' adaptation strategies to climate change

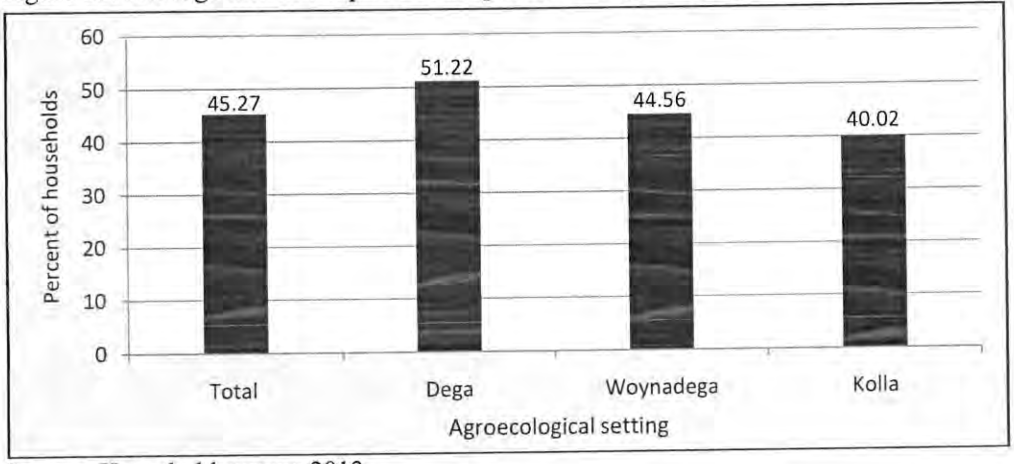
There are many alternative adaptation strategies to counterbalance climate change impacts and to enhance people's livelihoods. In this study, potential strategies for adaptations to climate change and different determinants to adaptation choices were identified. Some scholars contend that the adaptation measures reported by farmers might be production maximization driven rather than climate change (Madison, 2006; Nhemachena & Hassan, 2007; Temesgen, 2010). Despite this missing link, it can be assumed that farmers' actions are driven by climatic factors as was reported by farmers themselves. This section tries to analyze and discuss the adoption of different adaptation measures by smallholder households.

6.2.1. Rate of adopting adaptation strategies

Analysis was done to identify the most and least adopted adaptation strategies based on the proportion of households who adopt the possible adaptation options in each agro-ecological zone. The questions were designed for the farming households to enable them put a tick mark in front of the listed adaptation options they have used and leave otherwise with the help of data collectors.

Figure 36 and Table 24 demonstrate the application of adaptation strategies as measured in terms of percentage of the adopters. It is clear from the figure that the average adoption rate of climate change adaptation strategies in the three sites is 45.27%. The rate of adoption in the *dega* sites is above the average of the three agro-ecologies (51.22%) while it is below average in *woyna dega* (44.56%) and *kola* (40.02%). This implies that high rate of adoption of adaptation measures was reported in *dega* as compared to *woyna dega* and *kola* sites.

Figure 36: Average rate of adoption of adaptation strategies by agro-ecology



Source: Household survey, 2012

A key finding is that the households in *kola* site are less likely to adapt to climate change than households in *dega* and *woyna dega* which is consistent with the finding of Temesgen et al. (2009) and Bryan et al. (2011) for most adaptation strategies, but in contrary to the findings of Yesuf et al. (2008) conducted in the Blue Nile Basin of Ethiopia. Bryan's et al. (2011) findings in Kenya indicated that the households in arid district of Garissa are least likely to adapt to climate change, whereas households in the temperate coffee areas of Mukurweini and Othaya were most likely to adapt. The authors speculated that the low probability of adaptation in arid Garissa may be partly due to the fact that they are already coping with difficult climate conditions. For example, farmers in Garissa have to irrigate in order to grow most crops; therefore they would be less likely to report irrigation as an adaptation strategy because they are already doing this. The low level of adaptation is also an indication of limited adaptive capacity in this district as well.

The *kola* site is poverty stricken and environmentally fragile area. The harsh environmental and climatic conditions deter smallholder households from using modern technologies such as fertilizers, improved seeds and animal fodder species and irrigation. The poor also lack resources to timely prepare their farmlands, apply inputs in time, and manage their land intensively. Other reasons such as poor access to markets, infrastructure and institutional services like education, agricultural extension, credit, and other government provisions were mentioned. The low-level of adoption is also an indication of limited adaptive capacity in this agro-ecology – households are unable to adopt due to lack of resources needed for adaptation. Therefore, it is clear that vulnerability to climate change is closely related to poverty, as the poor are least able to respond to climatic stimuli (Burton et al., 2006).

Table 24 presents the percentage of households who have adopted different adaptation strategies by agro-ecology. Most of the adopted strategies by the farmers in the study areas are similar to other findings in the climate change adaptation literature (Mentez et al., 2008; Yesuf et al., 2008; Temesgen et al., 2009; Temesgen, 2010; Bryan et al., 2011). The highest rates of adoption in *dega* were reported with animal manure-compost (96.9%), terracing and changing planting dates (94.6% each), replanting crops (91.5%), chemical fertilizers (82.2%), improved seeds and changing consumption to cheaper food items (77.5% each), cultivating different crops (69.8%) and being involved in different livelihood activities (57.4%). The least adopted adaptation strategies in the same agro-ecology were use of herbicides (1.6%), pesticides (2.3%) and rainwater harvesting (3.9%).

Table 24: Percentage of households who use adaptation strategies by agro-ecology

Adaptation options	Total	*Dega*	*Woyna dega*	*Kola*
Manure and compost	**91.93**	**96.9**	**84.2**	**94.7**
Modern fertilizer	**75.87**	**82.2**	**88.0**	**57.4**
Pesticides	35.57	2.3	**81.2**	23.2
Herbicides	17.63	1.6	34.6	16.7
Selected seeds	**53.67**	**77.5**	**75.9**	7.6
Livelihood diversification	30.33	**57.4**	17.3	16.3
Crop diversification	**68.13**	**69.8**	**68.4**	**66.2**
Change of planting dates	**74.13**	**94.6**	**67.7**	**60.1**
Replanting crops	**73.27**	**91.5**	**60.2**	**68.1**
Irrigation	19.97	24.8	24.8	10.3
Water harvesting	7.6	3.9	3.0	16.0
Tapping ground water	13.17	14.0	2.3	23.2
Diversifying livestock	28.67	30.2	12.8	43.0
Improving animals species	13.33	23.3	4.5	12.2
Improved animal fodder	12.63	21.7	9.0	7.2
Terrace construction	**84.23**	**94.6**	**72.9**	**85.2**
Planting trees	**64.4**	**86.8**	44.4	**62.0**
Change to cheap food items	**69.93**	77.5	**66.9**	**65.4**
Seasonal migration	25.53	22.5	28.6	25.5
Average	**45.27**	**51.22**	**44.56**	**40.02**

Source: Household survey, March – Sept 2012, SPSS16 output using multiple response command

The most adopted strategies in *woyna dega* research site were the use of modern fertilizers (88%), manure-compost (84.2%), pesticides (81.2%), improved seeds (75.9%), terrace construction (72.9%), planting different crops (68.4%), changing planting dates

(67.7%), change food consumption to cheap items (66.9%), and replanting crops (60.2%) while the least adopted strategies were extracting underground water (2.3%), rainwater harvesting (3%), improved livestock species (4.5%), and improved animal fodder (9%), livestock diversification (12.8%), and diversification of livelihood activities (17.3%). The moderately applied strategies include planting trees (44.4%), use of herbicides (34.6%), and seasonal migration (28.6%). Pesticides application was exceptionally higher in *woyna dega* households (81.2%) than those in *kola* (16.8%) and *dega* (1.6%) corresponding to seven frequencies reported by households compared with *dega* (two frequencies) and *kola* (five frequencies) over the past ten years.

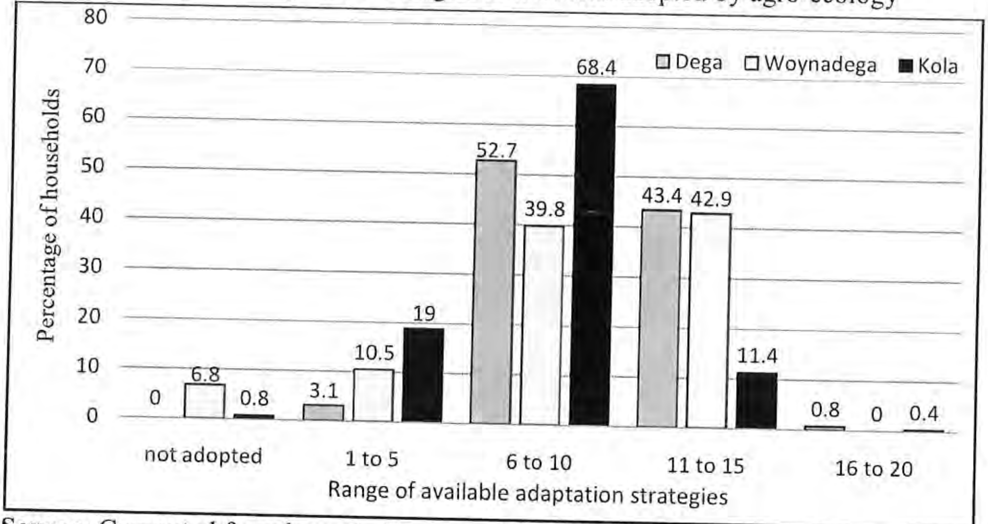
In the *kola* site, application of manure-compost (94.7%), terrace construction (85.2%), replanting (68.1%), crop diversification (66.2%), shifting food consumption to cheap crops (65.4%), planting trees (62%), changing planting dates (60.1%), and use of modern fertilizers (57.4%) were the most adopted adaptation strategies. Use of improved animal fodder (7.2), selected seeds (7.6%), irrigation (10.3%), improved animal species (12.2%) rainwater harvesting (16%), livelihoods diversification (16.3%), herbicides (16.7%), both pesticides and digging water well (23.2%), and seasonal migration (25.5%), and livestock diversification (43%) were the least adopted strategies.

The rates of adoptions of different adaptation measures by the households were found to be somewhat lower than Kenyan famers (Bryan et al., 2011). The high rates of adoption of the available adaptation strategies could be associated with being less expensive and easier access to households (Temesgen, 2009), which indicated that farming households do appreciate the seriousness of climate change-induced problems in the study sites and the implications for land productivity. Exceptionally, more use of pesticides (81.2%) and herbicides (34.6) was reported by *woyna dega* households than those in *kola* (23.2% and 16.7%) and in *dega* (2.3% and 1.6% respectively) because in *woyna dega* pests infestations were reported as the major hazards affecting the community. The least adoption rate of adaptation strategies could be attributed to the need for more capital, limited access, and lack of need for adopting them. For instance, access to improved livestock species, improved forage production, and herbicides are found to be limited to farmers. The limited application of irrigation for adaptation could be attributed to limited and/or no water resources potential for irrigation, or it requires more capital investment.

6.2.2. Range of farming households' adaptation strategies

As it is already discussed, the surveyed farmers adopted a range of adaptation strategies in response to climate change. The ranges of adoption by households vary across agro-ecologies.

Figure 37: Range of adaptation strategies households adopted by agro-ecology



Source: Computed from household survey data, March – September 2012

Figure 37 indicated that nearly 7% of the respondents did not take any adaptation measure in the *woyna dega* research site while it was found to be only 0.8% in *kola* site. All the farmers in *dega* have applied at least one strategy and hence the ranges of adaptation strategies were found to be many as compared with those used in *woyna dega* and *kola* sites. Only 3.1% of the surveyed households in *dega* had adopted at least 1–5 strategies out of the 19 strategies against 10.5% in *woyna dega* and 19% in *kola*. Nearly 53% of *dega*, 68.4% of *kola* and nearly 40% of *woyna dega* households employed 6–10 adaptation strategies. The rest more or less 43% of *dega* and *woyna dega* households used 11–15 adaptation strategies while this range was used by only 11.4% of *kola* households. Only one household used 16 adaptation measures in *dega* site while no one adopted over 15 strategies in other sites. The reason may be attributed to the better adaptive capacity in *dega* in terms of water resource potential, relatively good land fertility and less harsh climatic and environmental conditions to pursue different strategies – planting trees, irrigation, application of fertilizers, improved seeds, herbicides, and the like.

These results revealed that the households in the *kola* site are not only struggling against the harsh climate conditions but also have a more limited range of adaptation options available to them as was suggested by Bryan et al. (2011) for the arid Garissa households in Kenya. It may not also be necessary for farmers to adopt all the 19 strategies unless they are supposed to adopt as a package by the government. Besides, some strategies such as the use of pesticides and herbicides may not be needed in *dega* areas where pests and weeds are less prevalent. Rainwater harvesting may not also be applied in *dega* and *woyna dega* research sites. Lack of access to improved animal and fodder species also may constrain their adoption in the three research sites.

6.2.3. Composite index of adoption

A composite index of adoption of different adaptation strategies was calculated for the three study sites by counting the number of adaptation strategies applied by farming households using formula 3.4.3A (Barungi & Maonga, 2011). The results indicated that the households participated in this study have responded to the impacts of climate change using various adaptation strategies with varied index of adoption across the three study sites and individuals The computed adoption indices for individual households and composite adoption indices by agro-ecology are referred in Annex 7a-c and summarized in Table 25 below.

Table 25: Composite index of adoption of adaptation strategies by agro-ecologies

Agro-ecology	Composite index of adoption	Standard deviation	Minimum	Maximum
Dega	0.49	0.11	0.1	0.8
Woyna dega	0.44	0.19	0	0.75
Kola	0.39	0.14	0	0.8

Source: Household survey, March – September 2012

Table 25 presents the composite index of adoption of climate change adaptation measures farmers applied by agro-ecology. The composite index of adoption in *dega* was found to be 0.49 (standard deviation = 0.11; minimum = 0.1; maximum = 0.8). In *woyna dega* it was found to be 0.44 (standard deviation = 0.19, minimum = 0, and maximum = 0.75). The index was lower (0.39) in *kola* as compared with other sites (standard deviation = 0.14, minimum = 0, and maximum = 0.8). This index is low and it highlights the fact that the majority of the farming households have adopted few adaptation strategies out of the 19 strategies available to them.

6.3. Determinants of farmers' adaptation choices: Logistic regression analysis

The communities have many ideas on how to prepare for future climate change with a strong motivation to move out of poverty. However, their ability to adapt is constrained by many factors. Farmers who didn't take adaptation measures have pointed out many reasons for their failures to adapt including: limited access to information on climatic events and adaptation strategies, lack of money, limited knowledge and skill, shortage of labor, shortage of land, lack of market, poor access to water, lack of equipment, and lack of access to agricultural extension and other institutional services.

6.3.1. Evaluation of the model and test of significance

The model evaluation and tests of significance were conducted to see whether the selected model better fits to the data collected on the chosen variables. The fineness/robustness of the model to the data was measured by applying the SPSS classification table, the Hosmer-Lemshow test and co linearity and multi-co linearity statistics. The data collected through households survey on the questions asked whether households adopt or not the given alternative adaptation strategies (listed in Table 6) were entered into SPSS 16 against independent variables. In the process of running the model, the binary logistic regression was run for each dependent variable with the same independent variables (Listed in Table 6). In the SPSS command, the dependent variables were inserted to dependent variable list box and the independent variables were inserted to covariates box and then the categorical variables were changed into the categorical variables list box. After entering the variables in the appropriate list boxes, the necessary statistics such as classification plots, Hosmer-Lemeshow goodness-of-fit, correlation of estimates and confidence interval (CI) for Exp(B) were checked and then run at 95% confidence.

The classification tables of the SPSS output shows that 525 selected cases (households) were included in the analysis having no missed cases for each dependent variable. In the constant-only model, without any other information, the model helped to provide the percentage correct from 58%−92.6% for different dependent variables (adaptation strategies). This values have been compared with the changes in percentage correct that gained by including independent variables in the model (67.9% − 93.7%). It was this difference that made the logistic regression model provides a better fit to the data over the null model (the model only with the constant) (SPSS16).

The fit of the model resulted from the incorporation of the predictor variables is also observed from the Hosmer and Lemeshow Test which is the inferential goodness-of-test statistic that gives a Chi-squared values with a small value of degree of freedom. The test statistics for each dependent and independent variable are insignificant when the p-values are greater than 0.05 levels. This condition suggests that the model adequately fits the data since the null hypothesis of a good model fit to the data was tenable. The Hosmer-Lemeshow statistic indicates a poor fit if the significance value is less than 0.05 (SPSS 16). By doing this, independent variables with significant p-values (<0.05) were excluded from entering in the model. For, example in the first run of the model the independent variables, namely gender, land fertility levels, draught animal ownership, and access to training and number of relatives in a village were excluded for the land management practices as they had p-values less than 0.05. Similar works were done for other components of adaptation and those significant variables (having P-values less than 0.05) were excluded from the final model based on Hosmer-Lemshow test. This was the reason that the dependent and independent variables listed in Tables 26—29 and in the corresponding Annex 4 exhibit large variations because during the Hosmer-Lemeshow goodness-of-fit procedure all the independent variables were run with dependent variables as it is depicted in Annex 4.

The third way of checking the robustness of the model was assessing the multi-co-linearity (correlation between predictor variables). The study assessed co-linearity and multi-colinearity using two ways: using correlation matrices and variance of inflation factors (VIF). The correlation matrix is simply a table produced as one of the logistic regression results that indicates the correlation between two predictor variables. If the value of the correlation close to 1 or -1 indicates that there is co-linearity. The results of the analysis indicated that there was no correlation between two variables whose correlation value more than 0.8. The other method used to detect multi-co linearity was variance inflation factor (VIF). The variance inflation factors were checked the same way as can be done for the linear regression. Since logistic regression model has no way to examine multi-colinearity, the study ran a linear regression with the same predictors and dependent variables of the logistic regression model. The value of variance inflation factors of each variables were assessed to detect whether there is multi-colinearity or not. If the value of VIF is more than 10 there is multi-colinearity among predictors but the results of this thesis indicated that there was no multi-colinearity because the value of VIF for all variables were less than 10 (1.062 - 2.278) (Refer Annex 4).

6.3.2. Model results and discussion

Based on the household survey, from a number of predictor variables, some factors influence the decision to adopt a given adaptation option. The logistic regression analysis results are presented in Tables 26-29 and detailed discussion for each adaptation option is presented in the sections to come.

6.3.3. Land management practices

Manure-compost: It is a practice of spreading animal manure and related compost in the field for soil fertility maintenance for enhancing sustainable agriculture. In the study areas, the application of animal manures like *'fig'* (dry animal feces) combined with straws is important for soil fertility management. Most of the time, farmers apply manure near the homestead, rather than to land at a distant place. Compost is also prepared from animal manures, weeds, plant leaves as well as crop residues. However, the largest proportion of the inputs comes from animal manure. Several factors influence households' decision to use manure-compost in response to perceived changes in environment and climate. The logistic regression result (Refer Table 26) revealed that agro-ecology, family size, access to climate information and livestock ownership were statistically significant determinants of adoption of manure-compost (significant at 0.05 level).

Significant differences in the likelihood of households' application of manure-compost across agro-ecologies were observed. Although severe land degradation was reported in *kola* (0.55) and *woyna dega* (0.032) households were less likely to adopt manure-compost respectively than those in *dega.* The reason may be attributed to the fact that *kola* and *woyna dega* households mostly use animal dung as a major source of fuel than *dega* households. This finding challenges the purpose of climate-smart' agricultural development initiated by the government involved establishing agricultural activities that included existing techniques and knowledge that could increase the organic content of soils in addition to reducing erosions (Leulseged et al., 2013). This adds a fuel on the lives of *kola* households in addition to the severely degraded environment and tough climatic conditions, which have discouraged them to use modern fertilizers and other modern agricultural inputs.

In *dega,* modern batteries installed in the houses are the most important sources of lighting for 64% of the surveyed households as compared to 12% both for *kola* and *woyna dega* households. In addition, an increasing trend of forest supply was reported by the *dega* households, which in turn may help them to refrain from using animal dung and crop remnants for fuel. Most *woyna dega* households own relatively fertile farmlands which may not need manure-compost. Moreover, the area is suitable for modern fertilizers and that the households have relatively better capacity than those of *kola* households. This finding contradicts with the findings of Yesuf et al. (2008) as it pointed out that *dega* households were less likely to take climate change adaptation measures than *kola* households though not specifically to manure-compost use.

An increase in one person in the family increases the probability of the adoption of manure-compost by 4.343 times for the reason that it is labor-intensive activity. Access to climate information increased the likelihood of adopting manure-compost. For example, those households who had access to climate information were 2.887 times more likely to adopt it on their farmland as a land management practice. They may understand that application of manure-compost can facilitate the growth of crops so as to save them from being damaged by the expected drought conditions. As expected, a unit increases in the households' livestock ownership increases their probability of adopting manure-compost by 1.78 since livestock is the main source of soil fertility management input.

Table 26: Determinants of farmers' adoption of land management practice

Independent variables	Manure-compost		Modern fertilizer		Irrigation		Terrace building		Tree planting		Underground water	
	Sig.	Exp(B)	Sig.	Exp(B)	Sig.	Exp(B)	Sig.	Exp(B)	Sig.	Exp(B)	Sig.	Exp(B)
Agroe -*Dega*	**.000***		**.000***		**.01***		**.000***		**.000***		**.000***	
Agroe-*W/deg*	**.000***	.032	.950	1.028	.386	.651	**.000***	.09	**.000***	.06	**.00***	.08
Agroe-*Kola*	.442	.550	**.000***	.239	**.04***	2.24	.098	.44	**.003***	.35	.05	2.04
Age _ HH	.903	1.002	.193	1.014	.603	1.01	**.004***	.97	.922	1.00	.16	.98
Family size	**.000***	4.343	**.004***	1.718	.785	.98	**.046***	1.48	**.035***	1.31	.11	.69
Education	.949	1.008	.544	1.037	.498	1.05	.250	.92	.116	1.11	.22	1.08
Clim_info(1)	**.023***	2.887	.296	.769	.428	1.28	**.006***	2.24	.777	1.07	**.00***	3.98
Farm size	.419	1.362	**.002***	2.362	.808	1.05	.744	1.07	**.033***	1.360	.22	.69
Acc_water(1)	.767	1.246	**.001***	.312	**.00***	48.6	.375	1.48	**.049***	2.533	.650	1.22
TLU	**.000***	1.780	**.001***	1.252	.641	1.03	.388	1.06	.242	1.063	**.00***	1.26
Farm income	.864	1.000	.583	1.000	.552	1.00	**.036***	1.00	**.006***	1.000	.38	1.00
Nonfarm inco	.889	1.000	.234	1.000	.621	1.00	.808	1.00	.978	1.000	**.04***	1.00
Farm-to-farm exten(1)	.080	2.271	**.039***	1.741	.929	.971	.118	1.59	**.019***	1.757	.52	1.25
Exten_serv(1)	.926	1.047	.357	.787	**.00***	2.37	.792	.93	**.000***	2.300	.13	1.66
Perc_ temp(1)	.534	1.595	.128	.524	.804	.886	.563	1.30	.337	.696	.93	1.05
Percep_RF(1)	.988	1.011	.397	1.490	**.009***	2.296	.485	.68	.065	2.125	.96	1.03
Constant	.214	.153	.212	.356	.056	.173	.008	13.40	.452	.573	**.02***	.09

Source: Households survey, March – September 2012 **Note**: The reference category is not adopt
RF = rainfall

Although statistically insignificant, most independent variables showed positive association with the adoption of manure-compost. Thus, from this it can be inferred that these variables increase the chance of adapting manure-compost adaptation strategy against the impact of climate change.

Modern fertilizers: The very important focus of the extension system in Ethiopia is to increase production by using more artificial fertilizers. However, its application has been determined by several factors. The logistic regression estimates indicated that agro-ecology (*dega* and *kola*), family size, farmland size, access to water for irrigation, livestock ownership, and farmer-to-farmer extension were statistically significant having p-values less than the threshold (0.05) level (Refer to Table 26). All of these variables signify positive relationship with fertilizers application as they have parameter values greater than zero, except access to water for irrigation having a parameter value of less than zero.

Agro-ecological zones have also created significant variation among the rural households in the adoption of modern fertilizers. *Woyna dega* households were 1.028 times more likely to apply modern fertilizers than those in *dega* whilst *kola* households were 0.239 times less likely to adopt fertilizers. This result is expected because in the *kola* sites environmental conditions are so unfriendly to apply modern technologies like modern fertilizers and selected seeds. Instead, many farmers choose to use conservation tillage, mixed cropping, and crop rotation to maintain farmland fertility. These adaptation strategies are consistent with the principle of climate-smart' agricultural development initiated by the government for enhancing agricultural activities that included existing techniques and knowledge to increase the organic content of soils through conservation tillage, increasing water holding capacity and establishing more resilient crops and reducing erosion. In addition, integrated soil fertility management could lower fertilizer costs, increase soil carbon and improve yields. These 'multiple wins' are the centre of the concept of smart agriculture (Leulseged et al., 2013). However, same authors stated that a triple win approach requires adjusting institutions, policies, financing and markets to strengthen capacities for transformational change of agriculture systems at various scales.

Family size positively enhances the application of modern fertilizer. For example, an addition of a person in the family increases the probability of adopting fertilizer by 1.718 times, indicating that the larger the size of the household, the better the chance of adapting to climate change. Although there are controversial results on the role of family size, this result is supported by Temesgen's et al. (2009) findings which indicated a positive relationship between family size and adoption of different climate change adaptation measures.

Farmland and livestock ownership are measures of wealth status in the rural households. The results indicated that every additional unit of farmland and tropical livestock unit increase the probability of adopting modern fertilizers by 2.362 and 1.252 times respectively. Land has greater power in determining farmers' fertilizer application. In line with this, studies demonstrated that declining farm size has affected agricultural production in many parts of northern Ethiopia. The units of land divided up by each generation are declining to the level of insufficiency in size to apply new technologies and to support food security. On these small plots, many smallholder farmers are trapped in low productivity. As a result, they are forced to convert already low levels of assets (e.g. livestock) into cash to purchase food and hence many highland farmers have little capacity to adopt climate change adaptation measures even if they are willing to engage in agricultural intensification (Leulseged et al., 2013). Coupled with land shortage, rainfall variability and unpredictability persists, which is a key reason for Ethiopia now ranking as one of the countries at most 'extreme risk' from the effects of climate change.

The households who have access to farmer-to-farmer extension[7] were also 1.741 times more likely to adopt fertilizer, indicating the role of peer influence and social capital in climate change adaptation. On the contrary, households who have access to water for irrigation were 0.312 times less likely to adopt modern fertilizers as irrigation enables them to produce enough more than ones per year. Age of the household head, education, farm income, non-farm income, number of relatives in a village, and perception of rainfall change and variability signified positive correlation with households' fertilizer adoption decision. However, they are statistically not significant as they assume p-values greater than the threshold level (0.05).

Irrigation-water harvesting: Irrigation is an important adaptation strategy in drought prone communities though its application is determined by several biophysical and socio-economic factors. The regression analysis presented in (Refer to Table 26) indicated that agro-ecology, access to water, extension services, and perception of rainfall change significantly influence the application of irrigation against climate change. In aggregation, *kola* households were 2.238 times more likely to use irrigation-water harvesting together than *dega* households while those in *woyna dega* were 0.651 times less likely to adopt irrigation-water harvesting than *dega* households. More importantly, access to water increases the probability of adopting irrigation by 48.649 times within the households. However, when irrigation and water harvesting are disaggregated, *dega* and *woyna dega* households were more likely to adopt irrigation than *kola* households who showed higher propensity to use water harvesting than *dega* and *woyna dega* households. Households who have access to extension services were also 2.372 times more likely to adopt-irrigation-water harvesting schemes than those households who have no access to such valuable services. Households who perceived climate change and variability were 2.296 times more likely to apply irrigation-water harvesting strategy. This means, perceiving rainfall change has positive relationship with the use of irrigation which is consistent with the findings of Temesgen et al. (2009).

[7] In the farmer-to-farmer extension approach, innovative farmers can inspire and teach other farmers to incorporate the method they developed against climate change impact and found successful.

Family size, farmer-to-farmer extension and perception of temperature change showed negative relationship with irrigation use having statistically insignificant parameter values of greater than 0.05 level. Other statistically insignificant variables signify positive relationship, indicating increasing the chance of adopting irrigation-water harvesting strategies against climate change impact. Leulseged et al. (2013) expressed their concern in that the expansion of future irrigation is constrained by low levels of technology and the cost of energy and the authors acknowledged the focus of some key government initiatives now on improving small-scale irrigation expansion at a household level.

Constructing terraces: There are long-term benefits to households from adopting many sustainable land management (SLM) practices in terms of reducing soil erosion, increasing yields, reducing variability of yields, and making the households more resilient to climate change. However, the adoptions of these methods have been constrained by a number of biophysical and socio-economic factors. The logistic regression model results indicated that agro-ecology, family size, farm income, and access to climate information were statistically significant determinants in the decisions of households to construct terraces. *Woyna dega* and *kola* households were 0.085 and 0.439 times less likely to use terracing as a soil and water conservation strategy than *dega* households.

Age of the household head also affects terrace construction in the household. For example, for each year increase in age of the household head decreases the probability of adopting terraces by 0.967 times. This means that as terrace construction requires more energy, young people were more active in constructing terraces than those of old age households. This finding is supported by Madison (2006) who argued that older farmers are often less likely to adopt soil conservation practices because of their shorter planning horizons and a less than perfect capitalization of such benefits due to underdeveloped land markets. Family size also signified positive relationship with terrace construction. That is, a one person increase in the family can increase the probability of constructing terraces by 1.476 times for the reason that terrace construction is a labor-intensive activity. Households who had access to climate information were 2.239 times more likely to adopt terraces on their farmland. Even though not statistically significant, farm size, access to water, livestock ownership, farmer-to-farmer extension and farmers' perception of temperature changes showed positive contribution for the adoption of terraces by farmers.

Planting trees: Tree planting is another important component of sustainable land management in the rural communities. Planting trees counteract different types of environmental damage, generate income to serve as insurance against climatic shocks and provides shade for people and livestock. However, the planting and survival rates of planted seedlings have been determined by different factors. Agro-ecological zones, family size, farm size, access to water, farm income, farmer-to-farmer extension, and extension service were statistically significant in determining households' adoption of planting trees for adapting to climate change. The result implies the significant difference across agro-ecologies in the adoption of planting trees. For example, *woyna dega* and *kola* households were 0.06 and 0.347 times less likely to plant trees than those households in *dega*. The interview results and field observations confirmed that *dega* households have changed their productive lands to trees. Low survival rates of trees have discouraged households to plant more trees, particularly in *kola* and *woyna dega* agro-ecologies. Like any other land management strategies, family size, farm size, and access to water positively influences the adoption of planting trees. For instance, a one person increase in the family, a unit increase in the farm size, and access to water resources show 1.314, 1.36, and 3.533 times probability of planting trees respectively. Although farm income is statistically significant, its impact is very low on the adoption of planting trees. Access to extension services such as farmer-to-farmer and formal extension services increase the probability of adopting planting trees by 1.757 and 2.30 times respectively. Though statistically not significant, age, farm size, tropical livestock unit, and perception of temperature change indicated positive relationships with planting trees. From this we can infer that these factors increase the chance of adopting planting trees.

Extracting underground water: Rural communities who have faced surface water shortage have extracted water from the deep ground for the household consumption, livestock use, and agricultural practices. However, households' ability to extract it from underground is determined by different biophysical and socio-economic factors. The logistic regression estimation indicated that agro-ecological setting, access to climate information, livestock ownership, and non-farm income have positive and significant relationship with extracting underground water (See Table 26). *Kola* households were 2.036 times more likely to use underground water than *dega* households whilst *woyna dega* households were 0.083 times less likely to use it than *dega* households. Severe water shortage in *kola* sites has forced households to drill water holes while such is not true in *dega* and *woyna dega,* for there is relatively abundant surface water. Access to climate information increases the probability of extracting underground water nearly by 4 times. This means, lack of access to climate change information reduces the probability of extracting underground water.

Every additional tropical livestock unit (TLU) increases the probability of tapping underground water by 1.26 times. The shortages of water for the households' livestock prompt the farmers to use this adaptation strategy. Non-farm income is statistically significant; however it has not created variation in the adoption of underground water within the households. Although not statistically significant, other variables except age, family size and farm size, have positive relationships with using underground water by households.

6.3.4. Crop management practices

The second category of adaptation practice to climate change impact as grouped by climate change research community is changing crop management practices. For this study using improved seeds, changing planting dates, replanting, and planting a variety of crops were selected in the context of the study sites. Similar to other adaptation measures, the applications of these strategies have been determined by a number of socio-economic and biophysical factors. The logistic regression estimation identified different determinants of this group of adaptation measure (See Table 27).

Table 27: Determinants of farmers' adoption of crop management practices

Independent variables	Improved seeds		Use of variety crops		Change planting dates		Replanting crops	
	Sig.	Exp(B)	Sig.	Exp(B)	Sig.	Exp(B)	Sig.	Exp(B)
Agro-ecol – *dega*	**.000**		**.001***		**.000***		**.000***	
Agro-ecol – *w/dega*	.130	.543	**.024***	.453	**.000***	.071	**.000***	.109
Agro-ecology – *kola*	**.000**	.023	.125	1.598	**.000***	.085	**.046***	.454
Age of the HH	**.004**	.964	**.029***	.980	.133	.985	**.041***	.980
Gender of HH(1)	.735	1.140	.245	1.385	**.004***	2.264	**.034***	1.850
Family size	.076	1.520	.966	1.007	.217	1.240	.761	.950
Educational attainment	.769	.979	.405	1.047	**.005***	.853	.765	.982
Climate info(1)	**.046**	1.826	**.040***	1.570	**.001***	.438	.463	1.191
Farm size	**.005**	1.895	**.002***	1.905	**.015***	1.655	.320	1.183
Land fertility(1)	.824	1.095	.289	1.324	.732	1.097	**.038***	1.791
TLU	.684	.966	.277	.936	**.009***	.842	**.022***	.868
Draught animal	.955	1.012	.724	1.059	**.017***	1.557	.188	1.249
Farm income	**.022**	1.000	**.000***	1.000	.066	1.000	**.000***	1.000
Non-farm income	.349	1.000	.481	1.000	.183	1.000	.833	1.000
Farmer-farm exten(1)	**.008**	2.464	**.034***	1.675	.905	1.031	**.001***	2.309
Extension_service(1)	.842	1.062	**.015***	.562	.313	.774	.557	.865
Percept_ RF change	**	**	**	**	.36.2	.1.480	.467	1.339
Constant	.920	1.084	.539	.695	**.000***	13.393	.156	2.561

Source: Households survey *significant at 0.05 ** not fitted to the model (1) stands for 'Yes'

Improved seeds: In the case of this study, improved seeds include high yielding varieties, drought tolerant, short maturing and pests and diseases resistant species either induced or indigenous. The regression model results indicate that agro-ecology, age of the household head, access to climate information, farm size, farm income and farmer-to-farmer extension are statistically significant to explain variation in the adoption of improved seeds by households with a parameter value of less than 0.05 (See Table 27). All of these variables, except age have positive relationships with the adoption of improved seeds with parameter values greater than zero. Like the other adaptation strategies, agro-ecology exhibits significant difference in the households' adoption of improved seeds.

The likelihood of the households' adoption of improved seeds in *woyna dega* (0.543 times) and *kola* (0.023 times) were less likely to adopt improved seeds than *dega* households. Accesses to climate information, farm size, and extension services have positive association with the adoption of improved seeds having the probability of adopting it respectively by 1.826, 1.895, and 2.464 times. For those statistically not significant variables (except age, education, and TLU), including perception of temperature and rainfall change, have positive relationships with the use of improved seeds, indicating the chance of increasing adoption of improved seeds against climate change.

Planting variety of crops: Cultivating different crops is also considered as an important adaptation strategy to climate change impact. Still its adoption can also be affected by different biophysical and socio-economic factors. The logistic regression model results indicated that agro-ecology (*kola*), age of the household head, access to climate information, farm size, farm income, and extension services (both farmer-to-farmer and formal) were statistically significant as they assume p-values less than the threshold (0.05). All of which, except age, signified positive correlation with planting different crops (See Table 27).

Kola households were 1.598 times more likely to diversify crops than those settled in *dega* and *woyna dega*. It is clear that *woyna dega* households were 0.453 times less likely to diversify crops than *dega* households. This result deviates from crop diversification index values calculated on the basis of the proportion of crop land area coverage gathered from secondary data sources. In computing crop diversification index (inverse) (Chapter Five), the proportions of only major crops were taken for analysis, resulting in slightly higher crop diversification index in *woyna dega* than in *kola* and *dega* study sites. However, in this analysis, whatever the area coverage of crops is, the numbers of crops reported by farmers were taken which provides somewhat different result from crop diversification index presented in Chapter Five.

Households who have access to climate information and farmer-to-farmer extension services were 1.57 and 1.675 times more likely to plant different crops respectively than households who have no such access whilst extension service signified negative relationship. Every additional hectare of land to the households' farmland increases the probability of diversifying crops by 1.905 times. Although it is statistically significant, farm income has not created variation in planting different crops among the households. Except age and TLU, all those statistically insignificant variables showed positive association with planting different crops on the households' farmlands, indicating the chance of increasing the cultivation of variety of crops to reduce the adverse impact of climate change and extreme events.

Changing planting dates: changing crop planting dates as an adaptation strategy to the impact of climate change can be determined by several factors in the rural households. Agro-ecology, gender, education, climate information, farm size, livestock ownership and draught animal ownership significantly determine changing planting dates (See Table 27). *Kola* and *woyna dega* households were 0.071 and 0.085 times less likely to change planting dates than *Dega* households. Male-headed households were 2.264 times more likely to change planting dates than female-headed households. Every additional unit of farmland in the household and draught animal ownership increases the probability of changing planting dates by 1.655 and 1.557 times respectively. Family size, land fertility, farm and non-farm incomes, farmer-to-farmer extension, and perception of rainfall change which is consistent with the findings of Temesgen and colleagues (2009) showed positive relationship with changing planting dates. However, these variables are not significant in statistical terms having parameter values of greater than the threshold (0.05). On the contrary, age of the household head, education, access to climate information, and livestock ownership signified negative relationship with the use of changing planting dates as an adaptation measure.

Replanting crops: Replanting of crops is significantly influenced by agro-ecology, age, gender, land fertility, livestock ownership, and farm income and farmer-to-farmer extension. *Woyna dega* and *kola* households were 0.109 and 0.454 times less likely to replant crops as an adaptation measure than *dega* households. This is because immediately at the end of the rainy seasons, there is more soil moisture deficit, particularly in *kola* than in *dega*, which is discouraging replanting crops. A one year increase in age, decreases replanting by 0.98 times and male-headed households were 1.85 times more likely to use replanting crops than that of female-headed households. Land fertility level and farmer-to-farmer extension increase the probability of adopting replanting of crops by 1.791 and 2.309 times respectively. From those statistically significant variables, age and livestock ownership showed inverse relationship with replanting crops (Refer to Table 27).

Although statistically not significant, access to climate information, farm size, draught animal ownership, non-farm income and perception of rainfall change proved positive relationships with replanting of crops having parameter values of greater than zero, implying they can increase the chance of using replanting crops (See Table 27). From those non-significant independent variables, family size, education, and formal extension service indicate an inverse relationship with replanting of crops having parameter values of less than zero.

6.3.5. Livelihood strategies management

The third category of climate change adaptation recognized by climate change research community is managing livelihood strategies. In this study activity diversification, changing to cheap food crops/items, and seasonal migration were used under this category of adaptation to climate change. The logistic regression results are presented in Table 28.

Diversifying livelihood activities: livelihood activity diversification is determined by many biophysical and socio-economic factors. The logistic regression model results indicated that agro-ecological zone, and access to vocational training and extension services significantly influence the households' capacity to diversify livelihood activities (Refer to Table 28). *Woyna dega* and *kola* households were 0.133 and 0.145 times less likely to diversify livelihood activities than *dega* households. Access to vocational training would have a probability of increasing the adoption of livelihoods diversification by 2.467 times whilst the household who have access to extension service were 0.542 times less likely to diversify livelihood activities than the households who have no access to extension services. It is speculated that the extension program has mostly encouraged intensification rather than diversification. In line with this, FAO (2003:Viii) asserted that "The current agricultural extension approach in Ethiopia is focused on what is known as the "intensified package approach", which puts heavy emphasis on accelerating production, using fertilizer and improved seed, without careful analysis of agro-ecological zones, markets, infrastructure, farmers' choice and other sustainable development options." The recent CRGE initiative also prioritizes intensification of cultivation through improved inputs and better residue management to limit the soil-based emissions from agriculture and the pressure on forests from the expansion of land under cultivation. Intensification policy direction is also part of an earlier Agricultural Development-Led Industrialization/ADLI (Leulseged et al., 2013).

Table 28: Determinants of farmers' adoption of different livelihood strategies

Independent variables	Activity diversification		Change to cheap food crops		Seasonal migration	
	Sig.	Exp(B)	Sig.	Exp(B)	Sig.	Exp(B)
Agro-ecology – *dega*	**.000**		.522		**.000***	
Agro-ecology – *w/dega*	**.000**	.133	.348	.706	**.001***	.219
Agro-ecology – k*ola*	**.000**	.145	.286	.732	**.000***	6.965
Age of the HH	.680	1.004	**.000***	.965	**.035***	.978
Gender of the HH(1)	.885	.955	**.007***	2.130	.192	1.527
Family size	.384	.850	.257	1.204	.333	1.058
Educational attainment	.472	.959	.304	1.062	.800	1.014
Access to training(1)	**.006**	2.467	.060	1.963	**	**
Access to climate info(1)	**	**	**	**	**.000***	3.923
Farm size	.244	1.233	.182	1.345	**.013***	.569
Access to water	*	*	.615	.921	.865	.946
Tropical livestock unit	.636	.973	.783	1.090	**	**
Draught animal	**	**	**.038***	.719	**.001**	1.582
Farm income	.699	1.000	**.033**	.708	**.006***	1.000
Non-farm income	.099	1.000	.136	1.000	.408	1.000
No.of relatives in a village	.083	1.016	.195	1.000	.056	1.019
Farmer-to-farmer extension(1)	.056	1.721	**.021***	1.727	**.030**	1.792
Extension service(1)	**.012**	4.25	.097	1.477	**	**
Perception of temperature	**	**	**.013**	2.360	**.004***	3.825
Perception of rainfall	**	**	.187	1.666	.343	1.607
Constant	.973	.980	.443	1.724	**.000***	.008

Source: Households survey *significant at 0.05 ** not fitted to the model (1) = Yes

Age, farm size, farm income, non-farm income, number of relatives in a village, and farmer-to-farmer extension increase the probability of diversifying livelihoods though it is not significant in statistical terms. On the contrary, family size, gender (being male), educational attainment of the households head, and livestock ownership indicate a negative relationship with pursuing different livelihood activities. However, these variables are not statistically significant.

Shifting household consumption to cheap food items: At the times of climatic shocks, the households shift their daily consumption to less expensive food items. However, this strategy may be influenced by different factors. The regression model results show that age, gender, draught animal ownership, farm income, farmer-to-farmer extension and perception of temperature change significantly influence the adoption of cheaper food items with parameter values of less than the threshold (0.05). It is clear from Table 28 that a one year increase in the household head's age decreases the likelihood of shifting food consumption to cheaper food crops by 0.965. The reason may be that old age populations are not flexible to adjust the changes than young age population.

Female-headed households were 1.85 times more likely to shift their food to cheaper crops than male-headed households because women may be more affected by climate change.

Referring to Asfaw and Admassie (2004) Temesgen et al. (2009) discussed that male-headed households are more likely to get information about new technologies and undertaking risky businesses than female-headed households. A study by Nhemachena and Hassan (2007) cited in Temesgen et al. (2009) provide opposite results in that female-headed households are more likely to adopt climate change adaptation methods. The authors' conclusion was that women are more likely to adapt because they are responsible for much of the agricultural work in Southern Africa region and hence they have greater experience and access to information on various management and farming practices. Thus, Temesgen et al. (2009) concluded that the adoptions of new technologies or adaptation methods appear to be rather context specific. In the context of this study sites, female-headed households were more likely to adopt cheaper food items in their daily household consumption. As expected, a unit increases in farm income and draught animal ownership decreases the probability of households to shift their food consumption to cheap food items by 0.708 and 0.719 times respectively. This means, households who are with limited ownership of these resources have a chance of adopting cheap food items in their family. Farmer-to-farmer extension increases the probability of shifting to cheaper food items by 1.727 times. All statistically insignificant variables, except access to water indicated positive association with changing food items to cheap crops.

Seasonal migration: Currently, major human responses to inter-annual rainfall variability in Ethiopia include seasonal and inter-annual migration (Leulseged et al., 2013). People have made seasonal/temporary migration in search of job to buffer their financial shortages. However, this movement may be influenced by different factors (see Table 28). As the logistic regression model results indicate that agro-ecology, age of the household head, access to climate information, farm size, farm income, draught animal ownership, farmer-to-farmer extension and perception of temperature change are statistically significant variables in influencing households' seasonal migration decision. *Kola* and *woyna dega* households were 6.965 and 1.149 times more likely to seasonally migrate than those in *dega* respectively. The households' access to climate information increases the probability of migrating seasonally to adapt to climate change by 3.923 times. Contrary to the logic, a unit increases in draught animal ownership increases the probability of seasonal migration by 1.582 times. Interview results proved that participation in food aid and Safety Net Program is determined by livestock ownership. Accordingly, households who have no/one draught animal depending on the local context are included in the food aid or Safety Net Program. Excluded households who own draught animals have limited source of income to supplement their expenses. Thus, the available option for excluded households is to seasonally migrate for generating income.

The households who have larger farm sizes showed a lower propensity to migrate than those who have smaller size of this livelihood asset. For example, a unit increase in the households' farm size decreases the probability of deciding to seasonal migration by 0.569 times. Households who have access to farmer-to-farmer extension and perceived temperature change were 1.792 and 3.825 times more likely to migrate seasonally respectively. In terms of age, a year increase in age decreases the likelihood of people to migrate by 0.978 times in search of jobs as young people have limited access to different livelihood assets and for being physically strong than those old age household heads (Refer to Table 28). Leuleseged et al. (2013) also stated that intra-and inter-annual migration strategies are constrained by population density in the destination areas and the ethnic federal system established over the last two decades. They further argued that constraints on social mobility could be crucial in determining future adaptive capacity in Ethiopia.

6.3.6. Livestock management practices

The fourth category of climate change adaptation practices according to the climate change research community is related to livestock management.

Table 29: Determinants of farmers' adoption of livestock management activities

Independent variables	Diversifying livestock species		Use of improved livestock	
	Sig.	Exp(B)	Sig.	Exp(B)
Agro-ecology – *Dega*	**.000***		**.000***	
Agro-ecology - *Woyna dega*	**.001***	.195	**.000***	.050
Agro-ecology – *Kola*	**.000***	6.385	.156	2.200
Age of the household head	.378	1.009	.339	1.014
Gender of HH (female)	.224	1.488	.813	.901
Family size	.313	1.061	.649	1.039
Education attainment	.755	1.017	.844	1.014
Access to training (1)	**	**	.356	.644
Climate information (1)	.183	.727	.658	1.153
Farm size	**.002***	1.592	**.001***	2.027
Access to water (1)	.945	.978	.477	.733
Draught animal ownership	**.001**	1.580	.056	1.450
Farm income	.501	1.000	.261	1.000
Non-farm income	.376	1.000	.061	1.000
Number of relatives	.077	1.018	.841	1.003
Farmer-to-farm extension (1)	**.037***	1.766	.201	1.728
Distance to veterinary clinic	**	**	.490	1.003
Distance to improved livestock	**.000***	.996	**.000***	.994
Distance to product market	.897	1.000	.855	.999
Perception of temperature (1)	**.003***	3.978	.353	1.792
Perception of rainfall change (1)	.345	1.601	.219	2.768
Constant	**.000***	.007	**.000***	.009

Source: Households survey *significant at 0.05 **not fitted to the model, 1= Yes, included in the model

Livestock diversification: The result of the logistic regression model in Table 29 shows the variation among the households in adopting livestock diversification as a climate change adaptation method. Agro-ecological setting, farm size, animal ownership for traction, number of relatives in a village, farmer-to-farmer extension, and perception to temperature change have positive and statistically significant relationship with the adoption of livestock diversification, whereas distance to improved livestock market has negative and statistically significant relationship with the adoption of it.

Significant variation in the adoption of livestock diversification was observed across agro-ecological zones. For example, higher diversification of livestock species was identified in *kola* (6.385) than *dega* and *woyna dega* agro-ecological zones. Perceptions of temperature change increase the adoption of livestock diversification strategy by 3.978 times. This means that households who perceived more drought episodes were more likely to diversify their livestock holding through selling some livestock and purchase other kinds (cattle with goat) to reduce the risk of losing such valued assets. Ownership of farmland and draught power are measures of wealth status and adaptive capacity in the farming community. Accordingly, a unit increase in farm size and draught animal ownership increase the chance of adopting livestock diversification as an adaptation measure by 1.592 and 1.59 times respectively. Households who have access to farmer-to-farmer extension were 1.766 times more likely to diversify livestock whilst distance to improved livestock markets decreases its adoption by 0.994 times. Other statistically insignificant predictor variables, except access to climate information, proved positive relationship with the adoption of livestock diversification (Refer to Table 29).

Improved livestock species: Like other adaptation strategies, the adoption of improved livestock has been influenced by a number of factors. The results of the logistic regression model shows that agro-ecological zones, farm size and distance to improved livestock market have strong influence on the adoption of improved livestock species as an adaptation measure to climate change. Farmers in *kola* were 2.20 times more likely to use improved livestock species whilst *woyna dega* households were 0.05 times less likely to adopt improved livestock species than *dega* households. The results of the interview indicate that crop production packages were not effective in the *kola* sites until the end of 1990s. As a result the government has shifted its emphasis on livestock package as a specialized economic sector in the low potential *kola* areas, including offering credit for livestock. That is why higher probability of using improved livestock is identified in the *kola* sites than those in *dega* and *Woyna dega*. Farm size has a positive influence on the application of improved livestock species. For example, a unit increases in the household's farm size increases the probability of adopting improved livestock species by 2.027 times (Refer to Table 29). Although not statistically significant, longer distance to product markets negatively influences the use of improved livestock species against the impact of climate change. For example, a unit increment of time to reach such markets decreases the adoption of improved livestock species by 0.999 times.

This result is consistent with the findings of Madison (2006), which pointed out that as distance to output and input markets increases, adaptation to climate change decreases. Proximity to input and output markets is an important determinant of adaptation to the impact of climate change, presumably because the market serves as a means of exchanging information with other farmers.

In almost all adaptation measures agro-ecological setting is found to be the most statistically significant determinant in explaining variations among the surveyed households, except the adaptation option of cheaper food items. The different farming households who are living in different agro-ecological settings showed a propensity to employ different climate change adaptation measures. This is due to the fact that climatic conditions, soil, water resources, and other factors vary across agro-ecological zones, influencing the levels of farmers' perceptions to climate change and their decisions to take adaptation measures. In order to accommodate theses variations, context-specific adaptation measures are vital.

With almost all available adaptation options family size proved positive relationships except tapping underground water and seasonal migration. This means that households with large families are more likely to adapt to climate change. Referring to Yirga (2007) and Croppenstedt et al. (2003), Temesgen et al. (2009) saw the influence of household size on the use of different adaptation methods from two angles. The first assumption is that households with large families may be forced to divert part of the labor force to off-farm activities in an attempt to earn income in order to ease the consumption pressure imposed by a large family. The other assumption is that large family size is associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks. It is argued that households with a larger labor force are more likely to adopt agricultural technology and use it more intensively because they have fewer labor shortages at peak times.

Extension services are expected to enhance climate change adaptation through diffusing the new adaptation technologies and scaling-up of indigenous practices. However, the logistic regression results indicated that access to extension service has both negative and positive relationships with the adoption of the different adaptation measures, showing that the effect of extension on climate change adaptation is inconclusive. It indicated negative associations with the use of improved seeds, crop diversification, livelihood activity diversification, terrace construction, changing planting dates and replanting of crops. Creswell (2012) makes the case that a research report can provide additional results to confirm or disconfirm results of prior studies. In-depth interviews were held with extension experts why this became so. The experts mentioned three core violations of the requirements in the current extension approach. These are lack of understanding extension as a profession, so that mixing up of extension with politics, lack of maintaining extension as a process (pursuing it overnight in campaign), and failure to undertake extension through active client participation (top-down approach).

***(1) Lack of understanding extension as profession and the mix-up between politics and extension*:** Extension is a profession, which requires skillful and knowledgeable facilitators. Extension agents and extension group leaders need to be assigned based on farmers' needs and the type of livelihood activity the group leaders are doing best (for e.g. in crop, livestock, horticulture, and land management). As much as possible innovators or early adopters need to take the leadership position in the extension process. In the case of the study sites, however, the interviewees said, "Extension leadership in one-in-five[8] grouping has been given to politically trusted people, who cannot be a model for others in terms of adaptation performance and even in personal characteristics. They have served as controllers rather than facilitators of the extension system and hence he/she is not trusted and/or accepted by the group members, which has in turn resulted in rejection of the proposed adaptation strategies by farmers. Even those people who are deciding the execution of the technologies and teaching the farmers have no clear understanding of the issue in their hand. Extension is about helping farmers help themselves, whereas politics is about having control over resources.

(2) Lack of maintaining extension as a process –Extension system is a process that needs time for understanding the benefits that are to be obtained from using the adopted technologies by farmers and extension agents. The experts in the field strongly asserted that technologies for adaptations have to diffuse from innovators → early adopters → majority → late adopters → laggards. However, extension is simply carried out in the form of campaign and massive expansion over night, without maintaining the process and testing the effectiveness and efficiency of the adopted technology.

[8] Grouping of farmers for enhancing peer-learning, experience sharing, and mobilization in all development spheres

(3) Top-down extension approach: Another major weakness of the extension effort over the past twenty years has been its top-down approach and that it has not shown demonstrable change in the day-to-day lives of farmers in terms of improving food security or income. It has been mostly failing to maintain the bottom-up approach. The results of the interview indicated that although communication in the extension process is a two way interaction between the clients and extension agents, the latter have no time to carefully listen to their clients and to consider the ideas of their clients as an agenda for discussion in the research centers and concerned offices. Indigenous practices have usually been diluted by experts and less attention has also been given to farmers' competence in the design of different extension packages. That is, extension agents have not been in a position to include indigenous knowledge into the packages of practices they are extending. The farmers have not also been allowed to be actively involved in the process of extension. The target beneficiaries are largely expected to be passive recipients of externally formulated development proposals, resulting in a lack of enthusiasm for adaptation implementation by the intended beneficiaries. Interviewees also mentioned that awareness creation among the farmers by the extension system is considered a complementary activity.

All these misdeeds have resulted in many failures as experienced by farmers over the past years. For example, failures in water harvesting technology after a massive campaign, short duration of the potable water supply schemes, plantation of exogenous plant species at the expense of indigenous tree species, locally unsuitable soil and water conservation structures, improved seeds (lentil, chickpea, barley, etc) and livestock species, water pumps, farm implements, and similar other interventions had left bad images on the minds of farmers. Thus, even though farmers participate in the training and awareness rising sessions for seeking other services, they do not appear to apply what they learnt in practice. Mostly, but not always, people who have developed interest by their own perception, or through farmer-to-farmer extension in modifying the technological applications have also been effective in adopting different adaptation strategies. That is why with almost all adaptation strategies farmer-to-farmer extension signified positive correlation, indicating the importance of indigenous peer influence (farmer-to-farmer extension) in the adoption of different adaptation measures – actions taken against climate change.

Farm size, farm and non-farm income and livestock ownership are measures of wealth status in the rural households. Farmers with larger farmlands and livestock ownership are more likely to adopt most alternative adaptation measures than those with lower levels of land and livestock ownership. Although financial resource is expected to have paramount role in the adoption of different adaptation measures, it did not determine the adoption of different adaptation strategies. Interview results indicate that some strategies, for example, manure-compost application and terrace construction, does not require financial resources or some others such as fertilizers and improved seeds may be obtained through credit as a government package. This implies that the adoption of many adaptation strategies is mostly determined by the farmers' behaviors (being innovators, early adopters, late adopters and laggards), and previous experiences of technological failures. As the results in some adaptation measures are different from the findings of the previous studies, there is a need to explore the factors.

SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

7.1. Summary

Ethiopia is one of those countries in the world considered to be most vulnerable to the impacts of climate change. The changing patterns of rainfall, increasing temperatures, recurring droughts and massive land degradation have terrible effects for the poor people whose survival depends on rain-fed agriculture. Climate change impacts need to be considered in the context of widespread poverty, rapid population growth and management of natural resources. In light of this, it is vital that policy-makers, development planners, and the communities understand how to reduce vulnerability to the impacts of climate change and to ensure the communities' capacity to adapt to changes over time.

Studies have been conducted in Ethiopia to analyze the impacts of climate change on the agrarian population. Such studies analyzed crop yield or monetary impact of climate change and suggested adaptation measures without investigating the factors determining the choice of the adaptation options. Other studies also analyzed both the impact of climate change and the factors determining the choice of adaptation measures in agriculture in the wider geographical landscapes. Still some others assessed only the perception and adaptation strategies of farmers to climate change. Some of these studies were highly aggregated at national and sub-national levels and/or they were restricted to the pastoral lowlands.

Importantly, climate change related studies conducted in Ethiopia have not comprehensively addressed the inter-related nature of vulnerability, perception, and adaptation of the rural households to climate change impacts in the different agro-ecologies in terms of the five livelihood assets, the climatic factors and the adoption of different adaptation measures. These fragmented studies, having little local-specificity, have presented important limitations in addressing the actual dynamics of vulnerability, perceptions and adaptation in the different agro-ecological contexts of the country. The reason is attributed to the fact that the indicators may have limited values for identifying local-specific impacts and adaptation measures given the diversity of the wider agro-ecological and socio-economic landscapes of the country. As a result, these limitations inspired me to address vulnerability in terms of the five livelihood assets and farmers' adaptation strategies in the three agro-ecological settings of northwest Ethiopia. In doing so, this study focused on three central themes to address the knowledge gaps mentioned above. The first theme is related to the description of the biophysical and socio-economic characteristics of the selected study sites that have vital implications for livelihood creation of the rural households. The second is concerned with an examination of the vulnerability levels of the households to climate change impacts by integrating the five types of livelihood assets, the climatic factors and the adoption of different adaptation measures at the household and agro-ecological levels. Besides, the third theme deals with farmers' perceptions and adaptation to climate change including climate information, types of adaptation measures and factors influence the households' choices from the possible adaptation options.

Three approaches were employed to address the above themes. The first is interdisciplinary approach to describe the biophysical and economic characteristics of the three study sites. The second is the index approach guided by integrated vulnerability assessment framework (sustainable livelihood approach). This approach was adopted to calculate the livelihood vulnerability and the adoption indices to compare the vulnerability levels of households across the three study sites. The third approach is the discrete choice model whose purpose was to identify the most statistically significant determinants on the choice of the households' adaptation strategies.

The combinations of multi-stage, purposeful and random sampling techniques were used to select the study *woredas*, the specific sites and the sample households. The first stage was the selection of the three study *woredas* (districts) from northwest Ethiopia namely Dabat, Dembia and Simada based on the agro-ecological setting they are situated. To the requirement of the study, *kola* sites from Simada (Abay-Beshilo Basin), *woyna dega* from Dembia and *dega* from Dabat were selected. The purpose was to examine the vulnerability levels and adaptation strategies employed by the rural households against climate change impacts in the contexts of the three study sites. In the second stage, a total of 11 sites (*kebeles)*, eight from *kola* and *woyna dega* (4 from each) and three sites from *dega* areas were selected using simple random sampling method. By the third stage, 576 sample household heads were taken using systematic random sampling technique.

In order to address the specific research questions, both secondary and primary data were used. The secondary data was gathered from the National Meteorological Agency, Global Weather Data for SWAT and Offices of Agriculture. Then, the data was assessed whether or not it is adequate to answer the research questions formulated. Finally, the secondary data was not found to be adequate enough to answer all the research questions. Therefore, it was imperative to employ primary data collection tools such as household survey, focus group discussions, in-depth interview and field observation. Accordingly, primary data on the five types of livelihood assets, climatic extreme events and adaptation measures was collected from selected households.

The data collected on vulnerability contexts was analyzed using different quantitative methods in conjunction with qualitative techniques based on the integrated vulnerability and adaptation assessment of SLA. The biophysical and socio-economic characteristics of each study site was described using simple regression, standardized precipitation index, precipitation concentration index, coefficient of variation, aridity index, trend of yield stability index, and One-way Analysis of Variance (ANOVA).

The study found out that agro-ecological zones are one of the most important factors in determining vulnerability levels and adaptive capacity at the household and community levels. Unfriendly climatic conditions, depleted ecosystems, and fragile socio-economic contexts have dominated the *kola* study site, for its location is in the undulating landscapes of the Abay-Beshilo River Basin. For instance, over 65% of the farmlands and 60% of the dwelling houses of *kola* households are located in the most sensitive landscapes. The results of the forest resource assessment also depicted lower index of firewood supply in *kola* (−0.97) and *woyna dega* (−0.60) sites, indicating a higher rate of decline in forest resources. Conversely, a positive index value was detected in *dega* (0.79), indicating an opposite trend, somewhat increasing. Flooding, severe land degradation, soil erosion, recurrent droughts and erratic distribution of rainfall have become responsible for the increasing unproductive land areas in *kola*. As a result, higher percentage of the households (61%) owned poorer farmlands than those in *woyna dega* (15.8%) and *dega* (6.2%) study sites. This has in turn decreased agricultural production and increased poverty. For example, larger proportion of *kola* households (92.4%) reported a decreasing trend of crop yield than those in *woyna dega* (79.7%) and *dega* (79.84%) over the past two decades. This indicates that there has been high rate of crop yield decline contrary to over 8% national level agricultural production growth per year. Indeed, taking an average of major crops, very low crop yield per hectare was reported in *kola* (2.77 quintal) than in *dega* (5 quintal) and *Woyna dega* (4.32 quintal). However, official agricultural statistics on crop yields are inflated as experts' work performance is evaluated based on these records.

Accesses to different infrastructural facilities such as transport, pure water supply telecommunication, health, credit facilities, quality of shelter, and agricultural inputs are also more limited in the *kola* site as compared to *dega* and *woyna dega* sites. To demonstrate this difference, 86% of the roofs of the residential houses in the *kola* site were made of grasses as compared to only 7.5% in *woyna dega* and 7% in the *dega* site. Public transport is not accessible to 100% of the *kola* households followed by those in *dega* (68%) so that forms of transport to travel to the *woreda* towns is limited to walking, head-loading, and use of pack animals. Conversely, 37.6% of *woyna dega* households do not have access to public transport to travel to their *woreda* town. In terms of distance, the average time *kola* households travel to reach the nearest vehicle station, or road junction is nearly 8 hours whilst nearly 1 hour for *woyna dega* and only 35.5 minutes for *dega* households. To arrive at the telephone service centers, on average, *kola* and *woyna dega* households travel over 2 hours whilst less than 1 hour is traveled by the *dega* households. Again, exceptionally higher percentage of *kola* households (92%) utilizes water from unprotected sources than *dega* (7%) and *woyna dega* (8%) households.

In order to address the second theme, livelihood vulnerability indices were used to measure the vulnerability levels of the surveyed households by categorizing the indicators into seven components, which consist of natural, human, economic, physical, and social assets as well as climatic attributes and the inverse of index of adoption of the different adaptation measures. The results indicated that *kola* households ranked first in six out of the seven major components of vulnerability such as the five livelihood assets [human (0.60), natural (0.67), economic (0.67), physical (0.66), social (0.58)] and inverse of index of adoption of the different adaptation measures (0.72) when compared with those in *dega* and *woyna dega*. By climatic exposure indicators, *woyna dega* (grouped under the most resilient areas) households ranked first in vulnerability level (0.54 in *woyna dega*, 0.51 in *kola*, and 0.31 in *dega*). By all the components of vulnerability, *dega* which is grouped under the less resilient areas, comes to the last position, indicating least vulnerability level to climate change impacts. Therefore, the government's categorization of the country into resilient and less resilient areas may not work in all the areas of the county.

The third theme of this study analyzed the farmers' levels of perceptions and adaptation to climate change using descriptive statistics, index of adoption and binary logistic regression. The overwhelming majority of the farmers observed an increase in temperature (95% in *woyna dega*, 89.7% in *kola*, and 86.8% in *dega*) and a decrease/erratic distribution of rainfall (94.5% in *kola*, 91.5% in *dega*, and 88.7% in *woyna dega*). The farmers are aware that their locality is getting warmer and drier with an increased frequency of droughts and changes in the timing of the rains. Indeed, this perception is in line with the analysis of long-term temperature data in the study sites. The statistical analysis of the temperature data shows an increasing trend of maximum temperature (1.74^{0}C in *dega*, 1.58^{0}C in *woyna dega* and 2.17^{0}C in *kola*) over the past three decades. The minimum temperature had also increased by 0.76^{0}C in *dega*, 0.96^{0}C in *woyna dega*, and 1.024^{0}C in *kola*. Over the 32 years of observation, rainfall is characterized by large inter-annual and intra-annual variability with a substantial decrease in amount. The simple regression analysis indicates that 46.78mm, 516.99mm and 277.82mm rainfall amounts were went down over the past 32 years in *kola*, *woyna dega* and *dega* sites respectively (14.62mm in *kola*, 49.06mm in *woyna dega* and 71.9mm in *dega*).

Farmers also perceived the impacts of climate variability and changes on their livelihood resources; particularly higher perception level of adverse impacts was reported in *woyna dega* and *kola* sites. Those households who have had access to climate information have obtained the information from awareness creation training and education, advice from development agents, from radio, and from family members and friends. Consequently, farmers have adopted different adaptation measures to reduce the negative effects of climate change and extreme events. However, the rates of adoption somewhat vary by agro-ecology. The composite indices of adoption were found to be 0.49 in *dega*, 0.44 in *woyna dega* and 0.39 in *kola* sites.

The major adaptation strategies in *dega* areas include manure-compost (96.9%), terrace construction and changing planting dates (94.6% each), replanting of crops (91.5%), use of modern fertilizers (82.2%), selected seeds and shifting households' consumption to cheaper food items (77.5% each) and cultivating different crops (69.8%) and engaging in different non-farm activities (57.4%).

The most adopted strategies by *Woyna dega* households were use of modern fertilizers (88%), manure-compost (84.2%), pesticides (81.2%), selected seeds (75.9%), terrace construction (72.9%), cultivating different crops (68.4%), changing planting dates (67.7%), changing household consumption to cheaper food items (66.9%), and replanting of crops (60.2%). The moderately applied strategies include planting trees (44.4%), use of herbicides (34.6%), and seasonal migration (28.6%).

In the *kola* sites, application of manure-compost (94.7%), terrace construction (85.2%), replanting (68.1%), planting different crops (66.2%), shifting household consumption to cheaper foods crops/items (65.4%), planting trees (62%), changing planting dates (60.1%), and use of modern fertilizers (57.4%) were the most adopted adaptation measures. The moderately adopted adaptation measures include use of pesticides and tapping underground water (23.2% for each), seasonal migration (25.5%), and diversification of livestock species (43%).

The high rates of adoption of the available strategies as adaptation measures could be associated with the less expensive, the more profitability and the more suitability to the local contexts, and easier accessibility to the user farmers (Temesgen, 2009). Exceptionally, more use of pesticides (81.2%) and herbicides (34.6) were reported by *woyna dega* households than 2.3% and 1.6 in *dega* and 23.2 and 16.7% in *kola* respectively because in *woyna dega* pests and disease infestation were reported as the major hazards affecting crop production. The limited use of some adaptation strategies could be attributed to the need for more capital, limited access to the users, and not suitable to the local contexts. For example, accesses to improved livestock and fodder species, herbicides and water for irrigation are found to be limited and/or need more capital investment.

Results from the discrete choice model indicated that the different socio-economic, environmental and institutional factors have determined the farmers' choice of the alternative adaptation strategies. The most statistically significant determinant of adopting each strategy was agro-ecological setting, except shifting to cheaper food items. The level of education, gender, age, family size, farm size, livestock ownership, and access to water resources and to extension services, social capital, and perception of temperature and rainfall changes are other influencing factors to farmers' choices of the adaptation measures.

Income would be expected to have a positive influence on local level climate risk adaptation. However, income level did not create variation in the households' adaptation decision. This may be due to the fact that some adaptation options do not need financial expenses or some others may be provided through credit as government packages. What makes the difference here is farmers' expectation of the gains of using the adaptation strategies, behavioral changes to use the adaptation technologies and to take credit risks. In this regard, Barungi and Maonga (2011) based on the rational choice theory; argue that the behavior of human beings is motivated by the possibility of gaining benefit. The farmers are rational consumers of new technologies and they will only adopt a technology if they anticipate it will result in increased productivity.

Extension services indicated negative relationships with some adaptation strategies such as applications of modern fertilizers, planting different crops, livelihood activity diversification, change of planting dates, replanting crops and terrace construction with the parameter values of less than zero while it signified positive relationships with the use of manure-compost, selected seeds, irrigation-rainwater harvesting, tapping underground water and planting trees with the parameter values greater than zero. An important finding of this study is that farmer-to-farmer extension indicates positive relationship with almost all available adaptation measures, indicating the importance of peer influence and indigenous practices on the diffusion of adaptation technologies rather than dictating them from external bodies. Indeed, interview results pinpointed three core inter-related problems which have resulted in technological and technical failures in the current extension approach. These are: lack of understanding extension as a profession, lack of maintaining the process of extension diffusion, and top-down approach without/limited participation of the beneficiaries.

7.2. Conclusions

Despite the wider attention it has received from several researchers, climate change vulnerability, perception and adaptation have not been studied much in an integrated manner in Ethiopia. Particularly, the variations of farming households' vulnerability across agro-ecological zones have been neglected. It should be noted that studies considering agro-ecological zones will have important policy implications to identify appropriate development strategies in order to enhance the adaptive capacities of farming households. The present study is therefore, an attempt to fill the existing gap by examining the level of vulnerability and adaptation and their determinants across agro-ecological contexts of northwest Ethiopia.

This study provides ample evidence about the issues considered. The context analysis found out that there are differential contexts, conditions, and trends across the three study sites. More unfavorable biophysical and socio-economic contexts were identified in *kola* site having increasing exposure and sensitivity of the community to climate change and other stresses which have threatened the development efforts in the three sites. The changing patterns of rainfall, increasing temperatures, recurring droughts and massive land degradation have terrible effects for the poor people whose survival depends on rain-fed agriculture. Likewise, the livelihood vulnerability indices (LVI) have put the *kola* households to the most vulnerable position in all the five livelihood assets and adoption of different adaptation strategies. Most of the results of this thesis are in line with the findings of several empirical works. However, although the Amhara Regional Government has grouped the *woyna dega* site (Dembia *woreda*) under the most resilient and surplus producing areas, the LVI has put it in the second vulnerability position with respect to the six out of the seven major indicators and first in terms of climatic exposure indicators. On the contrary, the *dega* study site, which is grouped under the low-agricultural production potential, food insecure areas, took the least vulnerability position by all the major indicators. In line with this, more use of the adaptation measures is reported by the *dega* households, indicating strong association between the uses of more numbers of adaptation strategies and farming households' adaptive capacity. This again indicated that dividing any geographical area into high-low-potential dichotomies require integrated assessment of biophysical characteristics and socio-economic capacities of that particular area.

This vulnerability differential is found to be consistent with the hazard-of-place model which underlined that geographic exposure (site, situation and proximity to sources of hazard) and the socio-economic profile of the communities and places influence the hazard potential and the consequent impacts. However, it is vital to keep in mind that the LVI is a relative scale, and it should not imply that the *dega* households are entirely resilient to climate change. Vulnerability assessment provides a framework for identifying the social, economic and environmental factors which may create differential vulnerability situations of the studied community. Livelihood assets are the main measurements of vulnerability situations of the community, social groups, and places considered in this study. In a formative measurement model all the indicators chosen for measuring vulnerability have impact on the vulnerability of the communities in the studied sites. Failures in securing one component of the livelihood asset such as land, water or knowledge and skill may lead to failures in securing another such as income, material needs, or capacity to adapt to the impacts of climate change and associated extreme events. The composite vulnerability indices calculated using all the seven major components of vulnerability are going to measure households' vulnerability levels which are influenced by each indicator.

Farming communities in the highlands and dissected landscapes of northwest Ethiopia have been changing and adapting their livelihoods to changing environmental conditions for long. Recurrent droughts have been a major issue throughout history in the Ethiopian highlands like elsewhere in Ethiopia, and strategies to cope with, and adapt to these droughts are embedded in communities' traditional social structures and resource management systems. The overwhelming majority of the farmers have already understood that the climate is changing and their localities are getting warmer and drier coupled with frequent extreme events in the three study sites. In turn, they understood their being vulnerable to the adverse effects of climate change. Both local and scientific observations show that the climate is changing in the studied sites. Recent evidence includes increasing temperatures and drought frequency, as well as unpredictable rains that fall in shorter but more intense episodes. The magnitude and rate of current climate change, combined with additional environmental, social and political issues, are making many traditional coping strategies ineffective and/or unsustainable, amplifying environmental degradation and food insecurity, and forcing communities to rapidly find new livelihood strategies. Farmers' perception is an important precondition for preparing the communities better for dealing with the adverse impacts of climate change and associated extreme events. However, access to institutional information on climate change, its impacts and the possible adaptation options were found to be very weak still.

Adaptation is an important part of societal response to global climate change, which can significantly reduce adverse impacts of climate change. Planned, anticipatory adaptation has the potential to reduce vulnerability and realize opportunities associated with climate change effects and hazards. There are numerous adaptation strategies that would be applied to climate change risks and opportunities. Substantial reductions in climate change damages can be achieved, especially in the most vulnerable areas, through timely deployment of adaptation strategies. Enhancement of adaptive capacity is a necessary condition for reducing vulnerability, particularly for the most vulnerable socio-economic groups in the *kola* and *Woyna dega* sites. Activities required for the enhancement of adaptive capacity are essentially equivalent to those promoting integrated sustainable development in all biophysical assets and socio-economic sectors.

The farmers participating in this study have many ideas on how to prepare for future climate change, demonstrating a powerful motivation to move out of poverty and take their future into their own control. Despite this powerful sense of determination, farmers' ability to adapt to climate change and associated extreme events is constrained by many factors including increasing drought, land degradation; soil erosion, conflicts over scarce resources, which affect social capital and destroy assets that are key for adaptation (especially in the *kola* site); limited access to information (including that on weather, climate change as well as pest and disease outbreaks); limited education, skills and access to financial services and markets required to diversity households' livelihoods; inadequate government supports, capacities and coordination; demographic pressures, and top-down approaches for extension interventions which reduce the voice and adaptive capacity of the most vulnerable people and places.

Agro-ecological setting and farmer-to-farmer extension are found to be the most statistically significant determinants in the adoption of almost all the adaptation measures implying the need for designing local-context-specific adaptation strategies to increase the adaptive capacities of the most vulnerable households and that farmers have developed heavy trust on indigenous practices and their peers than on those are imposed from external bodies. Put in another way, farmers can learn better from other better-off farmers who have long-life experiences.

Contrary to farmer-to-farmer extension, formal extension services signified both positive and negative relationships with different adaptation strategies. In-depth interviews with extension professionals on the current extension approaches disclosed three core problems: limited understanding of extension as a profession, lack of maintaining the extension system as a process, and top-down approach with no/limited client consultation and participation. All the government interventions, including humanitarian food aid are largely politicized and are under the control of the party leaders either directly or indirectly. Any genuine opinion to any intervention is unlikely to exert influence either at a regional or local level and is more likely to be suppressed. In short, there is no genuine debate on the contents and directions of the current development interventions including the agricultural extension system.

7.3. Implications and recommendations

Climate change in northwest Ethiopia has occurred and will continue to occur in the next years and perhaps for decades. Key underlying derivers of vulnerability in the three study sites include environmental degradation derived from population pressure, poor access to resources and associated conflicts, socio-cultural factors, inadequate off-farm employment opportunities, poor access to infrastructure services such as transportation, health, education, input and output markets, lack of skill and knowledge, weak role of traditional social institutions and inadequate government policies coordination and capacities. In order to reverse its adverse impacts there should be an urgent need for addressing the farmers' problems to enhance community resilience through supporting them for the choice of better adaptation strategies. On the whole, this study identified three implications, namely: policy recommendations, education and further research as detailed in the discussions to come.

(1) Policy implications and recommendations

Adaptation to climate change involves a very broad range of measures directed at reducing vulnerability to a range of climatic stimuli (changes, variability and extremes).

Building Program (HABP), Complementary Community Infrastructure Program (CCI), and the Resettlement Program. The PSNP that operates as a safety net targeting transfers to poor households through public works and direct support should be strengthened and improved particularly in the *kola* site. Public works are used to mitigate the impacts of climatic and food insecurity risks on chronically food insecure farmers by providing employment to able-bodied laborers. In other words, public works is a provision of counter-cyclical employment on rural infrastructure projects such as soil and water conservation, road construction and maintenance, small scale irrigation and reforestation.

- **Undertake voluntary resettlement for most vulnerable *kola* households:** The voluntary resettlement program is one of the most important food security strategies of the Federal Government of Ethiopia. With this aim, Amhara Region has to strengthen voluntary resettlement scheme for the most chronically food insecure people of the *kola* site with better provision of health, education, road, water and other facilities supported with strong environmental impact assessment and mitigation measures.
- **Strengthening institutional services:** it is important for the agricultural development strategy of the study areas to have an institutional environment that facilitates farmer's accessibility to education, better extension provisions as per the peculiarities of the agro-ecological zones, and improved access to formal credit. For example, interventions should aim to build resilient livelihoods by supporting investment in key infrastructure and services. Construction of more water supply schemes, schools, health institutions and roads, their appropriate staffing and an increase in the number of human health care centers and services, including immunization and medical treatment, as well as training of community health workers, could help reduce impacts of diseases and mortality among vulnerable groups and ensuring a strong productive population that is less vulnerable to climatic shocks. Construction of veterinary centers as well as regular supply of key veterinary medicines could help reduce livestock mortality from preventable and treatable diseases, and reduce livestock vulnerability during droughts and extreme heat events.
- **Increasing farmers' access to input and output markets:** Introduction and dissemination of new agricultural (both crop and livestock) technologies and management knowledge to the farming community can increase the production and productivity of farmers through reducing pests, diseases, and weeds. These have in turn enhanced the adaptive capacities of communities against the increasing hazards of climate change. Practitioners should advocate for the improvement of market conditions, for example, provisions of improved crop cultivars and livestock species, development of policies that

support communities' interaction though trade, and increased revenue for the benefit of farmers, middle-traders and public services. Supports should be in the form of establishing and/or strengthening farmers' cooperatives to facilitate farmers' access to agricultural inputs and training the community in preservation and transportation of agricultural and handicraft products to maximize the benefits from such exchange of products and services.

(C) Designing and implementing local agro-ecological context adaptation measures

Vulnerability and adaptation to climate change are highly spatially differentiated and context-specific. Since northwest Ethiopia is endowed with a variety of agro-ecological zones, which differ in terms of climatic conditions, soil types, physical landscapes and socio-cultural conditions, a one-fits-all approach does not help much for reducing vulnerability and enhancing adaptive capacity. The reason is that there is tremendous variation in farming systems, population density, and socio-economic conditions in the different agro-ecological zones. For instance, in *kola* areas there is very erratic rainfall, high poverty and severe resource degradation. It should be noted that adaptation practices and any other development interventions considering agro-ecological zones will have important implications for enhancing the current performance of the agricultural sector. Therefore, rapid and sustainable adaptations can be brought about only if we take into account these variations, identify appropriate adaptation strategies which will take advantage of the development opportunities in each agro-ecological zone, and implement them accordingly. Therefore, extension agents and researchers as well as farmers' and community organizations need to design activities/programs that are suited to the peculiarities of each agro-ecological zone. To this effect, the government and non-governmental agencies should give emphasis to identifying and adopting appropriate adaptation technologies, yield increasing packages and new crop cultivars and livestock species that are suited to local agro-ecological conditions.

(D) Using traditional knowledge starting from what people are doing on the ground

Local communities are already observing and experiencing the effects of climate change, as well as implementing coping and adaptation strategies. Efforts to support climate change adaptation should be based on understanding of what people are already doing on the ground, assessing the effectiveness and efficiency of current coping strategies and how they might fare over the longer-term with climate change. For instance, the *dega* households have used batteries which have been charged with sunlight and connected with thin wires in the rural houses for lighting. As this strategy has important implications for forest and land resources management as well GHG emission reduction, the responsible bodies should support this strategy with some policy interventions and further replicate it to other areas. Moreover, farmers have ample experiences and knowledge in traditional irrigation, water harvesting, soil and water conservation, human and livestock medication, farming systems, hazard predictions, and in so many related issues. Hence, the introduced adaptation practices should be based on these farmers' novel experiences and knowledge domains. In addition, as discussions with different community groups (women, men, youth and children) can give insight into which community groups are vulnerable to what, and which adaptation strategies are implemented by different groups of farmers, participatory community consultations should aim to develop sustainable alternatives to replace ineffective or unsustainable practices.

(E) Improving current extension system: Extension efforts have attempted to transfer technology and best practices, mobilize farmers, and build their capacity, though this has proven difficult for many governments due to the large number of rural inhabitants, high poverty levels, diverse farming systems, and low capacity among extension agents as well as farmers. The results of the analysis in Table 26-29 reveal that the extension services have not brought significant variation in adoption of some adaptation strategies as expected. This could be due to the fact that development agents remain at the edge, never reaching the farmer and that the packages may not fit the agro-ecological settings. The three core problems such as: lack of understanding extension as a profession (mixing it with politics), lack of maintaining extension as a profession (pursuing it overnight in campaign) and failing to undertake extension through active client participation (top-down) were also identified. The problems related to extension services should be alleviated through:

- **Understanding extension as a profession:** Extension is a profession which needs skilful facilitators and knowledgeable facilitators and group leaders based on the farmers' needs and the type of livelihood activity the group leaders are doing best. As much as possible group leadership positions should be given to innovators (if any) or early adopters who have been trusted by neighboring farmers.
- **Maintaining extension as a profession:** As extension system is a process that needs time for capturing the benefits to be gained from using the technologies by farmers, diffusion should start from innovators to early adopters to majority to late adopters, which enables to test the effectiveness and efficiency of the adopted technologies.
- Maintaining bottom-up approach: a more consensus-based extension interventions should be strengthened so as to enhance the capacity of farmers thereby making them agents of their own transformation rather than considering them simply passive recipients of the

adaptation activities dictated from above. In the process of adaptation diffusion, adaptation planning requires close collaboration and active participation of climate and impact researchers, sectoral practitioners, decision-makers, policy analysts, the community and other stakeholders.

- **Building on community suggestions and recommendations:** as enhancing the adaptive capacity of farmers will require community-based and community-led interventions with tailored support from NGOs, donors, and government institutions, practitioners should promote adaptation strategies built on suggestions and recommendations from the local communities. Farmers have ample experiences in modifying farming practices and rangeland management practices, promoting alternative income generating activities, modifying livestock diversity, composition, and numbers, diversifying livelihood activities, producing, collecting, and preserving hay/straw, maintaining, rehabilitating and constructing water infrastructure, establishing community groups to promote local engagement in a range of social and economic activities; reducing conflicts over scarce resources, tree planting. In particular, policy-makers should be sure to draw on knowledge and experience from local communities as local farming communities offer valuable information regarding adaptation to changing climatic conditions that would not likely be acquired through other channels.

(F) Facilitate access to information and knowledge sharing: expanding awareness of increasing temperature and its potential impacts by providing reliable and up-to-date information to the public is essential. Information about the appropriate adaptive strategies should also be made available to the entire community of the study sites. As part of this effort, communication between policy-makers, non-governmental organizations, research institutions, the academia and the media, among other actors, should be strengthened in order to ensure the dissemination of accurate information to the vulnerable communities. To this effect, community-based early-warning systems, strong government institutions and information centers should be established and/or strengthened.

There is also a need for greater investment in data collection on socioeconomic and biophysical conditions for the study sites. Environmental and drought monitoring systems should be introduced at national, regional and local levels to monitor climate change and associated extreme weather events. Such systems would provide early warnings on predicted weather extremes, enabling stakeholders to take corrective measures in advance to minimize potential damages.

(G) Facilitate the provision of infrastructure: As part of the development process social and physical infrastructures should be improved and institutions dealing with climate-related issues including the meteorology agency should be strengthened to increase the country's adaptive capacity. It is most viable to suggest that strengthening institutions which can facilitate the implementation of improved water resource development, energy supply, transportation, telecommunication, education and health institutions, and access to shelter.

(H) Strengthen social capital: social network is playing an important role in reducing climatic risks during and after disaster. In the early phase of disaster, most of the searching and rescuing endeavors come from social network members. In the aftermath of disaster, social networks can facilitate the flow of information, provide various types of support, and help to maintain the mental health of the victims. Some policy implications can be drawn from the study. Since social network is so important, it is necessary to take it into consideration when making climatic risks management and mitigation policies. The government should try to maintain intact of social networks in hazard prone areas, and try to make good use of existing social network in reconstruction processes.

(2) Provide training and awareness raising education

(i) Improving farmers' social networks and relationships: Social networks and relationships have been disrupted by conflicts among the households from increasing competition for scarce water, farmland, rangeland, and forest resources. Social networks and relationships should be promoted in all interventions. To this effect, traditional conflict resolution mechanisms should be strengthened through religious leaders and respected figures to increase community attachment and collective actions to adapt to the impacts of climate change and associated extreme events. Moreover, clear property rights, fair allocation of the scarce resources and trainings which would enable to reinforce the farmers' managerial capacity as well as efficient use of resources should be given special attention from the concerned governmental and non-governmental organizations.

(ii) Farmers' membership statuses to different self-help associations were found to be almost none in all the three study sites, particularly in terms of traditional help associations. Thus, education about the importance of social networks and relationships and traditional self-help associations in the climate change adaptation processes and in disaster risk managements as a whole should be given for the community.

(ii) Some farmers have not shown attitudinal changes towards area-closure, cut-and-carry feeding system of livestock, soil and water conservation campaigns and other new strategies. Thus, continuous awareness raising education should be given for the households using extension agents and model farmers who become successful in the application of different adaptation strategies, or early adopters of some adaptation technologies.

(iv) For creating more climate change-resilient community, policy interventions should maintain all the three requirements of the extension system. In order to do so, awareness raising education should be given to enable the decision-makers and practitioners of all levels by extension professionals. In addition to extension efforts, there are other ways to build the capacity of small-scale farmers by providing them with basic and technical information that can help them improve their productivity and livelihoods. There are numerous non-formal educational methods including adult education programs and battery-operated radio, television, print media and plays and even mobile phones. Providing literacy and numeracy skills to adults who missed formal education during their childhood might be much successful for many farmers.

(3) Further research needed

This current research may not respond to all research needs and priorities related to climate-related farmers' vulnerability and adaptation in northwest Ethiopia. More research will be needed to complement and deepen the findings of this research. Key research priorities, suggested include:

(i) Given the data was collected only in three sites the results may not represent the respective agro-ecological zones of northwest Ethiopia. The findings of this research cannot necessarily be extrapolated to other areas within northwest Ethiopia, which might be exposed to different climate hazards and trends, or characterized by different biophysical and socioeconomic contexts, and might have different adaptation strategies and priorities. For example, this research mostly focuses on rain-fed subsistence farming areas, while commercial farming communities in the western lowlands have not been studied. This means that, the unfriendly biophysical contexts (very dissected and undulating landscape) giving higher vulnerability levels in the *kola* site of Abay-Beshilo River Basin may not represent other *kola* sites having different contexts such as the western lowlands of Metema and Quara. The relatively more resilient *dega* households may not also represent other *dega* areas that have different landscapes. For example, there may be less vulnerable *kola* households who reside in stable landscapes and proximity to different service centers, or there may be more vulnerable *dega* households in Janamora and Beyeda highlands than the *dega* part of Dabat. Thus, broadening the scope of this current research to other subsistent farming areas within northwest Ethiopia is needed to explore the actual vulnerability levels and adaptation strategies of the households and places located in different biophysical and socio-economic contexts.

(ii) The data obtained from the three study sites was aggregated together in the logistic regression estimation to examine the determining power of agro-ecology among other factors, in the adoption of various available adaptation options. Hence, disaggregated analysis of the determinants of adaptation is essential for identifying the other determinant factors to the specific sites located in different agro-ecological zones. In addition, through research plant and crop species which are more suitable to the degraded *kola* environments and for other agro-ecology-based sites need to be identified with prior attention from the government and other different stakeholder organizations.

(iii) Income is expected to have a positive influence on local level climate risk adaptation. However, it did not create variation in the households' adaptation decision. Similarly, extension services indicated negative relationships with some adaptation strategies such as applications of modern fertilizers, planting different crops, livelihood activity diversification, change of planting dates, replanting crops and terrace construction with the parameter values of less than zero. Thus, further research is needed to explore the underlying reasons.

(iv) Linkages and synergies between the policy measures suggested in this research and existing development policies, programs and reforms should be explored and built on (for example linkages with the Productive Safety Net Project and the extension programs).

(v) Continuous monitoring and research is needed to better understand climate change impacts and adaptation and how they are evolving over time. This would require the establishment of key indicators that could be monitored. Further analysis of the livelihood resources farmers owned is required for adapting to climate change, and how to efficiently manage them for the realization of optimal adaptation benefits of the vulnerable communities. This should include investigation of large uncertainties related to different development pathways, climate change mitigation, and effective adaptation strategies chosen.

(vi) Assessment of local climate change drivers (local deforestation and desertification affecting the local climate should be done.

(vii) A quantitative analysis of climate change impacts, vulnerability and adaptation using other quantitative methods instead of an index approach and binary logistic regressions in complement with qualitative research works is needed.

It is concluded that research is effective tool to generate evidence and knowledge to support policy and strategy making. Therefore, prior attention should be given to develop a culture and practice of participatory research in order to increase the understanding of local contexts, policy spaces and processes so as to influence climate change adaptation practices.

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Annex I (a): Household survey

<u>Title: **Comparative study of Rural Households Vulnerability and Adaptation to Climate Change in the three Agro-ecologies of Northwest Ethiopia**</u>

This questionnaire was prepared by the author based on (Moss et al., 2001; Hahn et al., 2009; Lamichhane, 2010; Temesgen et al. 2009, Temesgen, 2010 and others)

Objective of the study: the main objective of the study is to assess farmers' vulnerability levels, adaptation strategies they have used and determinants of their choice in *dega*, *woyna dega* and *kola* agro-ecologies of northwest Ethiopia. The data will be used only for academic purposes. First I kindly request you to participate in the study. Your answers are valuable for the success of the study, and hence I want you to give genuine answers.

Questionnaire code ______ **Date of interview** _________ **Hour** ____________

1. Location

101. *Woreda* _________ 102. Agro-ecology ________ 103. *Kebele* _______ 104 Village _______

2. Human Capital

2.1. Demography

201. Age ____________ **202.** Gender of the household head ________________

203. Family size including the head: (1) below15 years of age ________________
(2) 15–49 years __________ 50—64 years __________ (3) over 64 _________

2.2. Skills and knowledge (Education, training and access to information)

204. Educational attainment ______________________________________

205. Do your aged children attend school? Male _______ Female _______ Total ________

206. If not, how many of them do not attend school? M _______ F ________ Total ________

207. Distance to the following educational institutions in time?
A. Primary schools ________________ B. Secondary schools __________________
C. Preparatory schools________________ D.TVET centers _____________________

208. Is there anyone in the family who has got vocational training (1) Yes (2) No

209. Have you ever heard about climate change and its impact before this survey? (1) Yes (2) No

210. If yes, from whom? (1) Training and education (2) radio and television (3) from friends (4) from family members (5) development agents (6) *kebele* administrators _____________

2.3. Health

211. Is there a family member with chronic illness? (1) Yes (2) No

212. Is there any family member who faced climate related death, injury, or handicap in the past 20 years? (1) Yes (2) No

213. Is there anyone in the family who was absent from school or work due to climate induced illness the past three months? (1) Yes (2) No

214. How often does malaria occur in your locality? __________ (write **0** if not)

215. If you use malaria net, how many of you do you have in your family? _______ (if not write 0)

216. Are you benefitted from health package? (1) Yes (2) No

217. From where does your family get treatment in times of illness? (1) Modern health institutions (2) Traditional healers (3) Not at all

218. If your answer is 2 or 3, why? (1) Due to distance to the location of modern institutions (2) due to lack of awareness about modern medication (3) as I haven't any money (4) as modern institutions request high cost (5) other (specify) ____________________________________

219. What are the distances to the following health institutions in hours/minutes?
A. Health post/clinics _______ B. Health centers_______ C. Hospitals ______ KM
220. Have your children received vaccination? (1) Yes (2) No
221. If not, why not? ____
222. Do you have toilet facility to your family? (1) Yes (2) No
223. If not, why not? ____

2.4. Food and Nutrition

224. Have you faced food shortage per year? If yes, mention the number of months on average?_____
225. What are the coping strategies you use in times of food shortages? (1) selling animals (2) selling ornaments and house utensils (3) food aid/safety net (4) doing daily labor works (5) relatives/friends/credit/help (6) seasonal migration (7) other (specify) ________
226. How much time it takes to reach the food market? ____________ minutes/hours.
227. How often do your family members take food on average per day? _______________
228. If less than 3 meals per day, what is/are the reason(s)? (1) Food shortage (2) Due to cultural prohibition (3) other (specify) ____
229. How many food items does your family take on average per day? __________________
230. Have you given special attention for children, pregnant women, and sick people for their food? (1) Yes, I have special attention (2) No, it is similar to others
231. Based on local wealth category, what is your status? (1) Wealthy (2) Medium (3) Poor

3. Natural Capital

3.1. Farmland related questions

301. How many hectares of land do you own? (If you do not own, write 0)
Private _______ Rented _______ sharecropped _______ other (specify)________ Total _______
302. If you own private land, how did you get it? (1) through government redistribution (2)by way of sharing from parents (3) through inheritance from parents (4) for being gifted from relatives/friends (5) other _____
303. Number of plot you own? ____________________________________
304. Majority of your farmland topography: (1) plain (2) rugged/mountainous
305. Your farmland erosion intensity? (1) High (2) Medium (3) Low
306. Your farmland fertility status: (1) Fertile (2) Medium (3) Poor
307. To protect your farmland from erosion, what methods do you use?: (1) terracing (2) on-farm tree planting (3) cut-off drain (4) hill side terrace (5) contour ploughing (7) other (specify) _______________
308. Your farmland productivity as compared to the past 20 years or so: (1) increased (2) decreased (3) No change
309. What are the reasons for the increase or decrease?________________________________
310. Can you save food crops for drought years? (1) Yes (2) No
311. Can you reserve seeds for the next sowing season ? (1) Yes (2) No
312. What are your sources of livestock feed? (1) Common grazing lands (2) private grazing lands (3) fodder (4) straw/crop remnants (5) other (specify) ________________________________
313. For how many months do you face livestock feed shortage? __________ months (if no, write 0)
314. How do you cope up with livestock feed shortage? (1) by purchasing straw and hay (2) by producing modern fodder (3) by purchasing industrial by-products (4) by sending to relatives (5) by collecting wild grass and leaves (6) other (specify) ___________________________

3.2. Forest resources

315. What are the sources of firewood? (1) common forests and bushes/shrubs (2) private trees and shrubs (3) purchasing (4) own planted trees (5) other (specify) ______________________________
316. Firewood supply as compared to the past 20 or more years? (1) better (2) worse (3) same as before
317. What is the distance to reach the sources of firewood? __________ hours
318. Did you plant trees in the last rainy season? (1) Yes (2) No
319. If yes, what was the source of seedlings? (1) privately planted (2) purchased (3) free offer from

government offices (4) other (specify) ______________________

320. Have you ever got education/training on forest protection and tree plantation? (1) Yes (2) No

321. What is the status of common forests in your locality? (1) well protected (2) loosely protected with high deforestation (3) not protected at all/open access to all

3.3. Water supply for humans and animals

322. What are the sources of drinking water? (1) pipes (2) natural sources/rivers, streams, ponds) (3) other (specify) ______________________

323. Are developed water sites functional in your locality? (1) not built (2) built and functional (3) built but not functional

324. Is the water used for domestic purpose pure? (1) Yes (2) No

325. For how many months does your family face water shortage? 1) in drought years ___2) in normal years ___

326. How much liters of water do your families fetch per day? ______________________

327. How much time it takes to reach the water site? 1) in winter ________ 2) in summer ____________

328. Area of irrigated farmland ______________ hectare (if no, write **0**)

329. If you use irrigation, how do you get water (1) as I want (2) via allocation (3) other (specify) _______

330. Have you ever faced or heard conflict over water resources in your locality? (1) Yes (2) No

331. For how many months do you face water shortage for livestock?__________ (if no shortage, write 0)

332. What are the strategies you employ to cope up with shortage of water for livestock? ______________

4. Sources of livelihoods, income and expenditure

4.1. Livelihoods

401. What are the livelihoods of the family? More than one answer is possible. (1) crop production (2) livestock keeping (3) forestry (4) construction/carpentry (5) petty trade (6) handcraft (7) daily labor works (8) other (specify) ______________________

402. Write the productivity of crops you cultivate

Temporary crops	In good years	In bad years/ Qt	Average	Current market price/qt	Temporary crops	In good years	In bad years/ Qt	Average	Current market price/qt
Teff					Peas				
Barely					Chickpeas				
Wheat					Lentil				
Maize					Haricot bean				
Sorghum					Nug				
'Zengada'					Linseed				
Millet					Potato				
Oat					Others				
Beans									

Put X in front of perennial crops you own

Crop type	Own (X)	Crop type	Own (X)	Crop type	Own (X)
Eucalyptus		'*Tirngo*'		Papaya	
Khat		Sugar cane		'Beriberi'	
Banana		Mango		Onion	
Orange		*Zeytun*		Leaves	
'*Gesho*'		Coffee		Others	

403. Please mention the number of livestock you own

Ox _________	Heifer _______	Sheep/goat _____	Hen__________
Cow_________	Bull______	Mule/horse______	___________
Calf ________	Donkey ______	Beehive ________	___________

404. Please tell the number of draught animals you own _________________ (if not, write 0)

405. If you do not have draught animal, how are you ploughing your farmland? (1) by renting (2) by giving my land to sharecroppers (3) by digging (4) other (specify) ______________________

4.2. Sources of income

406. From the following sources of income, how much money do you earn per year on average?

Farm income	Birr/year	Non-farm income	Birr/ in year
Sales from crop		Trade	
Livestock sales		Daily labor works	
Livestock product sales		Construction/carpeting	
Forestry product sales		Handcraft	
Sales from honey and honey products		Mining products(stone, sand)	
Fruits and vegetables		Safety net and related works	
Renting lands		Remittance from relatives/friends	
Others		Others (specify)	

407.How many of the family members are engaged in non-farm job? ____________

408. If no family member is engaged in non-farm job, what are the reasons?
(1) lack of money (2) no alternative job (3) lack of skills and knowledge
(4) lack of implements (5) lack of market (5) other (specify) ____________________

4.3. Household expenditure

409. What is the average households' expenditure, excluding agricultural input expenses? (A) food: crop ________ salt & '*berberi*'__________ other _____________ sub-total _______________
(B) cloth ________ (C) education _________ (D) medication_________ (E) transport___________
(F) other (specify) ___________ ___________ _________Total ____________________

5. Physical Capital

5.1. Shelter

501. House walls are made of (1) wood/mud/thatch (2) stone and mud (3) cement and stone
(4) other (specify) ____

502. House roof made of (1) iron sheet (2) thatch (3) other (specify) ____________________

503. Topography of your house: (1) plain–free from flood (2) plain–exposed to flood (3) rugged/mountainous
(4) near rivers –exposed to flood

5.2. Energy supply and usage

504. Main source of energy for cooking: (1) firewood (2) charcoal (3) biogas (4) crop remnant (5) benzene (6) dung (7) leaves (8) other (specify) ______________________________

505. Main source of lighting (1) firewood (2) crop remnant (3) kerosene (4) biogas (5) candle
(6) other (specify) ____

506. When did you start to use fuel saving stove? ________ (if you do not use, write 0)

507. If you don't use, what is/are the reason(s)? ______________________________________

5.3. Transport and communication

508. What means of transport do you use to travel to your woreda town? (1) vehicle (2) pack animals (3) on foot

509. Does your locality get all year round transport service? (1) Yes (2) No

510. How much time it takes to reach public transport station/road? __________________

511. How much time does it take to reach public telephone center? __________________

6. Social capital

6.1. Networks and relationships

601. How many relatives do you have in your village? (sister, brother፣ father mother፣ children፣ aunt and uncle _____

602. The degree of your ties to relatives and neighbors (1) good (2) loose/ in conflict (3) no change

603. People's cooperation and support culture as compared to the past (1) increased (2) decreased (4) no change

604. Did you get farmer-to-farmer extension in the past months? (1) Yes (2) No

605. Had you got help from relatives and neighbors in the past 6 months? (1) Yes (2) No

606. Did you borrow money from relatives/neighbors in the past 6 months? (1) Yes (2) No

607. Did you lend money to relatives and neighbors in the past 6 months? (1) Yes (2) No

6.2. Organizational affiliations

608. Put x in front of groups to which you belong to

Type organization	Put (X)	Type of organization	Put (X)
Kebele Council		Credit and Saving	
Farmers' Cooperatives		Work Team	
Water Users Association		Religious	
Water Committee		Other	
Watershed Committee			
Land Administration Committee			

609. Is there a family member holding *kebele* position? (1) No (2) No

610. Do community-based groups and NGOs contribute to development? (1) Yes (2) No

Part 7. Institutional support

7.1. Policy issues

701. Do you feel that your land will be given for others? (1) Yes (2) No

702. Is your land certified? (1) Yes (2) No

703. If yes, are you encouraged by it to develop your land sustainably? (1) Yes (2) No

704. Do you get current information on government policies and strategies? (1) yes (2) No

705. Do government policies bring significant changes in your life? (1) Yes (2) No

706. What is the status of NGOs intervention to improve the lives of the people?
(1) encouraging (2) discouraging (4) neutral

7.2. participation, Leadership, and service delivery

707. How do you evaluate the decisions and services given by your *kebele* leaders? (1) encouraging
(2) discouraging (3) neutral

708. Do you participate in your kebele leaders' election? (1) Yes (2) No

709. If not, why not? ____

710. Do your good practices and views raised accepted by the kebele leaders and experts? (1) Yes (2) No

711. If not, why not? ____

712. How often have you been visited by extension agents in a cropping season? __________ (if not, write 0)

713. Time taken to arrive at the *kebele* office of agriculture? ______________

714. Time taken to arrive at the nearest veterinary clinic? ______________

7.3. Credit Access

715. Are there credit facilities in your *kebele*? (1) Yes (2) No

716. Amount of money borrowed from credit providers in the past five years? ____________ (if not, write o).

717. How do you evaluate credit procedures? (1) Fast (2) tiresome (3) neutral

718. Time taken to arrive at credit institutions? ____________

7.4. Input Provision

719. Distance to the following sources of input measured in time? Fertilizers ____________________
pesticides/herbicides __________ improved seeds ________ improved livestock species ____________

720. How many k.g. of modern fertilizer do you use per year? UREA _______ DAP_______ Total ______

721. What is the average agricultural expenditure? for input _______ for livestock purchase _______ for farm implements _______ other (specify) ________ total _________

7.5. Output markets

722. Are there better market facilities to sell your products? (1) Yes (2) No

723. Time taken to reach the product markets? ______________________________________

Part 8. Farmers' perception to climate variability and climate change

801. Temperature conditions in your locality: (1) increased (2) decreased (3) no change (4) I have no idea

802. What are the impacts of temperature increment in your locality?
(1) crop pests, diseases and weeds increased

(2) human and livestock diseases increased
(3) changes in land use and cropping patterns
(4) increase in extreme weather events (drought, flood)
(5) water resources reduced and totally dried up
(6) pasturelands deteriorated
(7) bringing changes in livelihoods
(8) food shortage/insecurity increased
(9) negative impacts on overall agriculture increased

803. The rainfall of your locality from year-to-year has (1) increased (2) decreased (3) become erratic (4) no change (5) I have no idea

804. What are the impacts you perceived from the rainfall changes? More than one answer is possible.
(1) change in crop patterns
(2) change in land use patterns
(3) reduced in crop and livestock productivity
(4) crop pests and livestock diseases increased
(5) greater impact on pasturelands
(6) increased rainfall intensity and hence soil erosion
(7) increase in extreme weather events (drought, flood)
(8) water bodies dried up and reduced in volume

805. What were the frequencies of the extreme events in your locality over the past 10 years (if not, write 0).
drought ________________ floods __________________ livestock disease __________
hailstorm ________________ crop pests ______________
crop diseases_____________ human diseases ___________

806. What are the numbers of livestock died in the past five years? Ox ___________ cow ____________
calf ________ sheep/goat _______ heifer ________ mule/horse ________ hen ________ donkey ________

Part 9: Adaptation strategies to climate change impacts

The purpose of this section is to identify the adaptation strategies used by famers to reduce the impact of climate change and the determinants of their choices.

901. Put an "X" in from of each adaptation strategy and then put the most adopted strategies in rank order.

Types of adaptation	What are the problems to use these strategies?
Manure and compost	(1) no livestock (2) used for fuel (3) my land does not need it (4) no private land (5) shortage of material (6) lack of knowledge (7) other ____________
Modern fertilizers	(1) lack of money (2) lack of information (3) lack of know-how (4) my land does not need it (5) high prices (6) less output (7) other ____________
Pesticides	(1) lack of money (2) lack of information (3) lack of knowledge (4) high price (5) shortage of supply (6) not effective (7) use traditional solutions (8) Others ____________
Herbicides	1) lack of money (2) lack of information (3) lack of know-how (4) higher price (5)not effective (6) I use weeding (7) other ____________
Diversifying non-farm activities	(1) lack of knowledge (2) lack of money (3) lack of market (4) lack of information (5) shortage of land (6) shortage of labor force (7) lack of alternative job (8) other ____________
Diversifying crops	(1) lack of knowledge (2) lack of money (3) lack of market (4) lack of information (5) shortage of land (6) shortage of labor (7) lack of oxen (8) other ____________
Using improved seeds	(1) lack of knowledge (2) lack of money (3) lack of supply (4) lack of information (5) shortage of land (6) shortage of labor (7) high price (8)not effective (9) my land does not need improved seeds
change planting dates	(1) lack of seed (2) no oxen (3) shortage of labor (4) lack of money (5) other ____________
Replanting	(1) lack of seeds (2) no oxen (3) shortage of labor (4) other ____________
Irrigation	(1) no suitable land (2) shortage of labor force (3) lack of money (3) lack of skill and knowledge
Water harvesting	(1) shortage of labor force (2) the land is not suitable (3) lack of skill and knowledge (4) lack of money Other (specify) ____________
Construction of water wells	(1) Shortage of labor (2) lack of knowledge (3) no water potential underground (4) others ______

Diversifying livestock	(1) shortage of labor force (2) lack of feed (3) lack of knowledge
Use of improved livestock species	(1) lack of money (3) higher price (5) no supply (7) lack of knowledge (2) lack of information (4) not effective (6) lack of feed food (8) others
Use of improved fodders	(1) shortage of labor force (2) lack of fodder seeds (3) not effective (4) lack of knowledge (5) land shortage (6) other (specify)
Construction of terraces	(1) labor shortage (2) insecure land ownership (3) I don't own private land
Planting trees	(1) rain shortage (2) my land is not suitable (3) lack of seedlings (4) other________
Changing to cheap food items	(1) lack of information (2) shortage of cheap crops (3) my farmland is not suitable for cheap crops (4) other (specify)________
Seasonal migration	(1) no one to take care of family (2) I don't have information about places with job opportunity (3) other (specify)
Other (specify)	other (specify)________

902. Please mention some of the best adaptation practices for your locality?________

903. What should the farmers do to overcome the negative impacts of climate change on their livelihoods?____

904. What should be the role of governmental and non-governmental organizations to reduce climate change impacts?

Thank you for your cooperation!!

Annex (1b): Interview Questions to Agricultural experts and DAs

1. What are the most frequently occurring climatic events that affect agricultural production negatively?
2. What do you think about the influence of climate variability on the agricultural sector?
3. Do you have the necessary technologies that would enable farmers to boost their agricultural production?
4. Do you think the famers in your district (*woreda*) are submissive to your education?
5. Do you support the farmers by providing selected seeds and better animal species?
6. To what extent are you aware of the current climatic situation of your district (*woreda*) in particular and the nation in general?
7. What are the major adaptation strategies that you educate the farmers to employ?
8. Do you think incentives provided from the government encourage farmers to cope up with climate related problems?
9. How do you evaluate government policies and strategies in relation to its effectiveness to address climate related problems on the agricultural sector?
10. How would you describe the state of soil fertility of your district (*woreda*)?

Annex 1(c): Interview Questions to Farmers

1. Do you have awareness on the current climatic situations?
2. Have you ever faced any type of climate related problem?
3. Are you accessed to gain appropriate information about climate and its impact on agriculture?
4. How do you evaluate the technological and educational service provided by the government experts and DAs?
5. How do you evaluate the efficiency of the DAs in providing the essential knowledge and skills related to agricultural production?
6. How do you evaluate government policies and strategies in relation to its effectiveness to address climate related problems as well as in maximizing agricultural production?
7. To what extent do you employ modern technologies for agricultural production?
8. Do you believe that the coping strategy/strategies you apply by yourself is effective?
9. Are you accessed to selected crops and livestock species? How do you evaluate their relevance?

	Households who haven't access to regular water supply	Sensitivity ↑ as pop. without regular water supply ↑ vulnerability ↑
	Average number of months with water shortage	Sensitivity↑as No. of months with food shortage↑vulnerability↑
	Average liters of water used by households per day	Sensitivity↑ as water consumption ↓ vulnerability vulnerability↑
	Time the household takes to reach drinking water sources in minutes	Sensitivity ↑ as distance to water sources ↑ vulnerability↑
	Households who reported water conflicts in their communities	Exposure ↑ as people reported conflict ↑ vulnerability↑
	Households who have no access to irrigation water (IW)	Coping-adaptive capacity ↑ as accessed IW ↑ vulnerability ↓

Proxies for economic capital and hypothesized relationships to vulnerability

Major components	Explanation of specific indicators	Hypothesized relationships to vulnerability
Farm& non-farm income	Average farm income	Coping-adaptive capacity ↑ as average farm income ↑ vulnerability↓
	Agricultural income diversification index	Coping-adaptive capacity ↑ as diversification↑ vulnerability ↓
	Non-farm income diversification index	
	Households who do not get remittance from relatives/friends	Adaptive capacity ↑ as remittance increases ↑ vulnerability↓
Credit access	HHs who do not have access to credit in their community	Adaptive capacity ↓ as people without access ↓ vulnerability
	Average money households borrowed in the last 5 years	Adaptive capacity↑ as average money borrowed ↑ vulnerability ↓
	Households who do not get money from credit providers	Adaptive capacity ↓as people without access ↑ vulnerability
	Time households take to reach to credit institutions	Sensitivity ↑ as distance to extension services ↑ vulnerability ↑
	HHs who reported tiresome procedures of credit institutions	Sensitivity ↑ as HHs reported tiresome procedure ↑ vulnerability↑
Livestock ownership	Households who do not own livestock unit	Adaptive capacity ↓ as people have no TLU ↑ vulnerability ↑
	Households who do not own any draught power to plough their land	Adaptive capacity ↓ as people have no draught power vulnerability
	Livestock owned by households in total livestock unit (TLU)	Adaptive capacity ↓as average TLU ↓ vulnerability
Livelihoods activities	Livelihood diversification index	Adaptive capacity ↑ as livelihood diversity ↑ vulnerability ↓
	Households who depend only on agriculture	Adaptive capacity ↓as people depend only on agriculture↑ vulnerability↑
	Crop diversification index	Adaptive capacity↑ as temporary crop diversity ↑ vulnerability ↓

Proxies for physical capital and hypothesized relationships to vulnerability

Major components	Explanation of specific indicators	Hypothesized relationship to vulnerability
Quality of shelter	Households whose their house wall made of wood and mud	Sensitivity ↑ as quality of walls and roofs ↓ vulnerability ↑
	Households whose house roof made of thatch	
	Households whose house located in hazard prone locations	Sensitivity ↑ as HHs reside in hazard prone locations↑ vulnerability↑
	Households who do not use fuel saving stove	Sensitivity ↑ as use of fuel saving stove ↓ vulnerability ↑
Energy supply	Households who do not use modern battery/electricity	Sensitivity ↑ as use of modern battery/electricity↓ vulnerability ↑
	Households entirely depend on firewood for light	Sensitivity ↑ as HHs depend on firewood for light↑ vulnerability ↑
Transport and telephone	Average time to reach the nearest vehicle station/road	Sensitivity ↑ as distance to reach the nearest station↑ vulnerability ↑
	Average time to reach public telephone center	
	Households who do not use vehicle to go to district (*woreda*) town	Sensitivity ↑ as people travel without vehicle↑ vulnerability ↑
	Households who reported absence of transport access all the year	Sensitivity ↑ as people with no access all round year ↑ vulnerability ↑
	Average distance to modern agricultural inputs	Sensitivity ↑ as distance ↑ vulnerability ↑ vulnerability ↑

Major components	Explanation of specific indicators	Hypothesized relationships to vulnerability
Access to input& output markets	Average amount of modern fertilizers used by farmers	Adaptive capacity ↑as fertilizer usage ↑vulnerability ↓
	Households who did not use modern fertilizer	Adaptive capacity ↑ as HHs do not use ↑ vulnerability ↑
	Average amount of expenditure for agricultural inputs	Adaptive capacity ↑ as agricultural expenditure ↓ vulnerability ↑
	Households who have no access to product markets	Sensitivity↑ as HHs reported market problem ↑ vulnerability↑
	Time taken by households to reach the nearest product markets	Sensitivity↑ as distance to product markets ↑ vulnerability↑

Proxies for social capital and hypothesized relationships to vulnerability

Major components	Explanation of specific indicators	Hypothesized relationships to vulnerability
Network & relationship	Number of relatives in a village	Adaptive capacity ↑ as number of relatives ↑ vulnerability ↓
	Households who have loose ties with their relatives & neighbors	Adaptive capacity ↓ as HHs with loose ties ↑ vulnerability ↑
	HHs who reported worse cooperation and support culture in their community	Adaptive capacity ↓ as weak cooperation↑ vulnerability↑
	HHs who did not get farmer-to-farmer extension in the last month before this survey	Adaptive capacity ↓ as HHs with no farmers' extension ↑ vulnerability ↑
	HHs who did not get any type of help from others in 6 month before the survey	Adaptive capacity ↓ as HHs did not get any help↑ vulnerability ↑
	HHs who did not get any loan from others in the past 6 months before the survey	Adaptive capacity ↓ as HHs did not get any loan↑ vulnerability ↑
	HHs who did not lend money in the past 6 months before the survey	Adaptive capacity↓ as HHs did not lend any money↑vulnerability↑
Organizational affiliations	Households who were not members of farmers' cooperatives	Adaptive capacity ↓ as membership ↓ vulnerability ↑
	Household who were not members in credit & saving group	
	Households who were not members of religious group	
	Households who were not members of other organizations (*Edir*)	
	Households who have no family members with *kebele* position	Adaptive capacity↓ as HHs with no position↓ vulnerability↑
Policy	Percentage of households who feel insecured of their farmland	Adaptive capacity↓ as insecure HHS ↑vulnerability ↑
	HHs not encouraged by the land certification to develop their land sustainably	Adaptive capacity↓ as HHS not encouraged ↑ vulnerability ↑
	Households who have no timely information on government policies	Adaptive capacity↓as HHS with no timely info↑ vulnerability↑
	Households who did not improve their life by government's development policies	Adaptive capacity↓ as HHS life not improved ↑ vulnerability↑
Leadership and service delivery	Households who are not happy with their local leaders' decisions and services	Adaptive capacity ↓ as unhappy HHs ↑ vulnerability ↑
	Households who did not participate in their leaders' election	Adaptive capacity ↓ as participation ↓ vulnerability ↑
	Average number of visits to farmers by DAs in a cropping season	Adaptive capacity ↓ as frequency of visits ↓ vulnerability ↑
	Households who have never been visited by DAs in a cropping season	Adaptive capacity ↓ as Nº. of HHs not visited ↓ vulnerability ↑
	Time households take to reach to the office of extension services	Sensitivity ↑ as distance to extension services↑ vulnerability↑
	Time households take to reach to the nearest veterinary clinic	Sensitivity↑ as distance to veterinary clinic ↑ vulnerability ↑

Climate variability/change and extreme event indicators

Major components	Explanations of specific indicators	Hypothesized relationship to vulnerability
Temperature	Mean standard deviation of the daily average maximum temperature by month	Exposure ↑ as maximum To variability ↑ vulnerability ↑
	Mean standard deviation of the daily average minimum temperature by month	Exposure↑ as minimum To variability↑ vulnerability ↑
Rainfall	Average monthly standard deviation of rainfall (1980-2011)	Exposure ↑ as rainfall deviation ↑ vulnerability ↑
Hazards Frequency	Average number of hazards occurred in the past 10 years	Exposure ↑ as frequency of droughts ↑ vulnerability ↑
	Reported death of livestock in the past 5 years	Sensitivity ↑ as death of livestock ↑ vulnerability ↑
	Households who reported their family members faced injury/death by climate hazards	Health Sensitivity ↑as injury and death↑vulnerability ↑

Source: Author's compilation based on Moss et al., 2001; Hahn et al., 2009; Lamichhane, 2010; Temesgen et al. 2009, Temesgen, 2010 and others)

Annex 3: Normalized vulnerability indices for major components and indicators

Indicators of vulnerability		*Dega*					*W/dega*					*Kola*	
1. Human capital	Unit	Observed	Max	Min	VI	Observed	Max	Min	LVI	Observed	Max	Min	LVI
1.1. Health indicators													
Distance to the nearest health post/center	Minute	43.70	550	2.00	0.07	100.9	550	2.00	0.18	131.84	550	2.00	0.23
Average distance to hospital	K.M.	27.11	250	8	**0.08**	51.57	250	8	**0.18**	164.29	250	8	**0.65**
HHs in which at least one chronically ill member	%	8.5	100	0	**0.09**	20.3	100	0	**0.20**	36.10	100	0	**0.36**
HHs faced with injury/death of family member(s)	%	1.6	100	0	**0.02**	45.1	100	0	**0.45**	32.30	100	0	**0.32**
HHs whose member missing work/school due to climate change induced illness	%	7.8	100	0	**0.08**	31.6	100	0	**0.32**	37.3	100	0	**0.37**
HHs who reported malaria in their locality	%	0	100	0	**0**	91	100	0	**0.91**	73.80	100	0	**0.74**
HHs who are not benefitted from health package	%	9.3	100	0	**0.09**	36.1	100	0	**0.36**	35.40	100	0	**0.35**
HHs who do not use toilet facility	%	88.4	100	0	**0.88**	91.7	100	0	**0.92**	67.70	100	0	**0.68**
Average Health Vulnerability					**0.16**				**0.44**				**0.46**
1.2. Skills and knowledge indicators													
Years spent on education (inverse index)	Year	0.99	1	0	**0.91**	0.88	1	0	**0.92**	0.69	1	0	**0.94**
HHs whose head never attended formal school	%	76.7	100	0	**0.77**	78.2	100	0	**0.78**	85.90	100	0	**0.86**
Inverse of farming experience index	Year	45.54	85	26	**0.75**	48.62	85	26	**0.723**	48.27	85	26	**0.73**
HHs whose family never got vocational training	%	86.8	100	0	**0.87**	89.5	100	0	**0.90**	88.6	100	0	**0.89**
HHs do not have info about climate change	%	59.7	100	0	**0.60**	21.1	100	0	**0.21**	42.6	100	0	**0.43**
Average distance to educational institutions	Minute	74.67	570	15.5	**0.14**	136.49	570	16	**0.21**	303.44	570	15.5	**0.52**
Average skills and knowledge Vulnerability					**0.70**				**0.68**				**0.74**
1.3. Demographic indicators													
Dependency ratio	Ratio	0.80			**0.80**	0.60			**0.61**	0.85			**0.85**
Female headed households	%	14	100	0	**0.14**	20.3	100	0	**0.20**	22.8	100	0	**0.23**
Family size in a household	N0.	5.64	17	1	**0.29**	6.70	17	1	**0.36**	5.88	17	1	**0.31**
Average demographic vulnerability					**0.41**				**0.39**				**0.46**
1.4. Food and nutrition indicators													
Number of food insufficient months in a year	Month	4	12	0	**0.33**	3.143	12	0	**0.26**	5	12	0	**0.42**
HHs who faced food shortage per year	%	96.9	100	0	**0.97**	91.7	100	0	**0.92**	98.1	100	0	**0.98**
Food diversification index (inverse)	No.	2.47	1	0	**0.41**	2.36			**0.42**	2			**0.50**
HHs whose members eat < 3 food items/day	%	54.3	100	0	**0.54**	66.7	100	0	**0.67**	90.7	100	0	**0.91**
HHs whose family members eat less 3 meals/day	%	20.2	100	0	**0.20**	14.3	100	0	**0.14**	66.2	100	0	**0.66**
HHs who are unable to save crops for contingency	%	89.1	100	0	**0.89**	88.6	100	0	**0.89**	96.2	100	0	**0.96**
Distance to food market	Min	50.96	780	3	**0.06**	138.59	780	3	**0.17**	163.59	780	3	**0.21**
Households who categorized themselves poor	%	24.8	100	0	**0.25**	29.3	100	0	**0.29**	63.9	100	0	**0.64**
Average food and nutrition vulnerability					**0.46**				**0.47**				**0.66**
2. Natural Capital													
2.1.land resource indicators													
Inverse of private landholding index	Hectare	0.784	5	0	**0.86**	1.818	5	0	**0.73**	0.799	5	0	**0.86**
Inverse of total landholding index	Hectare	1.112	8	0	**0.88**	2.043	8	0	**0.82**	1.046	8	0	**0.88**
HHs' land in rugged/Mt terrain location	%	36.4	100	0	**0.36**	22.6	100	0	**0.23**	65.4	100	0	**0.65**

HHs with high farmland erosion	%	6.2	100	0	**0.06**	16	100	0	**0.16**	45.3	100	0	**0.45**
Farmers with infertile farmland	%	7.07	100	0	**0.07**	3.8	100	0	**0.04**	62.1	100	0	**0.62**
crop yield per hectare (inverse)	Quintal	5.007	19.3	0.5	**0.81**	4.322	19.3	0.5	**0.83**	2.766	19.3	0.5	**0.89**
Crop yield trend stability	%	93.8	100	0	**0.94**	79.7	100	0	**0.80**	92.4	100	0	**0.92**
Average land resources vulnerability					**0.57**				**0.51**				**0.76**
2.2. Forest resource indicators													
HHs who did not own trees for firewood	%	20.4	100	0	**0.20**	33.4	100	0	**0.33**	78.8	100	0	**0.79**
Households who have no private trees (planted+N)	%	68.85	100		**0.69**	57.15	100	0	**0.57**	89	100	0	**0.89**
HHs who reported severe damage on common forests	%	52.8	100	0	**0.53**	69.2	100	0	**0.69**	93.2	100	0	**0.93**
Firewood supply trend stability	%	7	100	0	**0.07**	78.2	100	0	**0.78**	98.1	100	0	**0.98**
Distance to reach sources of firewood	Min	11.05	480	0	**0.02**	23.12	480	0	**0.05**	104.6	480	0	**0.22**
Average forest resource vulnerability					**0.30**				**0.49**				**0.76**
2.3. Water resource indicators													
HHs who utilize water from unprotected sources	%	7	100	0	**0.07**	7.5	100	0	**0.08**	91.6	100	0	**0.92**
HHs do not have access to regular water supply	%	3.9	100	0	**0.04**	57.9	100	0	**0.58**	74.5	100	0	**0.75**
average No. of months with water shortage	Month	0.05	8.5	0	**0.01**	1.527	8.5	0	**0.18**	2.405	8.5	0	**0.28**
Inverse of average liters of water per household	Liter	58.29	200	20	**0.82**	55.50	200	20	**0.84**	65.06	200	20	**0.80**
Average time to reach drinking water sources	Min	17.39	270	3	**0.05**	19.22	270	3	**0.06**	39.54	270	3	**0.14**
Households reporting conflicts over water	%	17.10	100	0	**0.17**	78.20	100	0	**0.78**	51.0	100	0	**0.51**
HHs who do not have access to irrigation water	%	76	100	0	**0.76**	73.70	100	0	**0.74**	93.5	100	0	**0.94**
Average water resource vulnerability					**0.27**				**0.46**				**0.62**
3. Economic/financial capital													
3.1. Livelihood diversification													
Inverse of livelihood diversification index	No.	0.29	1	0	**0.78**	0.44	1	0	0.69	1	1	0	**0.50**
HHs who depend only on agricultural income	%	85.65	100	0	**0.86**	91.53	100	0	**0.92**	93.08	100	0	**0.93**
Crop diversification index (inverse)		4.05	15	0	**0.93**		1	0	**0.89**	3.49	15	0	**0.96**
Average livelihood vulnerability					**0.86**				**0.83**				**0.80**
3.2. Income indicators													
Average farm income (inverse)	Birr	5985	60500	0	**0.90**	9962.4	60500	0	**0.84**	3754.7	60500	0	**0.94**
Agricultural income diversification (inv)	Birr	0.17			**0.86**	0.1			**0.91**	0.22			**0.82**
Non-agricultural income	Birr	1187	42600	0	**0.97**	1323	42600	0	**0.97**	925.76	42600	0	**0.98**
HHs who do not have off-farm employment	%age	62	100	0	**0.62**	69.9	100	0	**0.70**	86.3	100	0	**0.86**
HHs who do not get remittance from relatives/friends	%age	96.9	100	0	**0.97**	94	100	0	**0.94**	99.6	100	0	**1.00**
Average income vulnerability					**0.86**				**0.87**				**0.92**
3.3. Credit access indicators													
HHs who don't have access to credit	%age	3.9	100	0	**0.04**	15.8	100	0	**0.16**	43.3	100	0	**0.43**
Average money borrowed in the last 5 yrs	Birr	0.091*	1	0	**0.92**	0.134	1	0	**0.88**	0.068	1	0	**0.94**
HHs who didn't get money from lenders	%age	63.6	100	0	**0.64**	60.2	100	0	**0.60**	77.2	100	0	**0.77**
Time to reach the nearest credit institution	Min	56.8	720	0	**0.05**	128.22	720	0	**0.12**	378.96	720	0	**0.35**
HHs who reported tiresome credit procedures	%age	53.8	100	0	**0.54**	36.8	100	0	**0.37**	61.6	100	0	**0.62**
Average credit access vulnerability					**0.44**				**0.43**				**0.62**
3.4. Livestock ownership indicators													

HHs who don't own/less < 1 livestock unit	%age	9	100	0	**0.09**	7.7	100	0	**0.08**	15.6	100	0	**0.16**
HHs who don't own draft animal	%age	17.8	100	0	**0.18**	16.7	100	0	**0.17**	19	100	0	**0.19**
HHs who own only one draft animal	%age	38	100	0	**0.38**	24.1	100	0	**0.24**	23.2	100	0	**0.23**
Livestock ownership in TLU (inverse)	TLU	3.157	17.6	0	**0.85**	4.180	17.6	0	**0.81**	3.322	17.6	0	**0.84**
Time to reach veterinary clinic	Minute	48.67	480	3	**0.10**	122.63	480	3	**0.25**	152	480	3	**0.31**
Average livestock ownership vulnerability					**0.32**				**0.31**				**0.35**
4. Physical capital													
4.1. Shelter quality indicators													
HHs whose house wall is made of wood, mud/grass	%age	95.3	100	0	**0.95**	99.2	100	0	**0.99**	75.3	100	0	**0.75**
HHs whose house roof made of grass	%age	7	100	0	**0.07**	7.5	100	0	**0.08**	85.9	100	0	**0.86**
HHs whose house located in hazard prone areas	%age	3.1	100	0	**0.03**	33.1	100	0	**0.33**	60.1	100	0	**0.60**
Average shelter vulnerability					**0.35**				**0.47**				**0.74**
4.2. Energy indicators													
HHs who do not use fuel saving stove	%age	49.6	100	0	**0.50**	96.2	100	0	**0.96**	49.4	100	0	**0.49**
HHs who don't use modern battery/electricity	%age	36.4	100	0	**0.36**	88	100	0	**0.88**	88.2	100	0	**0.88**
HHs who are entirely dependent on firewood for light	%age	53.5	100	0	**0.54**	0.8	100	0	**0.01**	47.9	100	0	**0.48**
Average energy vulnerability					**0.47**				**0.62**				**0.62**
4.3. Communication indicators													
Aver. time to reach vehicle station/road	Min	35.5	780	2	**0.04**	59.06	780	2	0.07	476.84	780	2	**0.61**
Time taken to reach public telephone center	Min	52.59	660	3	**0.08**	120.05	660	3	0.18	122.76	660	3	**0.18**
HHs who don't use vehicle to go to *woreda* town	%	68.2	100	0	**0.68**	37.6	100	0	0.38	99.6	100	0	**1.00**
HHs who do not have transport access all the year	%	20.9	100	0	**0.21**	53.4	100	0	0.53	100	100	0	**1.00**
Average communication vulnerability					**0.25**				**0.29**				**0.70**
4.4. Access to input and output markets													
Average distance to reach to agricultural inputs	Minute	71.49	690.0	3.50	0.09	116.69	690.00	3.50	0.16	282.60	690.00	3.50	0.39
Amount of fertilizer used (inverse)	k.g	87.54	325	0	**0.79**	96.339	325	0	**0.77**	33.7	325	0	**0.91**
HHs who don't use modern fertilizer	%	20.9	100	0	**0.21**	3.1	100	0	**0.03**	49	100	0	**0.49**
Agricultural input expenditure (inverse)	Birr	3497	16000	0	**0.82**	2833.91	16000	0	**0.85**	1632.1	16000	0	**0.91**
HHs with no market for their products	%	12.4	100	0	**0.12**	13.5	100	0	**0.14**	37.3	100	0	**0.37**
Time taken to reach product market	Min	57.08	510	5	**0.10**	136.37	510	5	**0.26**	157.49	510	5	**0.30**
Average input and output market vulnerability					**0.36**				**0.37**				**0.56**
5. Social Capital													
5.1. Networks and relationships indicators													
Average number of relatives in a village	No.	7.51	150	0	**0.95**	15.19	150	0	**0.91**	8.79	150	0	**0.94**
HHs who have loose ties to relatives/neighbors	%	22.5	100	0	**0.23**	54.9	100	0	**0.55**	62.4	100	0	**0.62**
Societies' cooperation/support culture	%	31.8	100	0	**0.32**	74.5	100	0	**0.75**	73.7	100	0	**0.74**
HHs who don't get farmer-to-farmer extension/month	%	10.9	100	0	**0.11**	31.1	100	0	**0.31**	42.4	100	0	**0.42**
HHs who don't get help from relatives/neighb/6 month	%	18.6	100	0	**0.19**	30.1	100	0	**0.30**	35	100	0	**0.35**
HHs who didn't get loan from relatives/neigh/6 months	%	74.4	100	0	**0.74**	73.7	100	0	**0.74**	81.4	100	0	**0.81**
HHs who don't lend money in the past 6 months	%	68.2	100	0	**0.68**	69.9	100	0	**0.70**	85.2	100	0	**0.85**
Average networks and relationships vulnerability					**0.46**				**0.61**				**0.68**
5.2. Organizational affiliation indicators													
HHs who are not members of farmers' cooperatives	%	72.1	100	0	**0.72**	81.2	100	0	**0.81**	74.9	100	0	**0.75**

HHs who are not members of credit & saving group	%	69.8	100	0	**0.70**	93.2	100	0	**0.93**	90.9	100	0	**0.91**
HHs who are not members of religious groups	%	8.5	100	0	**0.09**	53.4	100	0	**0.53**	37.3	100	0	**0.37**
HHs who are not member of other organizations (*Edir*)	%	96.1	100	0	**0.96**	91	100	0	**0.91**	98.5	100	0	**0.99**
HHs who have no relative with *kebele* position	%	50.4	100	0	**0.50**	62.4	100	0	**0.62**	67.7	100	0	**0.68**
Average organizational affiliation vulnerability					**0.59**				**0.76**				**0.74**
5.3. Policy related issues indicators													
HHs who feel unsecured for their farm land	%	6.2	100	0	**0.06**	18	100	0	**0.18**	21.3	100	0	**0.21**
HHs who don't get encouraged by land certificate	%	12.4	100	0	**0.12**	9.8	100	0	**0.10**	13.3	100	0	**0.13**
HHs who have no information on gov't policies	%	2.3	100	0	**0.02**	7.5	100	0	**0.08**	36.1	100	0	**0.36**
HHs who are dissatisfied with gov't policy	%	6.2	100	0	**0.06**	11.3	100	0	**0.11**	33.8	100	0	**0.34**
HHs who are Dissatisfied with NGOs role in dev't	%	33.2	100	0	**0.33**	12	100	0	**0.12**	33.8	100	0	**0.34**
Average policy related issues index					**0.12**				**0.12**				**0.28**
5.4. Leadership and service delivery													
HHs who are unhappy by their local leaders' decisions	%	22.5	100	0	**0.23**	51.2	100	0	**0.51**	75.3	100	0	**0.75**
HHs who don't participate in local election	%	7	100	0	**0.07**	15.8	100	0	**0.16**	21.7	100	0	**0.22**
HHs who were not visited by DAs in a cropping season	Freq	1.69	10	0	**0.85**	1.18	10	0	**0.89**	1	10	0	**0.91**
HHs not visited by DAs in a cropping season	%	40.3	100	0	**0.40**	37.4	100	0	**0.37**	45.6	100	0	**0.46**
Average Leadership& service delivery index					**0.39**				**0.48**				**0.58**
6. Climate change/variability and Hazards													
6.1. Temperature variability indicators													
Mean SDEV of. monthly max temperature	0C	1.4	3.78	0.64	0.24	0.64	0.97	0.3	0.51	0.81	1.28	0.47	0.42
Mean SDEV of average monthly min temperature	0C	0.48	1.64	0.55	-0.1	3.25	4.56	1.8	0.53	1.7	2.27	1.5	0.26
HHs perceived increasing temperature	%	86.8	100	0	**0.87**	96.2	100	0	**0.96**	89.7	100	0	**0.90**
HHs perceived temperature related impacts	%	43.97	100	0.00	0.44	63.91	100.00	0.00	0.64	57.24	100.00	0.00	0.57
Average temperature index					**0.37**				**0.66**				**0.54**
6.2. Rainfall variability indicators													
HHs reported decreased rainfall	%	41.1	100	0	**0.41**	27.1	100	0	**0.27**	79.5	100	0	**0.80**
Average monthly STDEV of RF (1987-2011)	Mm	39.42	98.1	2.92	**0.38**	37.43	90.68	2	**0.41**	45.2	81.2	5.3	**0.56**
HHs reported Erratic rainfall	%	55.8	100	0	**0.56**	78.9	100	0	**0.79**	30.3	100	0	**0.30**
HHs reported rainfall deficit-induced problems	%	36.15	100	0	0.36	69.64	100	0	0.70	57.83	100	0	0.58
Average rainfall index					**0.43**				**0.54**				**0.56**
6.3. Hazard indicators													
Drought	Freq	1.30	10	0	**0.13**	2.49	10	0	**0.25**	5.35	10	0	**0.54**
Flood	Freq	0.30	10	0	**0.03**	3.11	10	0	**0.31**	4.34	10	0	**0.43**
Hailstorm	Freq	0.90	10	0	**0.09**	3.72	10	0	**0.37**	5.01	10	0	**0.50**
Crop pests	Freq	1.16	10	0	**0.12**	2.02	10	0	**0.20**	4.92	10	0	**0.49**
Crop diseases	Freq	0.61	10	0	**0.06**	5.35	10	0	**0.54**	4.34	10	0	**0.43**
Human diseases	Freq	0.10	10	0	**0.01**	6.95	10	0	**0.70**	4.57	10	0	**0.46**
Animal diseases	Freq	1.23	10	0	**0.12**	5.26	10	0	**0.53**	3.78	10	0	**0.38**
HHs reported death of TLU in the past 5 yrs	TLU	0.82	20.25	0	**0.04**	1.48	20.25	0	**0.07**	3.41	20.25	0	**0.17**
Average hazard index					**0.08**				**0.37**				**0.42**

Source: Computed from the household survey data (March – Sept, 2012), meteorology data **(1979-2010)** and some other secondary sources

Annex 4: Multi-co linearity statistics

	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Colinearity Statistics	
	B	Std. Error	Beta			Tolerance	VIF
(Constant)	.350	.165					
Agro-ecology	-.107	.029	-.196	-3.719	.000	.551	1.816
Age of the household head	.002	.002	.059	1.390	.165	.849	1.178
Gender of the household head	.056	.051	.050	1.112	.267	.763	1.310
Total family size	.078	.029	.124	2.677	.008	.713	1.403
Education of the household head	.003	.009	.012	.306	.760	.925	1.081
Family member who get training	.039	.057	.028	.689	.491	.939	1.065
Households heard about climate change	-.038	.040	-.041	-.954	.340	.827	1.209
Farmland size households own	.100	.028	.184	3.597	.000	.583	1.716
Farmland fertility level	.097	.047	.101	2.045	.041	.630	1.586
Access to water for irrigation	-.171	.054	-.134	-3.160	.002	.847	1.180
Number of livestock in TLU	.020	.011	.105	1.771	.077	.439	2.278
Number of draught animals	.026	.029	.052	.916	.360	.473	2.114
Farm income of households	0.00	.000	-.010	-.215	.830	.707	1.414
Non-farm income of households	0.00	.000	-.056	-1.348	.178	.900	1.111
Number of relatives in a village	.000	.002	.009	.208	.836	.880	1.137
Farmer-to-farmer extension	.067	.043	.069	1.551	.121	.774	1.293
Extension service	-.021	.041	-.023	-.512	.609	.764	1.309
Distance to chemical fertilizer center	0.00	.000	-.006	-.141	.888	.730	1.370
Perception of temperature change	-.108	.065	-.069	-1.666	.096	.889	1.125
Perception to rainfall change	.053	.070	.030	.748	.455	.941	1.063

Source: Model result from the household survey data, March – September 2012

Annex 5a-f: Raw data for meteorology records: Temperature and rainfall data

(a) Stations for interpolating rainfall data for the three agro-ecologies

Agro-ecology	Gauging station	Location X (degree)	Location Y (degree)	Area of influence	Weighted area
Dega	Dabat	37.9212	12.9575		
	Debark	37.9659	12.9575		
Woyna dega	Maksegnit	37.5518	12.388	65.69	6
	Aykel	37.0631	12.5584	233.65	22
	Azezo	37.4241	12.5529	287.6	27
	Gorgora	37.2969	12.2355	490.26	46
	Takusa	36.8750	12.330		
	Total			1077.2	100
	Stations	**Location**		**Distance (km)**	**Weighting factor $1/d^2$**
Kola	Mekdela	38.75	11.3964	40.75	0.000602
	Robit	38.4375	11.3964	24.53	0.001662
	E-Sarmidir	38.4375	11.0841	15.00	0.004444
	Estie	38.125	11.3963	63.00	0.000252
	Gumdewoyn	38.125	11.0841	37.59	0.000708
	Amhara Saint	38.75	11.0841	40.00	0.000625

Source: Compiled from NMA record, 2012 and Global Weather Data Center (1979 – 2010)

(b) Maximum temperature for dega by month

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	mean
1979	24.31	29.12	30.12	29.98	26.81	25.84	20.74	20.85	24.51	28.11	27.97	26.63	26.25
1980	27.84	27.12	30.65	30.31	29.57	25.37	20.42	20.81	26.81	28.14	27.8	26.75	26.80
1981	27.59	28.69	28.6	29.32	28.51	26.12	20.42	20.92	22.84	27.22	27.88	26.57	26.22
1982	25.65	26.09	29	30.35	29	25.91	21.07	19.47	24.62	27.42	27.38	26.23	26.02
1983	25.83	27.21	28.39	30.41	27.4	26.09	22.42	18.71	23.11	24.68	25.77	25.94	25.50
1984	26.39	28.42	29.82	30.99	28.22	23.93	20.95	20.77	23.83	27.65	27.03	25.79	26.15
1985	27.88	27.47	29.52	28.72	26.11	24.44	19.51	19.36	22.84	26.01	26.42	26.02	25.36
1986	26.51	29.12	30.18	29.35	28.85	21.69	19.22	19.61	21.92	26.53	26.93	25.68	25.47
1987	26.65	27.68	27.22	29.28	26.11	22.37	21.59	20.49	24.04	27.67	26.66	26.6	25.53
1988	27.17	27.2	30.22	30.82	29.57	24.6	17.5	18.95	21.89	25.16	26.85	26.05	25.50
1989	26.8	27.68	27	28.01	28.5	24.3	20.22	20.1	23.99	26.61	28.1	26.08	25.62
1990	26.51	26.37	29.86	29.98	30.34	26.06	20.17	20.92	23.78	27.52	27.63	27.23	26.36
1991	27.22	29.43	29.11	29.41	29.68	26.31	19.18	20.5	24.31	26.79	27.12	26.14	26.27
1992	26.79	27.81	30.23	30.13	29.59	24.9	20.63	17.18	22.35	24.81	25.83	25.44	25.47
1993	26.35	26.98	29.81	28.75	27.13	23.31	19.46	19.99	23.36	25.56	27.12	26.19	25.33
1994	27.14	28.42	30.68	31.01	29.02	23.04	17.04	18.41	22.81	27.65	27.19	26.48	25.74
1995	27.09	27.94	29.13	30.21	28.75	26.5	18.9	20.89	23.93	27.58	27.64	26.51	26.26
1996	27.45	29.01	28.55	30.08	26.9	21.41	19.66	19.82	23.63	26.87	26.4	25.4	25.43
1997	27.23	28.29	29.3	29.01	29.54	24.87	20.61	21.34	26.2	25.95	26.37	27.34	26.34
1998	27.64	28.62	30.16	32.32	28.55	25.01	18.71	18.39	23.14	25.51	28.24	27.26	26.13
1999	26.35	30.54	31.33	31.25	28.43	24.73	18.56	20.47	23	23.61	26.59	26.89	25.98
2000	27.65	28.84	31.1	29.68	29.26	26.51	21.82	20.42	25.61	27.65	28.34	27.6	27.04
2001	27.83	29.64	30.6	31.96	30.88	24.45	21.27	20.4	26.77	28.24	28.21	27.37	27.30
2002	27.5	30.21	31.54	31.36	31.52	27.59	24.18	22.81	26.67	29.52	28.1	28.08	28.26
2003	29.34	30.09	31.32	32.68	31.58	25.87	21.58	20.92	26.58	29.48	28.8	27.45	27.97
2004	28.86	29.47	32.03	31.48	31.22	26.02	22.53	22.43	26.98	29	28.68	27.89	28.05
2005	27.54	30.86	32.32	31.63	29.71	26.28	21.82	22.24	24.96	28.49	28.08	27.44	27.61
2006	28.76	30.71	31.12	30.31	29.44	26.95	21.36	20.32	23.79	28.03	27.63	27.25	27.14
2007	27.46	29.37	31.38	30.81	29.74	25.44	20.36	21.5	24.3	29.08	27.7	26.97	27.01
2008	27.87	29.41	31.15	30.29	29.9	25.95	21.62	22.21	25.03	28.23	28	27.01	27.22
2009	28.02	29.92	31.4	31	31.44	26.5	20.4	21.55	25.55	27.2	27.62	27.4	27.33
2010	28.19	29.5	29.87	30.2	28.22	24.67	19.79	19.12	23.22	27.68	28.49	25.08	26.17

Source: Interpolated from NMA and Global weather data for SWAT (1979-2010)

(c) Minimum temperature for dega by month

Year	Jan.	Feb.	Mar.	Apr.	May.	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	mean
1979	9.58	10.34	11.97	13.53	13.53	13.64	13.33	12.65	10.9	11.19	8.77	7.89	11.44
1980	8.27	11.29	13.38	14.77	14.66	14.11	13.28	12.59	11.5	10.76	10.2	7.63	11.87
1981	8.81	9.44	13.27	13.22	14.19	12.7	13.58	13.76	11.22	10.16	9.65	8.31	11.53
1982	10.27	10.45	12.83	13.47	13.76	13.27	12.75	12.69	10.65	9.91	9.56	7.69	11.44
1983	7.03	9.12	11.52	13.27	14.15	13.52	12.99	13.1	11.71	10.95	9.99	7.3	11.22
1984	6.77	8.66	12.53	14.03	13.87	13.3	12.64	12.51	10.96	9.73	9.84	7.94	11.07
1985	8.17	7.57	12.68	13.65	12.89	12.63	12.37	12.25	10.74	10.33	10.35	7.31	10.91
1986	6.32	9.89	12.37	12.68	13.53	13.64	12.42	12	10.87	9.73	9.92	7.76	10.93
1987	7.21	10.05	13.02	14.41	13.41	12.97	13.63	13.09	11.3	10.84	9.73	8.17	11.49
1988	9.49	11.21	12.79	14.23	13.81	13.05	12.88	13.12	11.8	10.36	8.62	8	11.61
1989	6.65	9.64	11.37	12.17	12.92	12.71	13.15	11.97	10.83	10.73	9.65	10.14	10.99
1990	9.08	11.07	12.95	13.85	14.73	13.3	12.71	12.36	11.57	10.57	10.33	8.36	11.74
1991	8.83	9.63	12.37	13.93	14.43	13.74	12.81	12.64	11.44	10.73	9.17	8.32	11.50
1992	7.8	8.74	12.84	13.61	14.23	13.22	12.66	12.41	10.76	10.75	10.54	8.52	11.34
1993	8.07	9.22	11.49	14.11	13.39	12.93	12.82	12.1	11.07	11.13	10.44	8.16	11.24
1994	7.59	10.44	10.7	14.84	13.68	13.43	12.69	12.27	10.7	10.36	9.25	7.15	11.09
1995	7.81	10.4	10.95	15.05	14.64	13.7	13.27	13.16	11.65	11.15	10.27	9.99	11.84
1996	8.59	9.87	13.02	14.97	13.6	13.04	12.97	12.4	11.05	10.29	11.03	9.51	11.70
1997	9.29	9.18	13.36	13.5	13.73	13.45	13.05	12.84	11.88	12.18	11.27	9.11	11.90
1998	10.11	10.24	12.46	14.85	15.27	13.9	13.37	13.09	11.73	11.17	9.75	7.85	11.98
1999	9.13	10.58	10.12	13.92	13.43	13.13	12.67	12.81	11.58	10.66	8.85	8.84	11.31
2000	7.62	9.42	11.61	13.82	14.11	13.61	12.73	12.41	11.54	11.75	10.47	8.82	11.49
2001	7.54	10.07	11.88	14.42	14.44	13.95	13.56	12.82	11.25	12.26	9.53	9.34	11.76
2002	9.13	10.46	12.97	13.12	14.29	14.46	13.49	12.65	11.62	11.47	11.03	9.52	12.02
2003	8.47	11.54	13.12	13.85	15.51	14.05	13.7	12.75	11.89	11.57	10.19	8.81	12.12
2004	9.21	10.13	11.84	14.35	13.86	13.78	12.88	12.78	11.42	10.91	10.86	9.26	11.77
2005	8.38	10.46	12.83	14.9	14.07	13.8	13.72	13.23	11.73	11.56	10.05	8.1	11.90
2006	8.56	10.37	11.83	13.72	14.96	13.98	13.73	13.41	12.08	11.71	10.35	8.44	11.93
2007	9.11	10.48	12.04	14.8	15.63	14.57	13.55	13.3	12.12	11.12	10.11	7.6	12.04
2008	9.75	9.48	10.55	13.53	14.77	13.86	13.23	12.63	12.24	11.87	9.77	8.59	11.69
2009	8.29	11.46	12.99	14.01	14.28	14.16	13.32	13.21	12.31	11.19	10.29	9.06	12.05
2010	9.22	10.64	12.62	15.71	14.96	13.99	13.69	13.21	11.8	11.23	10.67	8.54	12.19

Source: Interpolated from NMA and Global weather data for SWAT (1979-2010)

(d) Temperature data for Woyna dega interpolated from Gorgora and Azezo stations

Year	GTmin	GTmax	GorTmin	GorTmean	GTmean	GorTmean	mean	Tmax	Tmin	Tmean
1979	13.40	26.55	12.17	19.94	19.98	19.937	19.96	27.13	12.78	19.96
1980	13.08	26.47	12.51	20.48	19.78	20.482	20.13	27.46	12.80	20.13
1981	13.15	26.25	12.02	19.65	19.70	19.645	19.67	26.76	12.59	19.67
1982	13.28	26.73	12.00	19.62	20.00	19.620	19.81	26.98	12.64	19.81
1983	13.54	26.78	12.09	19.53	20.16	19.529	19.84	26.87	12.82	19.84
1984	12.96	25.85	11.73	19.74	19.40	19.745	19.57	26.80	12.35	19.57
1985	13.56	26.25	11.59	19.37	19.90	19.375	19.64	26.71	12.57	19.64
1986	12.25	26.38	11.67	19.38	19.32	19.379	19.35	26.73	11.96	19.35
1987	12.84	26.23	12.34	19.77	19.54	19.770	19.65	26.72	12.59	19.65
1988	11.17	25.83	12.13	19.49	18.50	19.492	19.00	26.34	11.65	19.00
1989	12.33	26.76	11.46	19.07	19.54	19.068	19.31	26.72	11.89	19.31
1990	13.58	26.77	12.15	19.99	20.17	19.993	20.08	27.30	12.86	20.08
1991	13.81	26.33	12.20	19.87	20.07	19.874	19.97	26.94	13.00	19.97
1992	13.76	26.13	12.07	19.54	19.95	19.536	19.74	26.57	12.91	19.74
1993	14.23	27.03	11.66	19.11	20.63	19.113	19.87	26.80	12.94	19.87
1994	14.38	27.26	11.87	19.55	20.82	19.545	20.18	27.24	13.12	20.18
1995	14.02	26.61	12.35	19.89	20.31	19.893	20.10	27.02	13.19	20.10
1996	13.79	26.99	12.19	19.46	20.39	19.460	19.92	26.86	12.99	19.92
1997	13.45	27.42	12.37	19.98	20.44	19.979	20.21	27.50	12.91	20.21
1998	12.68	27.30	12.55	19.89	19.99	19.887	19.94	27.26	12.61	19.94
1999	13.05	27.09	11.91	19.58	20.07	19.583	19.83	27.17	12.48	19.83
2000	13.64	26.81	12.08	20.17	20.23	20.167	20.20	27.54	12.86	20.20
2001	13.83	27.36	12.58	20.73	20.59	20.732	20.66	28.12	13.20	20.66
2002	14.08	28.08	12.65	21.39	21.08	21.385	21.23	29.10	13.36	21.23
2003	13.88	27.54	13.12	21.57	20.71	21.570	21.14	28.78	13.50	21.14
2004	14.16	24.32	12.57	21.38	19.24	21.376	20.31	27.25	13.37	20.31
2005	13.65	27.12	12.89	21.12	20.38	21.124	20.75	28.24	13.27	20.75
2006	13.59	27.27	12.77	20.65	20.43	20.653	20.54	27.90	13.18	20.54
2007	13.75	27.36	12.66	20.54	20.55	20.539	20.55	27.89	13.21	20.55
2008	13.71	26.67	12.62	20.93	20.19	20.933	20.56	27.96	13.16	20.56
2009	13.53	27.53	12.96	20.98	20.53	20.975	20.75	28.26	13.25	20.75
2010	14.42	27.33	12.71	20.59	20.87	21.116	20.99	28.16	13.57	20.99

(e) Temperature data for kola interpolated from Robit (R) and Mekdela (M) stations

Year	RTmax	RTmin	RTmean	MTmax	MTmin	Mmean	M+Rtmax	M+RTmin	R+MTmean
1979	28.00	10.38	19.19	27.49	10.27	18.88	27.75	10.33	19.04
1980	28.63	10.48	19.56	28.05	10.42	19.24	28.34	10.45	19.40
1981	28.05	10.18	19.11	27.57	10.19	18.88	27.81	10.18	19.00
1982	27.66	10.44	19.05	27.24	10.11	18.68	27.45	10.27	18.86
1983	27.99	10.47	19.23	27.25	10.09	18.67	27.62	10.28	18.95
1984	28.49	9.78	19.14	28.15	9.80	18.97	28.32	9.79	19.06
1985	27.94	9.64	18.79	27.33	9.55	18.44	27.63	9.60	18.62
1986	27.57	9.86	18.72	26.56	9.85	18.20	27.07	9.86	18.46
1987	28.41	10.51	19.46	27.81	10.10	18.96	28.11	10.30	19.21
1988	27.73	10.46	19.09	27.13	10.31	18.72	27.43	10.39	18.91
1989	27.37	9.94	18.66	26.97	9.64	18.30	27.17	9.79	18.48
1990	28.19	10.54	19.36	27.37	10.13	18.75	27.78	10.33	19.05
1991	27.95	10.36	19.16	27.06	10.35	18.70	27.51	10.35	18.93
1992	27.95	10.44	19.19	26.95	9.94	18.45	27.45	10.19	18.82
1993	27.95	10.17	19.06	27.13	9.72	18.42	27.54	9.95	18.74
1994	28.03	9.89	18.96	26.94	9.95	18.44	27.48	9.92	18.70
1995	28.24	10.57	19.40	27.12	10.13	18.63	27.68	10.35	19.02
1996	27.34	10.67	19.00	26.54	10.15	18.34	26.94	10.41	18.67
1997	28.61	10.88	19.74	27.94	10.60	19.27	28.27	10.74	19.51
1998	28.06	11.14	19.60	27.06	10.72	18.89	27.56	10.93	19.25
1999	28.49	10.26	19.37	27.52	9.84	18.68	28.00	10.05	19.03
2000	29.33	10.31	19.82	28.19	10.00	19.09	28.76	10.16	19.46
2001	30.06	10.73	20.40	28.81	10.47	19.64	29.44	10.60	20.02
2002	30.71	11.06	20.88	29.62	10.75	20.18	30.17	10.90	20.53
2003	30.18	11.30	20.74	29.50	11.05	20.28	29.84	11.18	20.51
2004	30.79	11.02	20.91	29.82	10.66	20.24	30.30	10.84	20.57
2005	30.41	10.95	20.68	29.64	11.00	20.32	30.03	10.97	20.50
2006	29.56	11.10	20.33	28.61	11.00	19.80	29.09	11.05	20.07
2007	29.63	10.81	20.22	28.85	10.66	19.76	29.24	10.73	19.99
2008	30.00	10.74	20.37	29.06	10.75	19.91	29.53	10.75	20.14
2009	29.93	11.06	20.50	29.46	11.03	20.24	29.69	11.04	20.37
2010	28.42	11.50	19.96	27.64	10.93	19.29	28.03	11.22	19.62

(f) Rainfall data for the three agroecology-based sites

	Dega	Mean	STDEV	SPI		W/dega	mean	STDEV	SPI	Kola	mean	STDEV	SPI
1979	1380.31	1373.04	220.29	0.03		1707.52	1466	147.84	1.63	730.9	686.95	70.64	0.62
1980	1354.37	1373.04	220.29	-0.08		1583.78	1466	147.84	0.80	761	686.95	70.64	1.05
1981	1515.3	1373.04	220.29	0.65		1469.62	1466	147.84	0.02	712.1	686.95	70.64	0.36
1982	1248.04	1373.04	220.29	-0.57		1305.79	1466	147.84	-1.08	725	686.95	70.64	0.54
1983	1477.01	1373.04	220.29	0.47		1505.59	1466	147.84	0.27	635.5	686.95	70.64	-0.73
1984	1191.85	1373.04	220.29	-0.82		1519.97	1466	147.84	0.37	554.4	686.95	70.64	-1.88
1985	1346.51	1373.04	220.29	-0.12		1521.79	1466	147.84	0.38	639.2	686.95	70.64	-0.68
1986	1627.88	1373.04	220.29	1.16		1510.14	1466	147.84	0.30	824.9	686.95	70.64	1.95
1987	1412.98	1373.04	220.29	0.18		1508.1	1466	147.84	0.28	618.9	686.95	70.64	-0.96
1988	1481.9	1373.04	220.29	0.49		1451.62	1466	147.84	-0.10	707.6	686.95	70.64	0.29
1989	1094.39	1373.04	220.29	-1.26		1508.75	1466	147.84	0.29	782.2	686.95	70.64	1.35
1990	1043.88	1373.04	220.29	-1.49		1246.7	1466	147.84	-1.48	733.5	686.95	70.64	0.66
1991	1387.55	1373.04	220.29	0.07		1235.69	146	147.84	-1.56	636.6	686.95	70.64	-0.71
1992	1491.36	1373.04	220.29	0.54		1312.29	1466	147.84	-1.04	710.3	686.95	70.64	0.33
1993	1250.42	1373.04	220.29	-0.56		1552.05	1466	147.84	0.58	689.3	686.95	70.64	0.03
1994	1787.7	1373.04	220.29	1.88		1371.03	1466	147.84	-0.64	846.9	686.95	70.64	2.26
1995	1251.02	1373.04	220.29	-0.55		1269.26	1466	147.84	-1.33	648.7	686.95	70.64	-0.54
1996	1584.43	1373.04	220.29	0.96		1689.45	1466	147.84	1.51	718.2	686.95	70.64	0.44
1997	1694.35	1373.04	220.29	1.46		1481.92	1466	147.84	0.11	617	686.95	70.64	-0.99
1998	1758.48	1373.04	220.29	1.75		1687.05	1466	147.84	1.50	797.3	686.95	70.64	1.56
1999	1307.23	1373.04	220.29	-0.30		1502.62	1466	147.84	0.25	616.1	686.95	70.64	-1.00
2000	1269.39	1373.04	220.29	-0.47		1632.79	1466	147.84	1.13	630.8	686.95	70.64	-0.80
2001	1681.25	1373.04	220.29	1.40		1654.31	1466	147.84	1.27	707	686.95	70.64	0.28
2002	732.33	1373.04	220.29	-2.91		1117.65	1466	147.84	-2.36	612.3	686.95	70.64	-1.06
2003	1336.74	1373.04	220.29	-0.16		1380.77	1466	147.84	-0.58	642.9	686.95	70.64	-0.62
2004	1206.19	1373.04	220.29	-0.76		1423.81	1466	147.84	-0.29	623.6	686.95	70.64	-0.90
2005	1293.36	1373.04	220.29	-0.36		1506.08	1466	147.84	0.27	628.4	686.95	70.64	-0.83
2006	1520.5	1373.04	220.29	0.67		1596.26	1466	147.84	0.88	735.3	686.95	70.64	0.68
2007	1473.29	1373.04	220.29	0.46		1527.71	1466	147.84	0.42	707.8	686.95	70.64	0.29
2008	1208.04	1373.04	220.29	-0.75		1413.2	1466	147.84	-0.36	598.6	686.95	70.64	-1.25
2009	1328.75	1373.04	220.29	-0.20		1210.26	1466	147.84	-1.73	645.6	686.95	70.64	-0.59
2010	1200.49	1373.04	220.29	-0.78		1508.4	1466	147.84	0.29	744.8	686.95	70.64	0.82

Source: Interpolated from NMA and Global weather data for SWAT (1979-2010)

Annex 6a&b: Climatic events, reported shocks, and ranks by FGDs over the past decade and diversification formula

(a) Reported climatic events ranked by FGDs over the past decade

Type of Hazards	Hazard frequency noted by respondents			HHs reported major shocks (%)			Ranks by participatory methods		
	Dega	*W/Dega*	*Kola*	*Dega*	*W/Dega*	*Kola*	*Dega*	*W/Dega*	*Kola*
DR	2	3	6	39.5	83.5	98.5	1	4	1
FSE	1	4	5	22.7	75.2	92.0	3	5	2
HS	1	4	6	45.0	94.5	97.7	2	7	3
CP	2	7	5	50.4	94.7	97.7	3	1	4
CD	1	6	5	40.3	84.2	97.3	5	1	4
HD	1	7	5	7.0	91.7	95.4	6	3	5
AD	2	6	4	69.8	90.2	96.6	7	3	3
Con.	*	*	*	17.1	78.2	51.0	4	6	7
UTR	*	*	*	*	*	*	*	2	3

DR = drought, FSE = flood/soil erosion, HS = hailstorm, CP = crop pests, CD = crop diseases, DH = human diseases, AD = animal diseases, con = conflict, UTR = untimely rain, * = not addressed by the questionnaire survey

Source: Field Survey from March to October 2012 and FGDs and interviews December – March 2012

(b) Crop and livelihood diversification index formula applied in this research

$$ICD = 1/((P_a + P_B + P_C \ldots + P_n)/N_c).$$

where, ICD = index of crop diversification;

P_a = proportion of sown area under crop a;

P_b = proportion of sown area under crop b;

P_c = proportion of sown area under crop c;

P_n = proportion of sown area under crop n;

N_c = number of crops.

Annex 7a-c: Data on adaptation options, adaptations used and indices

(a) Adaptations used, options available and adoption indices computed for *dega* agro-ecology

Adapt used	Option	Index	Adapt used	Options	Index	Adapt used	Options	Index	Adapt used	Options	Index
8	20	0.4	9	19	0.45	11	19	0.55	11	20	0.55
15	20	0.75	12	19	0.6	4	19	0.2	11	20	0.55
12	20	0.6	11	19	0.55	9	19	0.45	12	20	0.6
10	20	0.5	10	19	0.5	13	19	0.65	11	20	0.55
11	20	0.55	11	19	0.55	11	19	0.55	10	20	0.5
11	20	0.55	7	19	0.35	12	19	0.6	9	20	0.45
7	20	0.35	10	19	0.5	10	19	0.5	12	20	0.6
9	20	0.45	8	19	0.4	12	19	0.6	13	20	0.65
7	20	0.35	7	19	0.35	11	19	0.55	13	20	0.65
4	20	0.2	8	19	0.4	9	19	0.45	9	20	0.45
9	20	0.45	7	19	0.35	11	19	0.55	aver index		0.49
11	20	0.55	8	19	0.4	11	19	0.55			
8	20	0.4	10	19	0.5	9	19	0.45			
8	20	0.4	11	19	0.55	10	19	0.5			
13	20	0.65	10	19	0.5	9	19	0.45			
9	20	0.45	10	19	0.5	8	19	0.4			
11	20	0.55	12	19	0.6	8	19	0.4			
13	20	0.65	9	19	0.45	6	19	0.3			
11	20	0.55	10	19	0.5	6	19	0.3			
7	20	0.35	11	19	0.55	9	19	0.45			
9	20	0.45	16	19	0.8	11	19	0.55			
11	20	0.55	12	19	0.6	4	19	0.2			
11	20	0.55	8	19	0.4	10	19	0.5			
12	20	0.6	11	19	0.55	7	19	0.35			
12	20	0.6	11	19	0.55	11	19	0.55			
11	20	0.55	13	19	0.65	11	19	0.55			
11	20	0.55	9	19	0.45	11	19	0.55			
11	20	0.55	8	19	0.4	9	19	0.45			
10	20	0.5	6	19	0.3	11	19	0.55			
9	20	0.45	9	19	0.45	8	19	0.4			
10	20	0.5	9	19	0.45	9	19	0.45			
10	20	0.5	10	19	0.5	7	19	0.35			
6	20	0.3	11	19	0.55	9	19	0.45			
9	20	0.45	7	19	0.35	8	19	0.4			
8	20	0.4	7	19	0.35	11	19	0.55			
10	20	0.5	13	19	0.65	6	19	0.3			
11	20	0.55	11	19	0.55	11	19	0.55			
10	20	0.5	12	19	0.6	11	19	0.55			
11	20	0.55	11	19	0.55	2	19	0.1			
			9	19	0.45	9	19	0.45			

b) Adaptations used, options available& adoption indices computed for *w/dega* agro-ecology

used	Options	Index	used	options	Index	Used	options	index	used	options	Index
9	20	0.45	11	19	0.55	6	19	0.3	12	19	0.6
9	20	0.45	9	19	0.45	8	19	0.4	14	19	0.7
11	20	0.55	8	19	0.4	0	19	0	11	19	0.55
2	20	0.1	6	19	0.3	5	19	0.25	6	19	0.3
9	20	0.45	12	19	0.6	4	19	0.2	5	19	0.25
7	20	0.35	11	19	0.55	11	19	0.55	12	19	0.6
9	20	0.45	10	19	0.5	10	19	0.5	10	19	0.5
0	20	0	13	19	0.65	12	19	0.6	6	19	0.3
6	20	0.3	3	19	0.15	11	19	0.55	9	19	0.45
7	20	0.35	12	19	0.6	2	19	0.1	0	19	0
9	20	0.45	11	19	0.55	15	19	0.75	10	19	0.5
11	20	0.55	12	19	0.6	11	19	0.55	7	19	0.35
15	20	0.75	11	19	0.55	11	19	0.55	9	19	0.45
11	20	0.55	11	19	0.55	10	19	0.5	Aver		0.44
11	20	0.55	9	19	0.45	8	19	0.4			
7	20	0.35	6	19	0.3	0	19	0			
11	20	0.55	6	19	0.3	4	19	0.2			
11	20	0.55	7	19	0.35	1	19	0.05			
8	20	0.4	8	19	0.4	2	19	0.1			
11	20	0.55	9	19	0.45	13	19	0.65			
11	20	0.55	9	19	0.45	0	19	0			
10	20	0.5	2	19	0.1	10	19	0.5			
5	20	0.25	12	19	0.6	8	19	0.4			
11	20	0.55	11	19	0.55	11	19	0.55			
12	20	0.6	11	19	0.55	10	19	0.5			
10	20	0.5	11	19	0.55	8	19	0.4			
13	20	0.65	12	19	0.6	10	19	0.5			
0	20	0	12	19	0.6	11	19	0.55			
14	20	0.7	12	19	0.6	3	19	0.15			
8	20	0.4	10	19	0.5	10	19	0.5			
9	20	0.45	9	19	0.45	7	19	0.35			
11	20	0.55	8	19	0.4	11	19	0.55			
11	20	0.55	12	19	0.6	6	19	0.3			
12	20	0.6	4	19	0.2	0	19	0			
0	20	0	7	19	0.35	0	19	0			
11	20	0.55	13	19	0.65	11	19	0.55			
11	20	0.55	2	19	0.1	12	19	0.6			
14	20	0.7	12	19	0.6	11	19	0.55			
9	20	0.45	13	19	0.65	7	19	0.35			
9	20	0.45	10	19	0.5	8	19	0.4			
11	20	0.55									

(C) Adaptations used, options available and adoption indices computed for *kola* agro-ecology

Used	Option	Index	used	Option	Index	used	Option	Index	used	Option	Index	used	option	Index	Used	Option	Index	used	Option	Index
8	20	0.4	5	19	0.25	10	19	0.5	8	19	0.4	9	19	0.45	5	20	0.25	9	20	0.45
7	20	0.35	9	19	0.45	10	19	0.5	10	19	0.5	9	19	0.45	10	20	0.5	6	20	0.3
7	20	0.35	12	19	0.6	7	19	0.35	8	19	0.4	3	19	0.15	11	20	0.55	7	20	0.35
4	20	0.2	6	19	0.3	10	19	0.5	10	19	0.5	12	19	0.6	6	20	0.3	10	20	0.5
6	20	0.3	8	19	0.4	5	19	0.25	8	19	0.4	16	19	0.8	6	20	0.3	10	20	0.5
7	20	0.35	13	19	0.65	10	19	0.5	9	19	0.45	9	19	0.45	9	20	0.45	9	20	0.45
8	20	0.4	7	19	0.35	8	19	0.4	9	19	0.45	10	19	0.5	7	20	0.35	7	20	0.35
5	20	0.25	10	19	0.5	8	19	0.4	9	19	0.45	9	19	0.45	0	20	0	9	20	0.45
7	20	0.35	5	19	0.25	8	19	0.4	10	19	0.5	9	19	0.45	4	20	0.2	12	20	0.6
7	20	0.35	7	19	0.35	12	19	0.6	14	19	0.7	7	19	0.35	5	20	0.25	5	20	0.25
8	20	0.4	7	19	0.35	13	19	0.65	10	19	0.5	10	19	0.5	2	20	0.1	8	20	0.4
7	20	0.35	6	19	0.3	9	19	0.45	8	19	0.4	8	19	0.4	3	20	0.15	7	20	0.35
10	20	0.5	3	19	0.15	7	19	0.35	11	19	0.55	8	19	0.4	5	20	0.25	6	20	0.3
3	20	0.15	5	19	0.25	7	19	0.35	10	19	0.5	8	19	0.4	7	20	0.35	5	20	0.25
8	20	0.4	6	19	0.3	12	19	0.6	4	19	0.2	6	19	0.3	7	20	0.35	5	20	0.25
5	20	0.25	4	19	0.2	9	19	0.45	8	19	0.4	3	19	0.15	10	20	0.5	8	20	0.4
9	20	0.45	6	19	0.3	6	19	0.3	8	19	0.4	7	19	0.35	14	20	0.7			
9	20	0.45	1	19	0.05	7	19	0.35	8	19	0.4	4	19	0.2	7	20	0.35			
9	20	0.45	3	19	0.15	3	19	0.15	8	19	0.4	7	19	0.35	10	20	0.5			
9	20	0.45	7	19	0.35	7	19	0.35	6	19	0.3	5	19	0.25	10	20	0.5			
8	20	0.4	6	19	0.3	7	19	0.35	0	19	0	8	19	0.4	10	20	0.5			
10	20	0.5	7	19	0.35	8	19	0.4	6	19	0.3	9	19	0.45	9	20	0.45			
4	20	0.2	8	19	0.4	3	19	0.15	5	19	0.25	10	19	0.5	7	20	0.35			
5	20	0.25	10	19	0.5	1	19	0.05	7	19	0.35	6	19	0.3	9	20	0.45			
9	20	0.45	12	19	0.6	11	19	0.55	5	19	0.25	7	19	0.35	13	20	0.65			
13	20	0.65	4	19	0.2	12	19	0.6	6	19	0.3	1	19	0.05	8	20	0.4			
10	20	0.5	9	19	0.45	6	19	0.3	4	19	0.2	8	19	0.4	10	20	0.5			
6	20	0.3	10	19	0.5	10	19	0.5	7	19	0.35	10	19	0.5	4	20	0.2			
12	20	0.6	9	19	0.45	9	19	0.45	2	19	0.1	11	19	0.55	3	20	0.15			
5	20	0.25	10	19	0.5	10	19	0.5	7	19	0.35	11	19	0.55	5	20	0.25			
7	20	0.35	11	19	0.55	6	19	0.3	13	19	0.65	6	19	0.3	8	20	0.4			
5	20	0.25	10	19	0.5	11	19	0.55	9	19	0.45	7	19	0.35	8	20	0.4			
10	20	0.5	5	19	0.25	10	19	0.5	10	19	0.5	6	19	0.3	5	20	0.25			
9	20	0.45	10	19	0.5	10	19	0.5	13	19	0.65	11	19	0.55	5	20	0.25			
9	20	0.45	4	19	0.2	12	19	0.6	8	19	0.4	4	19	0.2	10	20	0.5			
8	20	0.4	6	19	0.3	8	19	0.4	7	19	0.35	12	19	0.6	9	20	0.45			
13	20	0.65	8	19	0.4	10	19	0.5	8	19	0.4	9	19	0.45	9	20	0.45			
6	20	0.3	2	19	0.1	9	19	0.45	8	19	0.4	5	19	0.25	5	20	0.25			
9	20	0.45	7	19	0.35	9	19	0.45	7	19	0.35	9	19	0.45	8	20	0.4			
13	20	0.65	10	19	0.5	9	19	0.45	8	19	0.4	11	19	0.55	7	20	0.35			
9	20	0.45	9	19	0.45	11	19	0.55	7	19	0.35	9	19	0.45	9	20	0.45			

Source: Computed from the household survey data, March - September 2012 based on equation 3.4.3A