

The Vulnerability of Smallholder Agriculture to Climate Variability/Change in Boset Woreda, Oromia Region, Ethiopia

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This is to certify that the thesis prepared by Emebet Bekele, entitled: *The vulnerability of Smallholder Agriculture to Climate Variability/Change in Boset Wored, Oromia Region, Ethiopia* and submitted in the partial fulfillment of the requirements for the Degree of Master of Arts (*Climate Change and Adaptation*) complies with the regulations of the University and meets the accepted standards with respect to originality and quality.

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Abstract

This paper examined vulnerability of smallholder agriculture to climate variability/change in the Oromia region of Boset Woreda by developing vulnerability index and comparing vulnerability indicators across the three agro-ecological zones. It also assessed the perceptions of farmers to climate variability/change, undertaken adaptation measures and perceived impacts of the event on the society. The study used semi-structured interview to gather data from households, government officials and experts; and secondary data from published and unpublished sources, and systematically analyzes the data both using qualitative and quantitative analysis. The result showed that the trend of gradual and extreme weather change increased agriculture vulnerability in the study area. According to the 30 years (1981-2010) metrological data, rainfall was decreasing with a rate of 2.2 mm while temperature was rising by 0.009^0c. Farmers at the area also agreed with the metrological data. 95.7%, 78.7 % and 93.1% of the respondents claimed that there had been an overall increase in temperature, flood and drought occurrence and decrease in rainfall respectively with compared to the past years. Regarding the agricultural impacts, 97.9% of the respondents stated having a considerable reduction of production while 88.8% increase in incidence of plant diseases. Similarly, 87.8%, 62%, 76.7%, and 58.6% of respondents perceived an increase in incidence of insects, animal diseases, weeds and flood and drought respectively. To cope with the impacts, on average 63 % of the farmers used one or more of adaptation mechanisms though, the coping mechanisms were not sufficient to tackle the challenges. The study also revealed that agro-ecology zone with low potential impact and high adaptive capacity had the lowest vulnerability level than with high potential impacts and low adaptive capacity. Accordingly, the warm moist lowlands agro-ecology zone had the lowest agriculture vulnerability level due to its low potential impact and high adaptive capacity followed by Sub moist mid highlands. In contrast, because of its combined high sensitivity and exposure and low adaptive capacity the warm Sub- Moist lowlands agro-ecology zone had the highest level of agriculture vulnerability. Thus, as climate variability/change is an unavoidable phenomenon, reducing the sensitivity of the farmers and the ecosystem and increasing the adaptive capacity of the farmers is very crucial so as to minimize the vulnerability of agriculture to climate variability/change.

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List of Acronyms/ abbreviations

CSA Central statistical Authority

ETM - Enhanced Thematic Mapper

FGDs- Focus Group discussions

GDP- Gross Domestic Product

GIS – Geographical Information Systems

GPS – Global Positioning System

HDI- Human development Index

IPCC- Intergovernmental Panel on Climate Change

LULC- Land Use Land Cover

NCCF- National Climate Change Conference

NMA- National Meteorological Agency

NMSA- National Meteorological Service Agency

PA- Peasant Associations

PCA – Principal Component Analysis

SMMiHL- Sub-Moist Mid Highlands

SPSS - Statistical Package for Social Sciences

TM- Thematic Mapper

UNDP- United Nations Development Program

USAID- United States Agency for International Development

USD- United state dollar

WMLL - Warm Moist Lowlands

WSMLL - Warm Sub-Moist Lowlands

Chapter One

Introduction

1.1. Background

Climate change presents a new and real threat of severe environmental, economic, political and security impacts in Africa (Thornton et al., 2006, Neil et al., 2007, Keffyalew, 2011). For a region that is already vulnerable to many non-climate stresses, climate change and its potential physical and socio-economic impacts are likely to exacerbate this vulnerability, leading to large scale instability. Climate change is likely to act as a risk multiplier aggravating water scarcity. Water scarcity on the other hand threatens food security by reducing agricultural productivity, as well as hindering human health and economic development. Water scarcity can also lead to additional environmental stress, as well as increase tensions within and between nations sharing water resources (Aymone et al., 2009).

Sub-Saharan African countries are most in danger of experiencing drought due to their large projected reductions in rainfall and the significant increases in temperature foreseen for that region; suffering will be most acute for poor and vulnerable populations. According to IPCC as cited in Allen (2003), Vulnerability is the degree to which a system is susceptible to, or unable to cope with adverse effects of climate change, such as climate variability and extremes. Thus, Vulnerability is a function of the character, magnitude, and rate of climate change and variation to which a system is exposed as well as the system's sensitivity and adaptive capacity. Vulnerability to climate change varies across regions, sectors, and social groups.

Global environmental changes tend to have a disproportional impact on agriculture compared to other economic sectors. Since agriculture relies directly on natural resources, those who work in agriculture are inherently vulnerable to change in climate, water availability, and land use (Bryan et al., 2009). The degree to which climatic events affect an agricultural system depends on a wide variety of factors: including the types of crops or livestock produced, the scale of the operation, the farm's orientation towards commercial or subsistence purposes, the quality of the natural resource base, and specific

human variables of the farm's managers (e.g. education, risk tolerance, age, etc.). Agriculture is also influenced by institutional factors, including the rules, norms and policies that govern land tenure, the availability of markets, financial capital, insurance and support programs, and the degree of technology development and distribution (Leon-Vasquez et al., 2003).

Sufficient evidence shows that the average temperature rise in Africa is faster than the global average and is likely to persist in the future (Gerald, 2010). The warming is definitely hazardous for agricultural activities in the continent as many of the crops are grown close to the thermal tolerance limits (Aymone et al., 2009). Further, the warming of few degrees and increase in frequency of extreme weathers strongly influences the agricultural production and make the society victim of the events and decreases the future adaptive capacities. There are many attempts to make a monetary evaluation of climate change impacts. One recent study, for example, estimated that African farmers, on rain fed land, will lose USD 28 per hectare per year for each $1^{o}C$ rise in global temperatures (Leichenko, 2001). Gerald (2010) also showed that rainfall decreases significantly in June, July and August over parts of the Horn of Africa which is the main crop cultivation season in Ethiopia.

Agriculture is the most important sector in the Ethiopian economy. The sector directly supports about 85% of the population in terms of employment and livelihood; contributes about 50% of the country's gross domestic product (GDP); generates about 88% of the export earnings; and supplies around 73% of the raw material requirement of agro-based domestic industries (Gene et al., 2011). It is also the major source of food for the population and hence; the prime contributing sector to food security (Yesuf, 2008). In addition, agriculture is expected to play a key role in generating surplus capital to speed up the country's overall socio-economic development. However, small-scale farmers who are dependent on low input and low output rain-fed mixed farming with traditional technologies dominate the agricultural sector. Besides, as researches conducted by Temesgen et al., (2008) and Temesgen (2010) on the vulnerability of agriculture to climate change have found out that decline in precipitation and increases in temperature are both damaging Ethiopian agriculture and increase its vulnerability. So, this study aims to assess the vulnerability of smallholder agriculture to climate change at the household level.

1.2. Statement of the Problem

Currently Sub-Saharan African countries are dealing with a number of socio-economic and environmental challenges. Some of these challenges are poverty eradication, diminishing resource degradation, controlling alarming population growth, improving low agricultural productivity etc (Temesgen, 2010). Though agriculture is given a prime emphasis as a core sector to solve the current challenges and to bring future sustainability to the continent, the sector is recently challenged by climate change (Gina et al., 2008).

Like many other developing countries, as CSA (2008) confirms, agriculture is the single largest livelihood of the majority of the population. It also provides the largest share of the economic activity, accounts for half of the GDP (CIA - World Fact book, 2013). As agriculture is the backbone of the country, it is believed to continue to be the determinant sector to bring sustainable economic development to the country (CSA, 2008). Nevertheless, agriculture in Ethiopia is heavily dependent on the timely onset, amount, duration, and distribution of rainfall. Different literatures emphasize that countries which have economies largely based on weather-sensitive agriculture are vulnerable to climate change (Getnet, 2010, Dejene, 2011, Abate, 2009, Zenebe et al., 2011).

The fact that Ethiopia is an agrarian country and mainly depends on rain fed agriculture makes it far more vulnerable to climate variability and change. Though this is the case, there has been not much research on the vulnerability of agriculture to climate change in Ethiopia. Even though there are few research works which have been done by different researchers on the vulnerability of agriculture to climate change, they focused on farmers vulnerability by considering the socio-economic aspects and neglecting the physical factors which play a great role on its vulnerability to any change (Temesgen, 2010, Abate, 2009). Further, the past studies focused on large scale than small scale like in a household level. Owing to the above mentioned facts, it is, thus, imperative to understand how much vulnerable the agriculture is to climate change at the lowest levels of the society, such as households and communities. So in a way of filling the gaps mentioned above, this study aims to assess the vulnerability of agriculture to climate change in the Boset Woreda at a household level.

1.3. Objectives

1.3.1. General objective

The general objective of the study is to assess the vulnerability of smallholder agriculture to climate change.

1.3.2. Specific objectives

The specific objectives of this study are to:

- Evaluate the local climate situation and trends of variability/change
- Assess perceptions of local people to climate variability/ change and its perceived agricultural impacts
- Explore the local coping and adaptation strategies undertaken by the farmers
- Asses factors that contribute for agriculture vulnerability to climate change
- Categorize highly vulnerable agro-ecological zone (s)
- Produce agriculture vulnerability map

1.4. Significance of the Study

The issue of the impacts of climate variability/change is widely studied in the world (McCarthy et al., 2001, Gene et al., 2011, Marye, 2011). The impact of the change in climate brings serious damages especially in developing countries and is making the resources of the countries more vulnerable. Compared with water resources, forests and other natural ecosystems, agriculture is more vulnerable to climate variability/change, thereby scientifically assessing agricultural vulnerability to climate change is of great significance to the formulation of policy and effective adaptation strategies. Moreover, agriculture vulnerability mapping aims to be useful in the decision making process for identifying appropriate sites for specific adaptation and mitigation actions. Thus, agricultural vulnerability maps produced from this study can be useful for development agents and Non-Governmental Organizations (NGOs) to facilitate scaling up of best practice strategies with success stories from similar risk zones elsewhere.

1.5. Scope of the Study

This study was carried out in the Oromia region of Boset woreda. Apart from area scope, the study was limited to the vulnerability of smallholder agriculture to climate variability/change. The study also assessed perceptions of local people to climate variability/ change and its perceived agricultural impacts, local coping and adaptation strategies undertaken by the farmers.

1.6. Limitation of the Study

Agricultural vulnerability analysis is the result of various climatic parameters and high level application of models. Despite various efforts to make the research more scientific, reliable and applicable, some limitations have been observed on the process of completion of the work. Full records on climatic elements are not observed and comparison reference years have not been set since a detailed work in this area had not been undertaken previously. Since many climate related data relevant for the topic of this study are not available or accessible, only rainfall and temperature data have been used for this study.

1.7. Organization of the Paper

This research paper is organized in five chapters. Chapter one presents the introduction of the study which includes background of the study, statement of problems, objectives , scope , significance and limitation of the study . Chapter two provides overview of vulnerability and agricultural vulnerability related concepts. Chapter three explains the methodology employed for the study. It justifies the choice of research strategy, design, sample, data collection and analysis techniques. Chapter four presents the findings from the data collection and gives an analysis and discussion of the presented findings and chapter five offers conclusions and recommendations.

Chapter Two

Review of Related Literature

2.1. Introduction

Climate change has drawn the attention of most governmental and non-governmental organizations as it is becoming a major issue that is affecting the survival of humankind. Of all the sectors agriculture is the most sensitive to climate change and a slight increase or decrease in its value brings a considerable impact to agricultural production (Ana, 2006). Climate change is affecting the agriculture of Ethiopia significantly, and it will inevitably have a huge impact on agricultural production in the future (Gene et al., 2011); they further stated that even if the impact might be different from location to location, as a whole it will be unpleasant and adverse.

As Ethiopia is a large agricultural country, strengthening the evaluation of agricultural vulnerability to climate change bears more practical significance (Getnet, 2010). Getnet (2010) further explained that by studying the impact of climate change on agriculture and the agricultural vulnerability to climate change in different regions, it is of great significance for proactively adapting to climate change, developing effective adaptation measures and ensuring sustainable agricultural development, and also for providing a scientific basis for decision making. In addition, scientific and reasonable evaluation of the vulnerability will provide meaningful results for risk analysis of climate change (Thomas, 2012). Hence, the assessment of agricultural vulnerability to climate change is not only necessary, but it also is an important part of the research of climate change impact and adaptation.

2.2. Concepts and Definitions of Vulnerability

Vulnerability is defined in different ways in different fields. As defined by Chamber, (1989) vulnerability is experience of unexpected happenings and trauma and the ability to survive this experiences. Adger (1996) name two section of vulnerability; the first is the results of an incident have on humans (social vulnerability) and the second is threat that such an incident

may happen (the experience). Therefore, according to him, vulnerability shows both internal and external extent. The internal extent talks about frailty and uncertainty so much as the capability to predict handle and pull through from the shock of danger. The external extent explores the experiences of threat and shocks.

Moser (1998) changes the focus of vulnerability from emphasizing internal/coping and external/exposure, and examine two similar but different factors: sensitivity and adaptive capacity (or resilience). The IPCC Third Assessment Report, as explained by McCarthy et al. (2001), reconciles both sides by adding a third component to vulnerability, defining 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. Vulnerability is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity".

As of the IPCC (2007), a vulnerability definition consistent with that of the third assessment report. Under this framework, a highly vulnerable system would be one that is very sensitive to modest changes in climate, where the sensitivity includes the potential for substantial harmful effects, and for which the ability to adapt is severely constrained.

Luers et al. (2003) distinguish three domains of vulnerability: present criticality, adaptive capacity, and climate change hazard. They have also proposed a method for quantifying vulnerability (given the system, outcome variable, and stressor of concern) based on its three components: exposure, sensitivity, and adaptive capacity. Turner et al. (2003) recognize that vulnerability is determined not by exposure to hazards alone, but also depends on the sensitivity and resilience of the system that is experiencing such hazards. These authors develop an integrated conceptual framework of vulnerability built on these three major dimensions of vulnerability, namely exposure, sensitivity and adaptation/resilience.

In general vulnerability refers to the degree to which a system is susceptible to or unable to cope with adverse effects of climate change (including climate mean, variability, and extremes), and it is a function of the character, magnitude, and rate of climate variation to which a system is exposed, its sensitivity, and its adaptive capacity (McCarthy et al., 2001).

2.3. Approaches to Vulnerability Analysis

There are three major conceptual approaches to analyzing vulnerability to climate change: the socio-economic, the biophysical (impact assessment); and the integrated assessment approaches (Fusel, 2007).

2.3.1. Socio- economic approach

The socio-economic vulnerability assessment approach mainly focuses on the socio-economic and political status of individuals or social groups (Adger et al., 1999; Fusel, 2007). Individuals in a community often vary in terms of education, gender, wealth, health status, access to credit, access to information and technology, formal and informal (social) capital; political power and so on. These variations are responsible for the variations in vulnerability levels. In this case, vulnerability is considered to be a 'starting point' or a 'state' i.e. a variable describing the internal state of a system) that exists within a system before it encounters a hazardous event (Allen, 2003; Kelly et al., 2000). Thus, vulnerability is considered to be constructed by society as a result of institutional and economic changes (Adger et al., 1999).

2.3.2. Biophysical approach

The biophysical approach assesses the level of damage that a given environmental stress causes on both social and biological systems (Kaly et al., 1999). Fussel (2007) identified this approach as a 'risk-hazard approach' and denoted the vulnerability relationship as: a hazard-loss relationship in natural hazard research; a dose response or exposure-effect relationship in epidemiology; and a damage function in macroeconomics. Kelly et al. (2000) referred to the biophysical approach as an 'end-point analysis' responding to research questions such as: 'What is the extent of the climate change problem?

2.3.3. The integrated assessment approach

The integrated assessment approach combines both socio-economic and biophysical approaches to determine vulnerability. The 'hazard-of-place model' by Cutter et al. (2000) is

a good example of this approach, in which both biophysical and socio-economic factors are systematically combined to determine vulnerability. The vulnerably mapping approach is another example in which both socio-economic and biophysical factors and combined to indicate the level of vulnerably through mapping (O'Brien et al., 2004).

2.4. Methods for Measuring Vulnerability to Climate Change

The most common methods for analyzing vulnerability to climate change employed in vulnerability literature are the econometric and indicator methods (Leichenko et al., 2001).

2.4.1. Econometric method

This method uses household-level socio-economic survey data to analyses the level of vulnerability of different social groups. The method is divided in to three categories: vulnerability as expected poverty; vulnerability as low expected utility; and vulnerability as uninsured exposure to risk. All three share common characteristics in that construct a measure of welfare loss attributed to shocks (Hoddinott et al., 2003).

This method was used by Temesgen et al. (2009) to assess farmers' vulnerability to climate extremes in Ethiopia. They estimate the probability of the income of households falling below a poverty line, and classify vulnerable households as those with more than 50 per cent probability of falling below the poverty line. The authors are able to identify the share of vulnerable households in different agro-ecological zones, and differentiate between vulnerable households that are poor today and vulnerable households that are not poor today. The results are highly sensitive to which poverty line is used; with a poverty line of 2 USD a day almost all households are poor today and likely to remain poor due to climate extremes.

There are limitations to using econometric approaches to measuring vulnerability to climate change. Such as, this method is based on observed data will have to rely on already observed climate variability to measure vulnerability to climate change. Second, point to high data requirements and that the form of the utility function must be assumed, as weaknesses of the economic approach (Sofie, 2012).

2.4.2. Indicator method

The indicator method of quantifying vulnerability is based on selecting some indicators from a set of potential indicators and then systematically combining them to point out the levels of vulnerability. These levels of vulnerability may be analyzed at local, regional and global level (Adger et al., 1999; Leon-Vasquez et al. 2003, Morrow, 1999).

Two options are available for calculating the level of vulnerability using this method at any scale. The first is assuming that all indicators of vulnerability have equal importance and thus giving them equal weights (Cutter et al. 2000). The second method assigns different weights to avoid the uncertainty to equal weighting given the diversity of indicators used (O' Brien et al. 2004). In line with the second method, many methodological approaches have been suggested to make up for the weight differences of indicators.

Different researchers conduct their researches using this method. For instant, Glwadys et al. (2010), apply this method in an analysis of vulnerability to climate change and variability in South Africa. They use frequency of past climate extremes and predicted changes in rainfall and temperature by 2050 as indicators of exposure to long-term changes in climate and changes in climate variability. The underlying assumption is that the larger the predicted change, the greater the exposure. To capture sensitivity, agricultural characteristics such as irrigation rate, land degradation index, crop diversification index, share of small-scale agriculture and rural population density, are used. Finally, adaptive capacity is captured through indices of household assets, such as social capital :share of farmers in farmer organizations, human capital: literacy rate, number of socioeconomic characteristics such as farm income, farm size, agricultural share of GDP and access to credit. The authors find that the provinces that are expected to experience the largest exposure to climate change are not always the most vulnerable; rather vulnerability is closely linked to social and economic development.

O'Brien et al. (2004), also use an indicator approach to assess vulnerability to climate change and economic globalization, defined as exposure to import competition, in India. Vulnerability to climate change is measured by combining indicators of adaptive capacity,

such as soil quality, water availability, human and physical capital, outside employment opportunities and presence of infrastructure with a Climate Sensitivity

Some limitations to this method are the subjective nature of the indicators chosen, and the fact that the aggregate indicators of vulnerability do not reflect local institutions that may increase or decrease sensitivity and adaptive capacity (Sofie, 2012).

2.5. Definition of Agricultural Vulnerability to Climate Change

Agricultural vulnerability is defined by different scholars and groups in different ways based on the objective of the intended research. The US department of agriculture defined it as the capability of the agriculture to cope with the impact of climate change even though there are works being done on adaptation works (Reilly, 1996); whereas the IPCC defined agricultural vulnerability, as mentioned by Shengcai et al., (2011), on the base of its sensitivity and adaptive capacity to climate change which is different in location, time, and socio- economic and environmental situations.

These days most research works defined agricultural vulnerability to climate change as change in the function of characteristics of climate variability, magnitude, and rate of variation within the agricultural system, and the system's sensitivity and adaptive capacity, and it is the degree to which the agricultural system is susceptible to or unable to cope with adverse effects of climate change including climate variability and extreme events (Shengcai et al. 2011).

2.6. Vulnerable Groups and Systems to Climate Variability/Change

People who live on arid or semi-arid lands, in low-lying coastal areas, in water-limited or flood-prone areas, or on small islands are particularly vulnerable to climate change (Pearson and Langridge, 2008). It is clear that climate change will, in most parts of the world, adversely affect socio-economic sectors, including water resources,

agriculture, forestry, fisheries and human settlements, ecological systems, and human health, with developing countries being the most vulnerable (IPCC, 2000). The report further stated that the importance of agricultural activities for the economies of most African countries, combined with the farming sector is reliance on the quality of rains during the rainy season, make countries in this region particularly vulnerable to climate change.

As Ethiopia is one of the countries in Africa, with current intensity and pattern of climate variability or change, and the resultant adverse effects currently the country is facing, there is no a single social or economic sector in the area which is expected to be free from climate change-induced impacts and shocks. Almost all sectors are vulnerable to impacts of climate change (Abate, 2009). But, the most vulnerable sectors to climate variability and change in the context of Ethiopia include: Agriculture (crop cultivations and livestock rearing), water, health, forests, pastures, biodiversity, education and energy; although, the magnitude of vulnerability and degree of sensitivity to climate change-induced shocks and hazards vary from sector to sector. Also, in terms of livelihood means, smallholder rain-fed farmers and pastoralists in the country are found to be the most vulnerable to climate change shocks (Keffyalew, 2011).

2.7. Climate Change Observations in Ethiopia

Ethiopia has been affected by climate variability and extremes for long time. Drought, hunger and famines are the dominant part of Ethiopia's history which is caused by climatic and non-climatic related disasters. As the country is resides in a very sensitive part of the world for climate changes, relatively small events during the growing season, like too much or too little rain at the wrong times, can spell disasters (Alebachew et al., 2011).

Climate Trend Analysis of Ethiopia which is built by US Geological Survey, USAID and the Famine Early Warning Systems indicate that there are a significant reduction in rainfall and increases in temperature over the period from mid 1970s to 2000s in many areas of the country (Keffyalew, 2011).

According to the UNDP Climate Change Profile which has done by McSweeney et al., (2008) for Ethiopia, the mean annual temperature in Ethiopia has increased by 1.3°C between 1960 and 2006, at an average rate of 0.28°C per decade. The report further stated that daily temperature observations show significantly increasing trends in the frequency of hot days, and much large increasing trends in the frequency of hot nights. The average number of hot days per year in Ethiopia has increased by 73 (an additional 20% of days) between 1960 and 2003. The rate of increase is seen most strongly in June-August when the average number of hot days has increased by 9.9 days per month (an additional 32% of days) over this period. The average number of hot nights per year increased by 137 (an additional 37.5% of nights) between 1960 and 2003.

The frequency of cold days has decreased significantly in all seasons except December-February. The frequency of cold nights has decreased more rapidly and significantly in all seasons. The average number of cold days per year has decreased by 21 (5.8% of days) between 1960 and 2003. This rate of decrease is most rapid in September-November when the average number of cold days has decreased by 2.3 days per month (7.4% of days) over this period (McSweeney et al., 2008).

The average number of cold nights per year has decreased by 41 (11.2% of days). This rate of decrease is most rapid in June- August when the average number of cold June to August nights has decreased by 3.7 nights per month (12% of nights) over this period (McSweeney et al., 2008).

2.8. Climate Change Projection in Ethiopia

Due to the high inter-annual and inter- decadal rainfall variability it is difficult to detect long term rainfall trends in Ethiopia. Between 1960 and 2006, no statistically significant trend in mean rainfall was observed in any season. The decrease in rainfall observed in July to September in the 1980's recovered in the 1990s and 2000s. In addition, there are insufficient daily rainfall records to identify trends in daily rainfall variability and changes in rainfall intensity (McSweeney et al., 2008). According to the National Meteorological Agency,

Ethiopia experienced 10 wet years and 11 dry years over the last 55 years, demonstrating the strong inter-annual variability (Ethiopian NMA, 2007).

According to the UNDP Climate Change Country Profile for Ethiopia, the mean annual temperature is projected to increase by 1.1 to 3.1°C by the 2060s and by 1.5 to 5.1 °C by the 2090s. It is also projected that there will be a substantial increase in the frequency of days and nights that are considered 'hot' in the current climate, and a decrease in the frequency of days and nights that are currently considered 'cold'. It is projected that 'hot' days will occur on 19-40% of days by the 2060s and 26-69% of days by the 2090s. The number of 'hot' days and nights will increase most rapidly in the months of July to September. Cold nights will decrease in frequency more rapidly than cold days, and are projected by most models to not occur at all by the 2090s (McSweeney et al., 2008).

Mean annual rainfall in Ethiopia is projected to increase, mainly as a result of increasing rainfall in the short rainy season (October to December). Projected changes in the April to June and July to September rainy seasons are more mixed but tend towards small increases in the south (especially in the south-west) and decreases in the north-east. It is also projected that the proportion of rainfall that falls in heavy precipitation events will increase throughout the country, especially during the July to September and October to December rainfall (McSweeney et al., 2008).

2.9. Climate Change and Ethiopia Agriculture

Ethiopia is highly vulnerable to climate variability and change. This is because of very high dependence on rain fed agriculture, which is very sensitive to climate variability and change, under-development of water resources, low health service coverage, high population growth rate, low economic development level, low adaptive capacity, inadequate road infrastructure in drought prone areas, weak institutions and lack of awareness (NMSA, 2007). Vulnerability assessment based on existing information and rapid assessments carried out under National Adaptation program of Action of Ethiopia has indicated that the most vulnerable sectors to climate variability and change are agriculture, water resources and human health. Agriculture is the most important sector in the Ethiopian economy (Temesgen,

2007). However, productivity and competitiveness of this sector is increasingly constrained by temporal and spatial variability of climate (NCCF, 2009). In addition, most of the country is becoming more prone to drought (NMSA, 1996). Droughts destroy farmlands and pastures; contribute to land degradation, causes crops to fail and livestock to perish. During the 1984–1985 drought, the GDP declined by about 10 percent and the 2002-2003 drought cause over 3 percent decline. Flooding in turn causes significant damage to livestock and animal health, and the water-logging of productive land undermines agriculture by delaying planting, reducing yields, and compromising the quality of crops, especially if the rains occur around harvest time (World Bank, 2006).

The NMSA (2007) summarizes the impact of Climate change on agriculture in Ethiopia as follows:

Table 1: Impacts of climate change on agriculture in Ethiopia

Sector	Potential impact
Agriculture	• Shortening of maturity period and decrease in crop yield • Change in livestock feed availability • Effects of climate change on animal health, growth and reproduction • Impacts on forage crops quality and quantity • Change in distribution of diseases • Changes in decomposition rate • Change in income and prices • Contracting pastoral zones in many parts of the country

Source: NMSA, 2007

2.10. Adaptations to Climate Variability/Changes

Adaptation to climate change impacts in general and to the agriculture sector in particular is an existing phenomenon. The agriculture sector has the capacity to adapt provided that technologies, resources, and management changes have been undertaken relatively quickly (Mendelsohn et al., 2000).

Throughout human history, societies have adapted to natural climate variability by altering settlement and agricultural patterns and other facets of their economies and lifestyles. In the past human history, adaptations to climate have been remarkably successful. Coping with climate has not always been easy or successful as the records of collapsed societies reveal and there are still limits to adaptations. This long record of adapting to impacts of weather and climate is through changes in behavior, choices of technology and infrastructure, use of market instruments and public policies. Crop diversification, weather and seasonal climate forecasting, drought and hurricane early warning systems, flood protection, weather derivatives, and establishment of coastal-setbacks are only a few examples of proactive adaptation measures (McCarthy et al., 2001).

Decisions on the type of adaptation are often made by individuals, groups within society, and organizations and governments on behalf of society. Some adaptation measures may be taken at individual level. Others like rainwater harvesting and investments, building dams, releasing new cultivars that are more drought resistance require collective actions. These time societies have inherent capacities to adapt to climate change and have developed different adaptation and mitigation strategies to combat climate change. They have developed knowledge, skills, technology, institutional arrangements and strategies that are important foundations for adapting to long-term climate change (Marye, 2011). Communities have always adapted to climate variations by making preparations based on their resources and knowledge accumulated through experience of past weather pattern. The adaptive measures that households use when faced with climate change could also differ in terms of their ease of implementation, equity effects, lag between implementation and effect, their cost of

implications, compatibility with other programs, and agencies implementing measures (Admassie, 2008).

The capacity to adapt to climate change also varies across countries, social groups and regions over time. These capacities will depend to a large extent on the availability of natural resources, their level of development, their resource base, technological knowhow and level of information about climate change, and their scientific & technical capacity (Meseret, 2009). Greater economic resource availability increases adaptive capacity while the lack of it limits adaptation options. Technological options limit range of potential adaptation choices. Hence, adaptation measures are very much related to socio-economic conditions of the country and community given basic forms of adaptations including micro-level adaptations such as diversification and intensification of crop and livestock production, changing land use, irrigation and altering the timing of operations, market responses, institutional changes and technological developments (Kabubo et al., 2006; Darwin et al., 1995).

2.11. The Need for Addressing Climate Change in Ethiopia

Ethiopia is one of the least developed countries with most of its economic bases dependent on climate sensitive sectors. Looking only at the agricultural sector, it has been subjected to variable and unpredictable climatic conditions, such as erratic and intense rain with distorted seasonality, increased temperature resulting in longer drought seasons, recurrent drought, failing harvest seasons, new crop pests, livestock diseases, etc (Zenebe et al., 2011).

Different studies which have done by different scholars, such as Temesgen et.al. 2008, Temesgen, 2010, Hamza, 2012, confirmed that Ethiopia is highly vulnerable to climate change with the least adaptive capacity. Another study by Alebachew et al., 2011, also stated that climate change is and will be a major challenge against the country's efforts towards achieving food security and environmental sustainability. Moreover, the World Bank's study of the Economics of Adaptation to Climate Change in 2008 indicates that climate change has the potential to reduce Ethiopia's GDP growth by 2-6% by 2015, with losses in the worst-case scenario rising to 10% by 2045.

Thus, as climate change is affecting the socio-economy and environmental resource of Ethiopia, addressing the issues is crucial for the betterment of the country.

2.12. Conceptual Framework

In this study, vulnerability to climate change is conceptualized as a function of three factors: exposure, sensitivity, and adaptive capacity. Exposure can be interpreted as the direct danger or stress together with the nature and extent of changes in climate variables (temperature, precipitation, and extreme weather events). Sensitivity describes the human–environmental conditions that aggravate the hazard, or trigger an impact. Exposure and sensitivity are intrinsically linked and mutually influence potential impacts. Adaptive capacity represents the potential to implement adaptation measures in efforts to avert potential impacts. Exposure affects sensitivity, which means that exposure to higher frequencies and intensities of climate risk, highly affect the outcome. Exposure is also linked to adaptive capacity. A higher adaptive capacity reduces the potential damage from higher exposure. Given a fixed level of exposure, the adaptive capacity influences the level of sensitivity. In other words, a higher adaptive capacity results in lower sensitivity and vice versa. Therefore, sensitivity and adaptive capacity adds up to total vulnerability.

2.13. Calculating Vulnerability Indices

From the conceptual framework, we see that the vulnerability of a given system largely depends on its exposure and sensitivity, and the ability for effectively coping with the impacts and associated risks. Vulnerability may be mathematically defined as:

$$V = f\,(AC - (E+S))$$

Where V is vulnerability, AC is adaptive capacity, E is exposure and S is sensitivity. A higher adaptive capacity is associated with a lower vulnerability, while a higher sensitivity and exposure is associated with a higher vulnerability. Thus, given the above equation, vulnerability is defined as a function of a range of biophysical and socio-economic factors, commonly aggregated into three components that estimate the adaptive capacity, sensitivity, and exposure to climate variability and change (Pearson et.al, 2008).

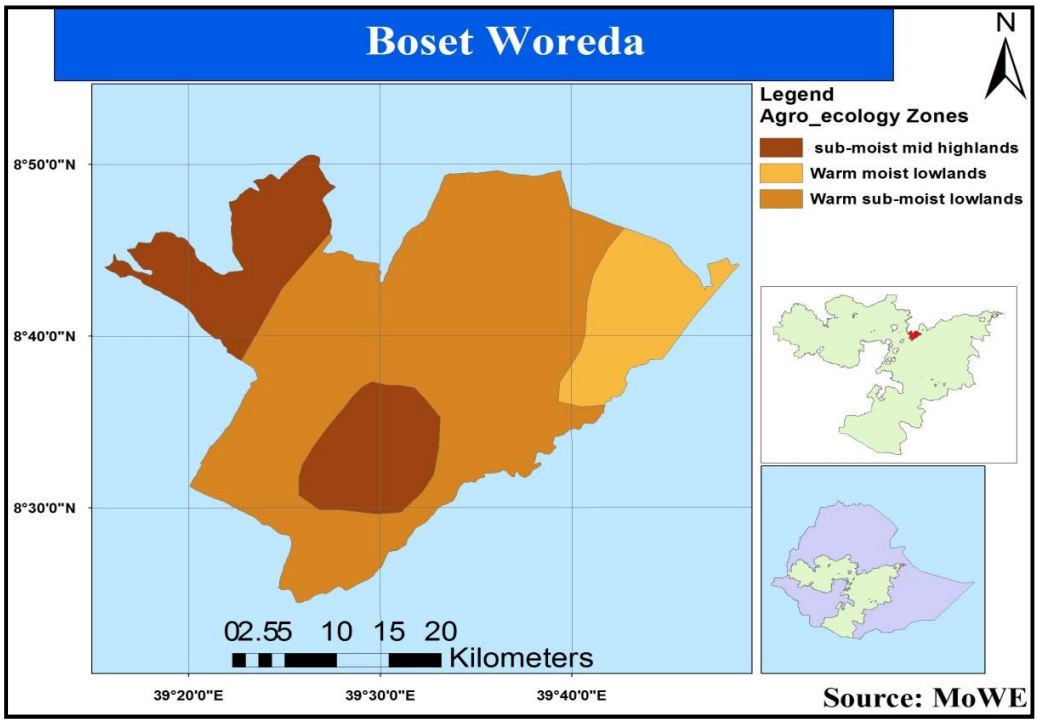
Chapter Three
Description of the Study Area and Research Methodology

3.1. Physical settings

3.1.1. Location

The study was conducted in Boset Woreda (district). The Woreda is one of the Woredas in East Shewa zone that lies between 8°24' to 8°51' North latitude and 39°16' and 39°50' East longitude which is located about 125 Kilometers south east of the capital Addis Ababa. It is bounded by Fentale Woreda in the East, Awash River in the West, Arsi Zone in the south and Amhara region in the north. The Woreda is divided into 33 rural kebele (the smallest unit of local government) Administrations and four sub-urban towns. The total land area of the Woreda is 1378.4 square kilometers.

Figure 1: Location map of Boset woreda



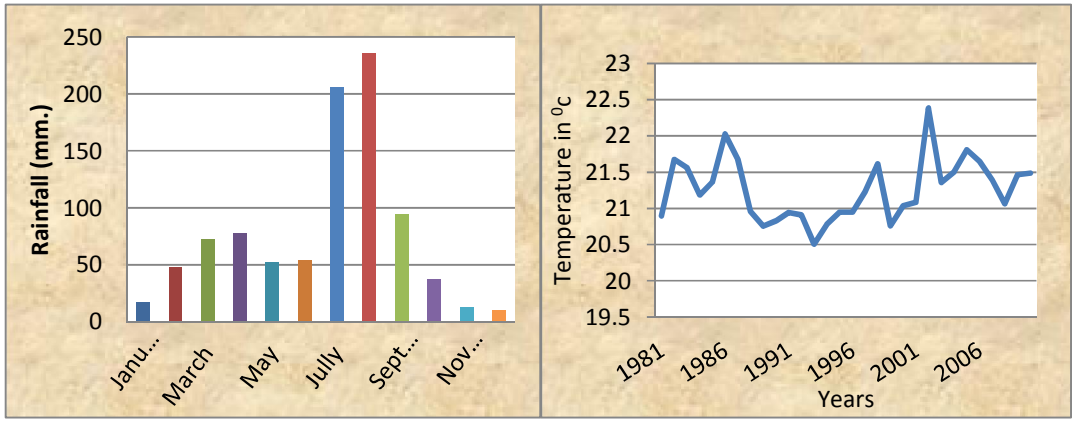
3.1.2. Topography

Boset woreda is located in the midst of the Rift valley, which extends from the North to South. According to the agricultural Bureau of the Woreda, its altitude varies from 1000-2000 meters above sea level which is mainly Kolla (low lands), characterized by warm climate. A topography that varies from flat or gently undulated areas to sloppy hill and ranges and deep incised gullies is a typical land future of Boset woreda. Boset Guddo (2247m) is the highest peak in the district. Awash is the most significant river in the district. Tebo is another river that flows in the district. According to the same source, soil mostly derived from volcanic ashes origin, varies from red ash in hilly areas to light sandy loam in the lower and flat areas.

3.1.3. Climate

The study area falls under the agro-ecological zone of arid and semi arid. It is dominated by flat land with rolling and undulating features. Nearly 90 % of the Woreda is below 1500 meters. Boset Guddo, 2247 meters above sea level, is the highest peak in the Woreda. The area experiences three seasons namely the bega (the long dry season), "belg" (the short rainy season) and kremt (the long rainy season). According to the Woreda agricultural bureau, Boset Woreda is characterized by hot and dry weather with the annual average temperature in the range of 25^0c to 37^0c and receives an average 700 to 800 mm of rainfall per annum. The area is divided in to three agro-ecology zones namely warm moist lowlands (WMLL), warm sub-moist lowlands (WSMLL) and sub-moist mid highlands (SMMiHL).

Figure 2: Total monthly rainfall and average monthly temperature (1981-2010)



3.1.4. Soils and Vegetations

The soils of the Woreda is mostly derived from volcanic ash origin, varies from red ash in hilly areas, to light sandy loam in the lower and flat areas. Major soil types are Andosols (49.4%), Lithosols (36.1%), Cambisols and Luvisols (11.4%) and Fluvisols (3.1%). There are different types of natural vegetations that range from forests to grass lands in the Woreda. However, scanty bushes on the top of some hilly areas and thinly scattered acacia trees in the farm land are the only forest ruminants in the area.

3.2. Socio-economic Characteristics

3.2.1. Population

Based on the census carried out in 2007 by CSA (Central statistical Authority), the total population of the Woreda is estimated to be 142,112 of which 52.02 % were male and 47.98 % were female. The average population density of the woreda is 111.5 persons per square kilo meters which is the second least densely population area in East Shoa Zone, next to Fentalle Woreda. The annual population growth of the woreda is 3 % with an average family size of 5.

3.2.2. Farming system and livelihood activities

The People of the area practice various livelihood and income generating activities mainly crop production and animal husbandry in addition to petty trading and daily labor. Crop production plays a major role in income generation in the area and cereals such as Maize, teff, haricot beans, wheat, barley and sorghum are the major crops grown. Crop production is mainly rain fed. According to the Agriculture and Rural Development Office of the Woreda, rain water harvesting is practiced at low level in the area. Households who practice rain water harvesting activity mainly produce onion, tomato, mango and papaya for market consumption. Next to crop production, rearing livestock is the most important means of livelihood in the Woreda amongst the majority of the farmers, and hence, there are numerous

3.2.3. Infrastructure

Boset has103 kilometers of all weather, 97 kilometers of dry weather roads, 3 manual telephone stations and an agent post office. Regarding water service, 45% of the total population of the district, 36% of the rural and 87% of the urban residents had access to potable water supply. Firewood, crop residue, dung, charcoal and kerosene were sources of domestic energy supply in their order of importance.

As far as health is concerned, there are 33 health stations in all rural kebeles of the woreda and 4 clinics. On the other hand, the woreda has 15 elementary and 3 junior secondary schools, one high school and one preparatory school. Similarly, the district has 2 animal health clinics. Other infrastructures such as 24 hours hydroelectric service, mobile and landline telephone services and one commercial bank are also found in the woreda.

There are four non-governmental organizations (NGOs) running their respective projects in the district. These are CARE International-Ethiopia, Lutheran World Federation/Ethiopian Evangelical church of Mekane Yesus (LWF/EECMY), CARE Shewa and Christian Children Fund (CCF). They deal with environmental rehabilitation and other development activities.

3.3. Data Types and Sources

For this study, both primary and secondary data were used to assess the vulnerability of agriculture to climate change in the study area. The specific study site, Boset Woreda, was selected for this study as it is one of the areas that is known for its unpredictable climatic conditions, particularly drought and erratic rainfall.

The data for the study were collected by developing vulnerability indicators (Table 3) based on the IPCC working definition of vulnerability as a function of exposure, sensitivity, and adaptive capacity. The selection of indicators has been done through an extensive review of previous reports, researches and vulnerability assessment manuals. The indicators incorporated both the socio-economic and bio-physical aspects of agriculture. Hire

In this paper, households adaptive capacity was assessed by wealth (farmland and livestock ownership), access to different infrastructure and institutions, availability of technology and income diversification. On the other hand, sensitivity of households to climate change was evaluated by level of crop diversification, dependency on rain fed agriculture, availability of water, grazing land and drug for animals, usage of chemical and organic fertilizer on their land. Regarding exposure, since all the agro-ecological zones are located in the same Woreda, exposure is almost uniform across the people residing in the area. However, there has been variation in the perception of households in the detection of change of these climate elements. Therefore, in this study exposure is measured in terms of household perception about temperature, rainfall, drought and flood pattern and occurrences compute overall socio-economic based agricultural vulnerability.

For the household survey, out of the total 33 rural kebeles administrations found in the Woreda five kebeles were selected purposely based on agro-ecological zone, that are warm sub-moist lowlands (WSMLL), warm moist lowlands (WMLL), and sub-moist mid highlands (SMMiHL). The list of individual households was obtained from the kebele administration bureau. From the five kebeles five percent of the households, proportional to the number of individual households living in each kebele, were selected. The sample households were selected using simple random sampling through lottery method.

Table 2: Sample size by agro-ecology zones

Woreda	Agro-ecology zones	Kebeles	Total households	Sample size
Boset	WSMLL & SMMiHL	Qombe Gugisa	707	35
	WSMLL & SMMiHL	Ararso Bero	1075	53
	SMMiHL	Merqo Oda Lega	579	29
	WSMLL	Dengore Tiyo	1061	85
	WMLL	Qawa Hara Mirqa	1686	54
	Total		5108	256

Source: Author's own construction, 2013

Table 3: Vulnerability indicators

Determinants of Vulnerability	Indicators	Unit of Measurement	Hypothesized Functional Relationship Between Indicators and Vulnerability
Exposure	Change in temperature Change in precipitation Change in drought occurrence Change in flood occurrence	Percentage of households who perceived a change on this elements compared to the past	Increasing temperature, flood and drought occurrence and decreasing precipitation, increasing vulnerability
Sensitivity	Crop diversification	Percentage of households who grow only one crop per agricultural land per growing season	The higher the percentage of households who use multiple cropping on their farmland, the lesser the vulnerability
	Availability of grazing lands	Percentage of households who agreed on the availability of grazing lands	The higher the percentage of households who agreed on the availability , the lesser the vulnerability
	Availability of water for livestock	Percentage of households who agreed on the availability of water	The higher the percentage of households who agreed on the availability , the lesser the vulnerability
	Dependency on rainfed agriculture	Percentage of households are totally dependent on rainfall	The higher the percentage of households who are dependent on rainfall, the higher the vulnerability
	Availability of drug for livestock	Percentage of households who agreed on the availability of drug for livestock	The higher the percentage of households who agreed on the availability , the lesser the vulnerability

	Natural resource conservation practice	Percentage of households who are engaged in this activity	The higher the percentage of households who practiced natural resource conservation , the lesser the vulnerability
	Chemical fertilizer usage	Percentage of sample HHs who used chemical fertilizer on their farmland	The higher the percentage of households who used chemical fertilizer on their farmland , the lesser the vulnerability
	Organic fertilizer usage	Percentage of sample HHs who used organic fertilizer on their farmland	The higher the percentage of households who used organic fertilizer on their farmland , the lesser the vulnerability
Adaptive capacity	Livestock ownership Farmland ownership Access to non-agricultural income Access to formal/non-formal credit Economic support from relatives/family	Percentage of households who own or have access	The higher the percentage households with asset ownership and access to these income sources the lesser the vulnerability
	Saving money	Percentage of households who saved money	The higher the percentage households save money, the lesser the vulnerability
	Household size	Percentage of households that have household size less or greater than the average of East Shewa zone i.e. 4.8 person/ household	The larger the farm size the lesser the vulnerability The higher the percentage households with lower household size (less than the average), the lesser the vulnerability

	HHS that have formal education	Percentage of households that have formal education	The higher the percentage of households with formal education, the lesser the vulnerability
	HHs who face market related problem	Percentage of households who faced market problems	The higher the percentage of households with market problems, the higher the vulnerability
	Access to different services such as health services, insecticide and pesticide supply sources	Percentage of households who have access to this services in the nearby area	The higher the percentage of households who have access these services in the nearby area, the lesser the vulnerability
	HHS who use improved seed	Percentage of households who used improved seeds on their farmlands	The higher the percentage of households who used improved seeds, the lesser the vulnerability
	HHS that engaged in irrigation activity	Percentage of households practiced irrigation activity	The higher the percentage of households who engaged in irrigation activity, the lesser the vulnerability

Source: Author's own construction

After determining the sample population, socio-economic and bio-physical data were directly collected from farmers and other stakeholders. Moreover, in order to get detail information, focused group discussions and key informant interviews were carried out. The Key informants were Peasant Association (PA) administrators, development agents and community based organizations office holders whereas the focused group discussions were conducted with elders, women, youth groups and sector office experts.

Secondary data were gathered from different sources including books, journals, and unpublished materials available at the woreda administrative and agricultural bureau. Data on the selected indicators for the study were also gathered from various organizations like the Agriculture Bureau of the Woreda and East Shewa Zone, CSA, Ministry of Water and Energy of Ethiopia and The National Meteorology Agency (NMA).

To detect the Land Use/Land Cover (LULC) of the area, as it is one of the bio-physical factors that contributes for the vulnerability of agriculture, 30 years consecutive satellite imageries with fifteen years interval (1981 TM, 1996 TM and 2011 ETM with spectral resolution of 28, 28 and 15 meters respectively) were used. The satellite imageries were obtained from SERVIR Global. Besides, to collect ground truth points GPS instrument was used.

To understand the climate trend of the Woreda, thirty years station climate data were obtained from the NMA. The climatic elements were monthly maximum, minimum and mean temperature and monthly and daily records of precipitation. In addition to the station data, grid data with 0.1 decimal degree interval (100 grid points) of thirty years (1981-2000) were collected from NMA.

3.4. Data Analysis

As explained on the above sections, for this study vulnerability of agriculture to climate variability/change is a function of three components which are adaptive capacity, sensitivity and exposure. In order to make the data more suitable for analysis, first the values of the indicators were standardized as they are in different units of measurement. As Vincent (2004) explained, having considered the theoretical determinants of provincial farming sector vulnerability and selected appropriate indicators for its capture,

there must be some form of standardization to ensure that all the indicators are comparable. For this study the method used by the United Nations Development Program (UNDP)'s Human Development Index (UNDP, 2002) was used. According to UNDP, life expectancy index is calculated in HDI as a ratio of the difference of the actual life expectancy and a per selected minimum and the range of per determined maximum and minimum life expectancy. In the study, by taking this approach, standardization of selected variables is made using the equation given below.

$$\text{Yags} = \frac{Y_{ac} - y_{min}}{Y_{max} - Y_{min}} \ldots\ldots\ldots\ldots \text{ Equation 1}$$

Where:

Y_{ags} is standardized value of the agro-ecology

Y_{ac} is the actual observation of the sample households in the agro-ecology

Y_{min} is the minimum value of the observation

Y_{max} is the maximum value of the observation

In this study, since all variables are measured in percentage, the minimum and maximum values are 0 and 100 respectively. As an example for a variable of 'farmland owner ship,' if all the respondents own farmland, the value is 100 and it is 0 if no household owns farmland for the specific respondent.

After computing the normalized score, as all vulnerability components have no equal contribution for the vulnerability of the agriculture to climate variability/change, the indicators were ranked by giving unequal weight. In order to avoid subjectivity on giving ranks for the indicators, Principal Component Analysis (PCA) method was used.

Suppose there is a set of N variables (a*1j to a*zj) that represent the N variables (attributes) of each households. PCA starts by specifying each variable normalized by its mean and standard deviation. For instance, a1j= (a*1j-a*i)/s*1, where a*1 is the mean of a*1jacross region and s*1 is its standard deviation. The selected variables are expressed as linear combination of a set of underlying components for each household, j.

$$a_{1j} = V_1 A_{1j} + V_{12} A_{2j} \ldots\ldots + V_{1N} A_{Nj,}\ \text{j} = 1 \ldots . \text{j} \ldots\ldots\ldots\ldots \text{ Equation 2}$$

$$a_{N1j} = V_{N1}A_{1j} + V_{N2}A_{2j} + \cdots + V_{NN}A_{Nj} \ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation 3}$$

Where the A's are the components and the V's are the coefficients on each component for each variable. Since only the left hand side of each line is observed, the solution to the problem is indeterminate. Principal component analysis (PCA) overcomes this indeterminacy by finding the linear combination of the variables with maximum variance, usually the first principal component A1j and then finding a second linear combination of variable orthogonal to the first, with maximum remaining variance and so on. Technically the procedure solves the equations $(R-\lambda I)\ v_n=0$ for λ_n and v_n where R is the matrix of correlations between the nth component for each variable. Solving the equation yields the characteristic roots of R, λ_n (also known as the Eigen values) and their associated eigenvectors, v_n. The final set of estimates is produced by scaling the v_{ns} so that the sum of their square sums to the total variance, another restriction imposed to achieve determinacy of the problem.

The scoring factors from the model are recovered by inverting the system implied by equation 3. This yields a set of estimates for each of K principal components.

$$A_{1j} = f_{11}a_{1j} + f_{12}a_{2j} + \cdots + f_{1N}a_{Nj} \ldots\ldots\ldots \text{j} = 1, \ldots . \text{j} \ldots \text{ Equation 4}$$

$$A_{k1j} = f_{N1}a_{1j} + f_{N2}a_{2j} + \cdots + f_{NN}a_{Nj} \ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation 5}$$

The first principal component, expressed in terms of the original (un-normalized) variables, is therefore an index for each household based on the following expression.

$$A_{1j} = \frac{f_{11}\left(a^*_{1j-}a^*_{1-}\right)}{s^*_1} + \ldots\ldots \frac{f_{12}\left(a^*_{Nj-}a^*_{N-}\right)}{s^*_N} \ldots\ldots\ldots\ldots\ldots\ldots \text{ Equation 6}$$

The critical assumption of PCA is that, undefined 'common information' is in fact determined by the underlining phenomenon that the index is trying to measure (in this case vulnerability) which unfortunately cannot be statistically verified since it depends on the correct identification of relevant variables of indicators, and is, therefore, largely a matter of judgment. One of the advantages of PCA (apart from the objectivity of the weight) is that it estimates the contribution of each variable to the underlying common

phenomenon and thus enables us to rank the indicators according to their importance in determining the household level of vulnerability.

The reason for the selection of this method was that large variation in any one of the indicators would not unduly dominate the contribution of the rest of the indicators and distort inter areal comparisons.

To get the specific contribution of each determinant (adaptive capacity, sensitivity and exposure) to the overall vulnerability, first the value for the major components using the formula specified below were determined. In the formula, the standard value of every indicator variable was multiplied by its respective weight (derived from the first PCA result). Then, add the multiple of every indicator variables together and divide the result to the sum of their weights to arrive at the final value of every determinant component.

$$\mathrm{AC_{ags}}, S_{\mathrm{ags}}, E_{\mathrm{ags}} = \frac{\sum_i^j P_i Y_{ags}}{\sum_i^j Y_{ags}} \ldots\ldots\ldots\ldots \text{ Equation 7}$$

Where:

AC_{ags}, S_{ags}, E_{ags} are adaptive capacity, sensitivity and exposure of the agro-ecology zones respectively.

Yags is standardized value of each of the agro-ecology zones

Pi is the weight of the indicators.

To get the final vulnerability index of the agro-ecology zone (V_{Iag}) value, the sum of S_{ag} and E_{ag} were subtracted from A_{Cag} value. But here instead of assigning equal weights to all the three major components, a relative weight was allocated based on the number of the total variables that constitute these components. Therefore, the final value of the agro-ecology vulnerability index can be determined using the following equation:

$$VI_{ag} = \frac{NI_{AC}\, AC_{\mathrm{ag}} - NI_S S_{ag} - NI_E E_{\mathrm{ag}}}{NI_{AC} + NI_S + NI_E} \ldots\ldots\ldots\ldots \text{ Equation 8}$$

Where:

VI_{ag} is the vulnerability index of the agro-ecology zone

AC_{ag}, S_{ag}, E_{ag} are the adaptive capacity, sensitivity and exposure of the agro-ecology respectively.

NI_{AC}, NI_S and NI_E are the number of indicator variables that constitute for adaptive capacity, sensitivity and exposure respectively.

As explained before, vulnerability is the net effect of adaptive capacity, sensitivity and exposure thus, higher net value show less vulnerability and vice versa.

To identify and delineate the different LULC units, the satellite imageries were pre-processed and these imageries were classified using supervised classification method. For the satellite imagery taken before the recent time, the interpretation and classification cannot be ground truthed. In contrast, the recent satellite image which is taken during the research period can be directly ground truthed. To establish the classification in the latter case, depending on the nature of reflectance signature in the study area, ten numbers of classes were selected for each LULC unit as a training area. Then the maximum likelihood classification method was applied for identifying land use/land cover types for the study area as a whole. The post-interpretation and classification phase involved preparation of LULC maps from 1981, 1996 and 2011 satellite imageries of the area. For land use land cover classification, ArcGIS 10 and ERDAS imagine 10 were used.

Moreover, local temperature and rainfall trends were analyzed using SPSS and Excel. The grid points were also changed to vector data using Global Mapper 12 and exported to ArcGIS 10. Then, temperature and rainfall values of grid points were changed into raster format for spatial and value change detection.

Chapter Four

Results and Discussion

4.1. Profile of the Respondent Households

The survey results revealed that of the total household heads included in the survey, 82.4% were male-headed households and 17.6% were female-headed. The average age of household heads was 46 years and the average household size of the respondents was 5.92 with ranges from 2 to 13 members per household. Regarding marital status, 61.7% of the respondents were married, 10.9% were widowed, 14.5 % were divorced and 12.9% were single/unmarried.

Out of the total 256 respondents 30.9% were illiterate, with no formal education of any kind and thus were unable to read and write. 17.2% of the respondents stated that they could read and write, while 37.1% have attended primary and 16.8 % secondary school (Table 4).

The dominant income sources in the study area were farming and livestock production. Out of the total respondents 28.5% practiced only farming where as 69.5% of them engaged in mixed farming. Only 2% of the total sample population practiced animal husbandry. Farmers in the study area diversify their income by means of petty trade (52.5%), fuel wood and charcoal selling (15%) and daily labor work (50%).

Table 4: Characteristics of the respondents

Characteristics of the respondents		Frequency	% respondents
Sex	Male	211	82.4
	Female	45	17.6
Age	18-25 Years	43	16.8
	26-30 Years	28	10.9
	31-35 Years	75	29.3
	35-40 Years	58	22.7
	> 40 Years	52	20.3
Marital Status	Married	158	61.7
	Unmarried	33	12.9
	Divorced	37	14.5
	Widowed	28	10.9
Educational Level	Illiterate	74	30.9
	Read and Write	44	17.2
	Primary education	95	37.1
	Secondary education	43	16.8
Household size	1-3	66	25
	4-6	94	35
	>7	53	20.7
Livelihood activities	Farming only	73	28.5
	Animal husbandry	5	2.0
	Mixed farming	178	69.5
	Other	0	0.0
Other income sources	Petty trade	42	52.5
	Firewood/Charcoal selling	12	15.0
	Daily labor work	40	50.0

NB: Multiple responses
Source: From Author's field survey, 2013

4.2. Trends and Patterns of Local Climate

4.2.1. Trends and patterns of rainfall

The average amount of rainfall of the area from the year 1981-2010 was 914.97 mm with a rate of variation of about 35%. The pattern of the rainfall has shown a trend of decline with a rate of 2.20 mm. (Table 5 and Figure 3).

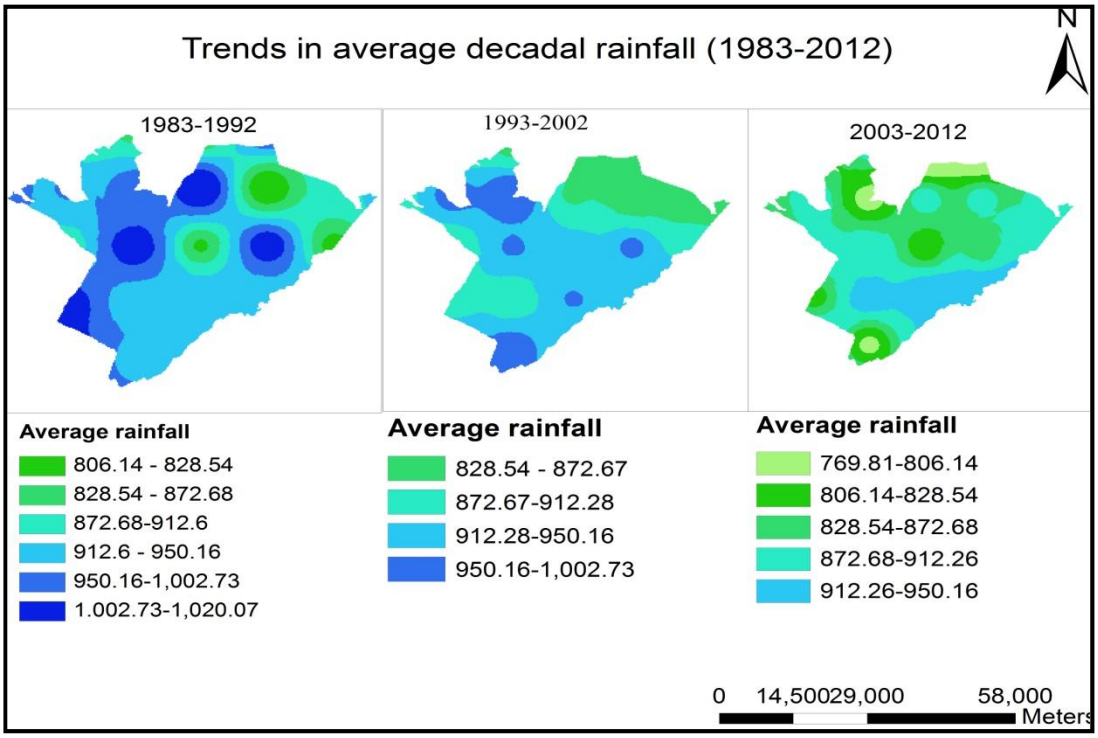
Table 5: Annual and seasonal pattern of rainfall

Seasons	1981-2010			1981-1990			1991-2000			2001-2010		
	Mean	Coef. of variation (%)	Trends	Mean	Coef. of variation (%)	Trends	Mean	Coef. of variation (%)	Trends	Mean	Coef. of variation (%)	Trends
Average annual rainfall amount	914.9	32	-2.20	960.2	46	+34.4	913.6	15	+21.3	870.9	28	-7.5
Average "belg" rainfall amount	74.9	87	-0.77	97.3	101	+20.2	56.7	65	+8.03	70.52	55	-8.3
Average "meher" rainfall amount	495.8	44	-0.39	496.8	70	-6.01	497.3	11	-7.64	493.4	35	-1

Source: Computed from raw data obtained from NMA, 2013

The mean annual rainfall amount, which was 960.27 mm in the period between 1981and1990, decreased to 913.65 mm. in the period between 1991 and 2000. In the next decade (2001-2010), the amount continued decreasing and fell to 870.98 mm. The rate of variation of the average rain fall in the years 1981and1990, 1991 and 2000 and 2001 and 2010 were 46%, 15%, and 28%, respectively. From this result it is possible to conclude that there has been strong rainfall variability in the study area.

Figure 3: Trends in average decadal rainfall

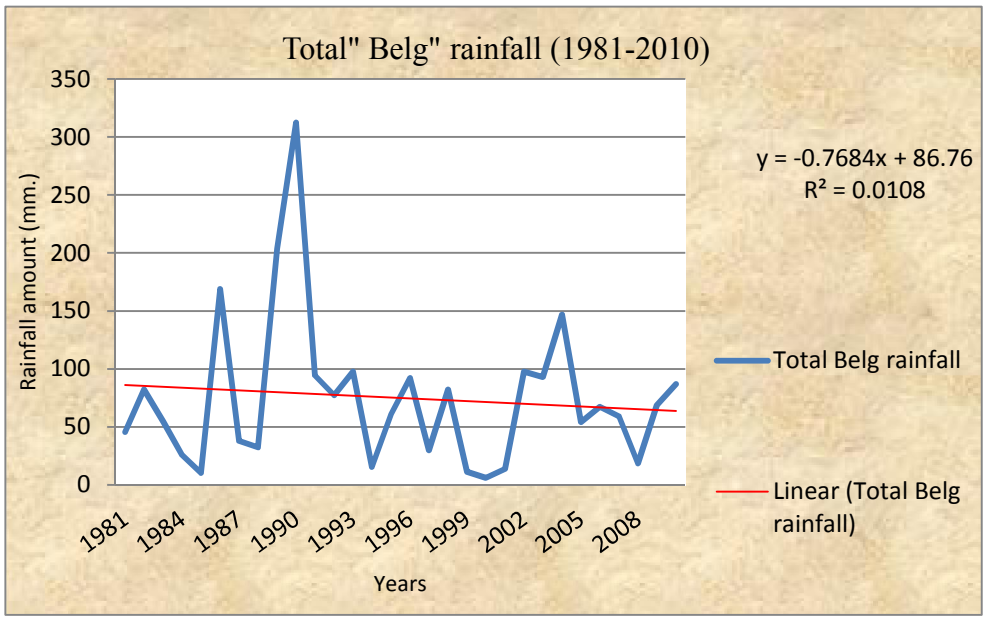


Source: Author's own construction, 2013

Moreover, 30 years rainfall monthly grid data showed that there is a decreasing trend of rainfall over the Woreda. As the figure above displays, in the first and second decade the majority of the study area received 912.26 to 950.16 mm of rainfall. However, the situation has changed in the third decade and 825.55 to 872.68 mm of rain was the rainfall amount that most of the areas received.

The "belg" rain in the study area has also shown a declining trend. In the first decade (1981-1990) the area received an average of 97.3 mm of rain which decreased by about 42 % to 56.7 mm in the years between 1991 and 2000. Though it showed a slight improvement in the amount of rain received during the period 2000-2010, which was 70.5 mm, the rainfall has decreased by about 28% compared to the first decade (Table 5 and Figure 4).

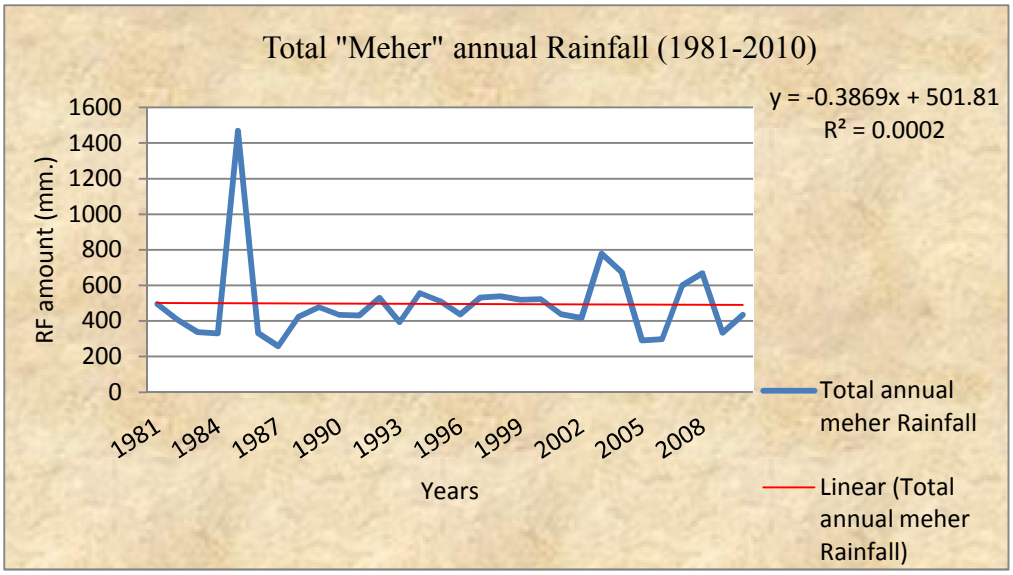
Figure 4: Variability and trend of "belg" annual rainfall



Source: Author's own construction, 2013

In the period 1981-2010, as table 5 and figure 5 present, the mean annual "meher" rainfall has shown a decreasing trend with a smaller change from one decade to the other. Though this is the case, inter annual "meher" rainfall variability especially in the first (1981-1990) and last (2001-2010) decades is high with a variation of 70% and 35%, respectively.

Figure 5: Variability and trend of "meher" annual rainfall



Source: Author's own construction, 2013

In general, the pattern of the rain in the study area has shown a trend of decline with 32% inter annual variation. The rate of variation was also higher in the two seasons but in comparison, "belg" rainfall has shown more variability than "meher" rain.

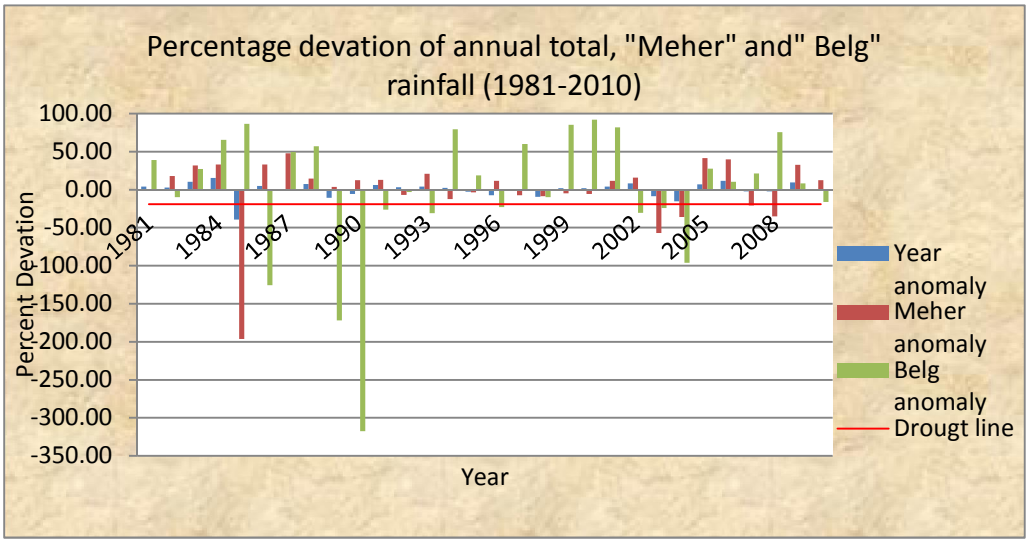
4.2.2. Meteorological drought in the study area

Meteorological drought refers to a deficiency of precipitation, as compared to average conditions, over an extended period of time. It basically originates from the deficiency of precipitation and focuses on the physical characteristics of drought (Mohammad, 2005) rather than impacts associated with shortage of precipitation. Meteorological drought leads to a depletion of soil moisture and has always an impact on crop production. The National Meteorological Agency of Ethiopia (NMA, 1996a cited in Marye, 2011), defined meteorological drought years based on seasonal rainfall anomalies. According to NMA droughts occur over a region if the negative anomaly from the mean seasonal rainfall is 19% or more. Further droughts are classified as moderate if the seasonal rainfall deficiency is between 21% and 25% whereas a seasonal rainfall deficiency of 25% or above is defined as severe drought.

Based on this criterion, it was found that the area has experienced a number of drought years. In the period between 1981 and 2010, one moderate and four severe droughts in "meher" and ten severe droughts in "belg" seasons have occurred. In the same period, one

annual severe drought has occurred. All the four severe droughts which occurred in "meher" season took place between 2003 and 2010. This clearly indicates that the occurrence of drought increased over time. Generally, as can be seen from the figure below, the frequency of drought has increased in both "meher" and "belg" season over the period mentioned above.

Figure 6: percentage deviation of annual total, "meher" and "belg" rainfall

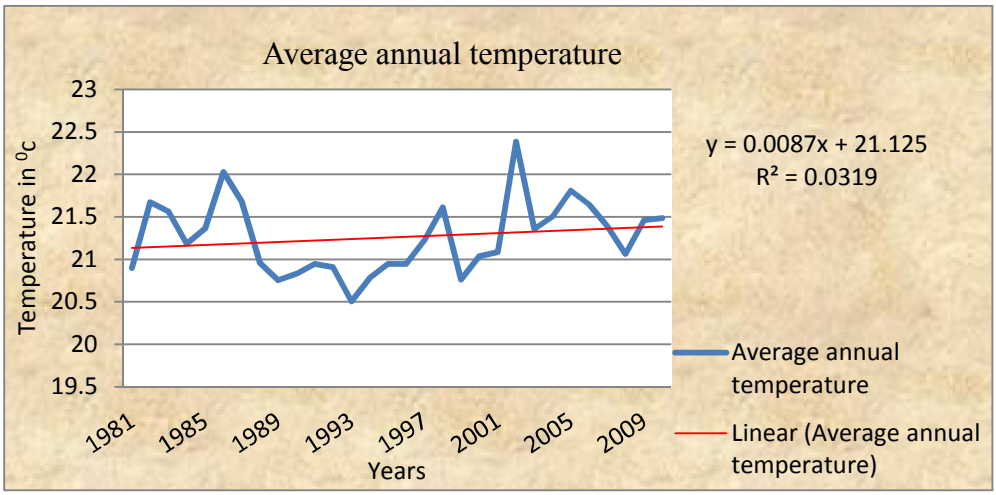


Source: Author's own construction, 2013

4.2.3. Trends of temperature variability and change

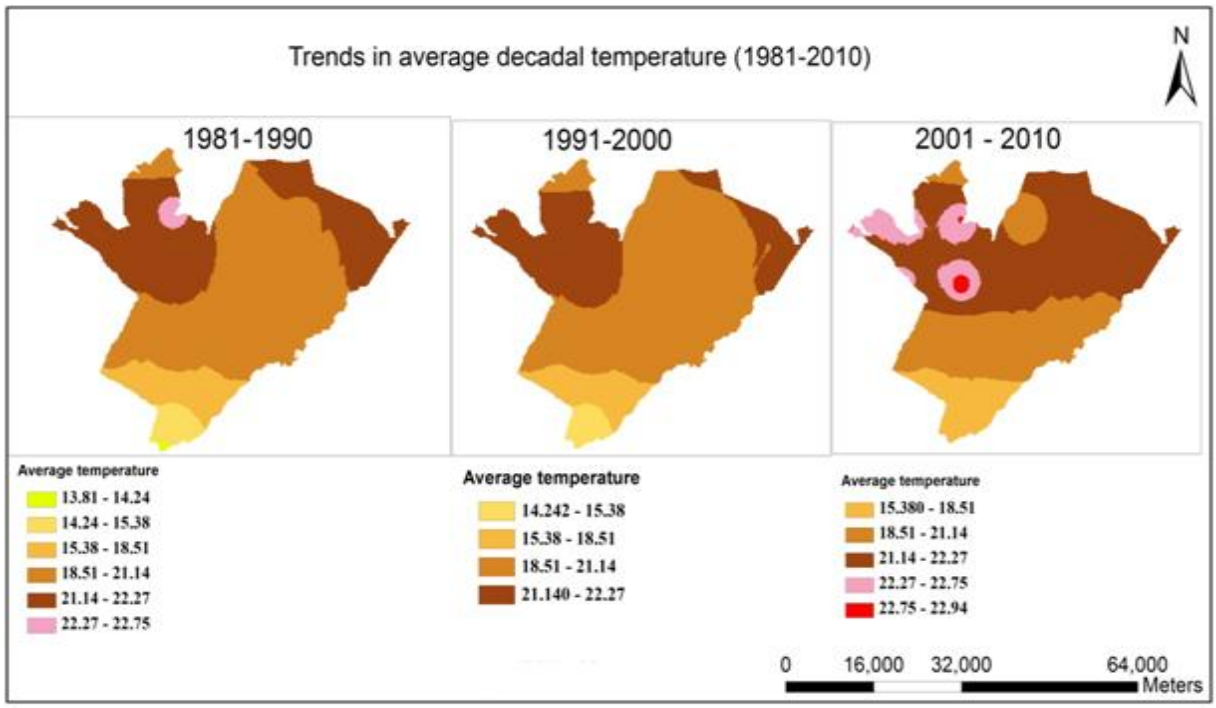
The mean annual minimum and maximum temperature of the study area for the last thirty years has been increasing with a trend of 0.009^0c (Figure 7).

Figure 7: Variability and trend of annual total Temperature



Source: Author's own construction, 2013

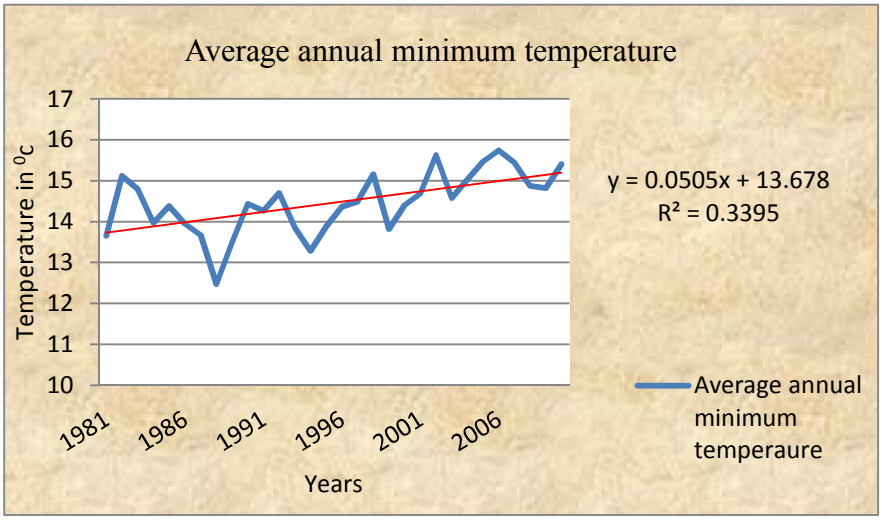
Figure 8: Trends in overall decadal average temperature



Source: Author's own construction, 2013

The temperature trend from the grid data shown in figure 8 has supported the results obtained from the station data. Mean temperature value from 1981-1990 was 21.9^{o}C while mean temperature for the years 1991-2000 was 20.96^{o}C and 21.51^{o}C for the years between 2001 and 2010 with annual variability of 2 %, 1 % and 2 % respectively.

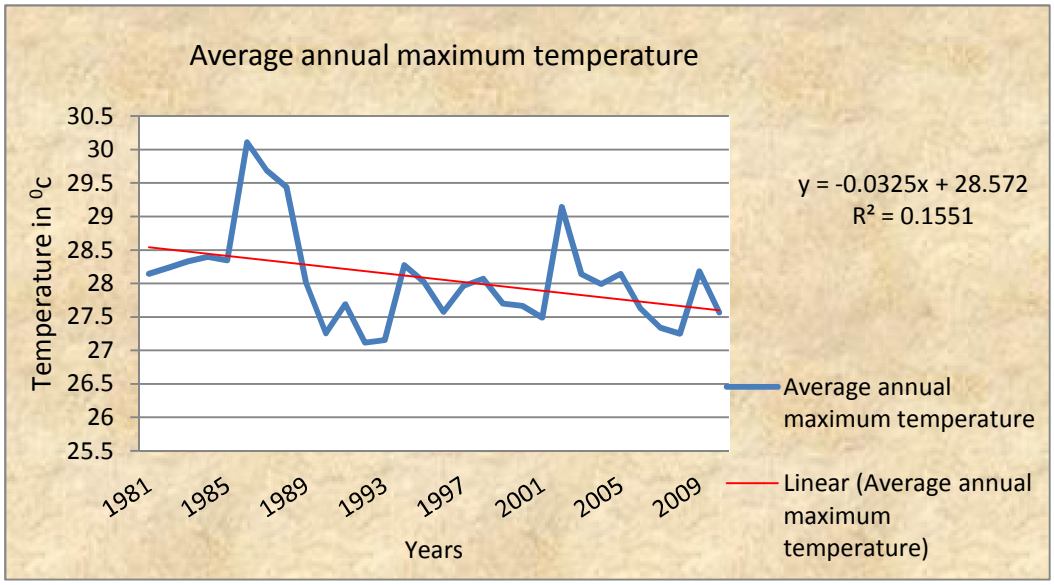
Figure 9: Average annual minimum temperature



Source: Author's own construction, 2013

The annual maximum temperature has shown a decreasing trend whereas the minimum temperature has shown an increasing trend with a rate of 0.05 ^{0}c, even higher than the average annual temperature trend (Figure 9 and 10). Furthermore the mean average minimum temperature has increased by about 7% and the mean annual maximum temperature decreased by about 2 % from the year 1981 to 2010 with inter annual variability of 5% and 2% respectively. From this it is possible to conclude that though the mean annual maximum temperature has been decreasing, there has been an overall increase of temperature in the study area.

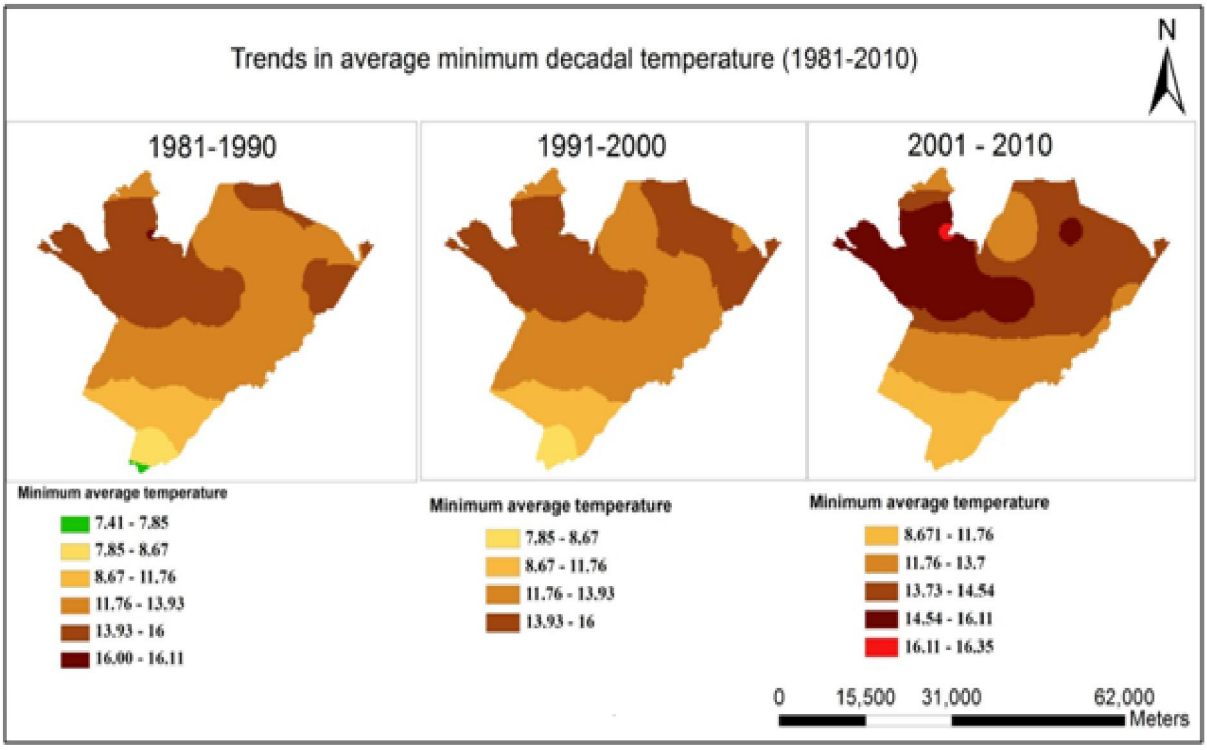
Figure 10: Variability and trend of annual Maximum Temperature



Source: Author's own construction, 2013

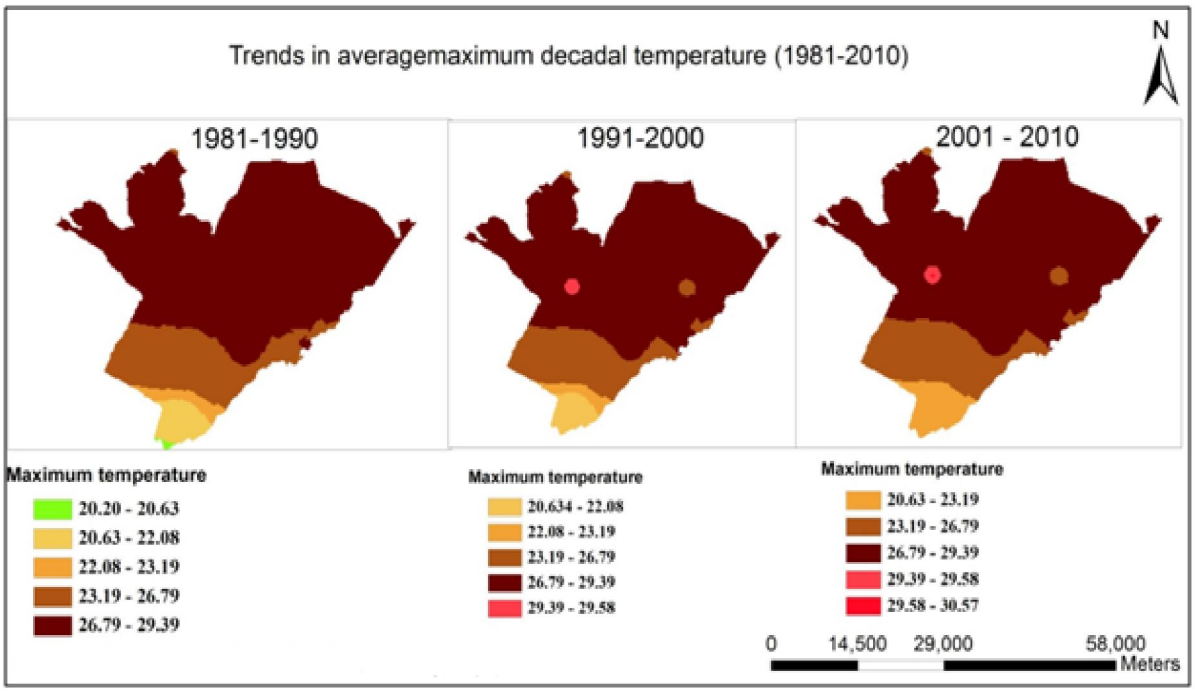
The maps (Figure 11 and 12), which were developed from the grid data, demonstrate that both minimum and maximum temperature have been increasing. However, like the result obtained from the station data the rate of increase has been higher for the minimum temperature than the maximum.

Figure 11: Trends in minimum average decadal temperature



Source: Author's own construction, 2013

Figure 12: Trends in maximum average decadal temperature



Source: Author's own construction, 2013

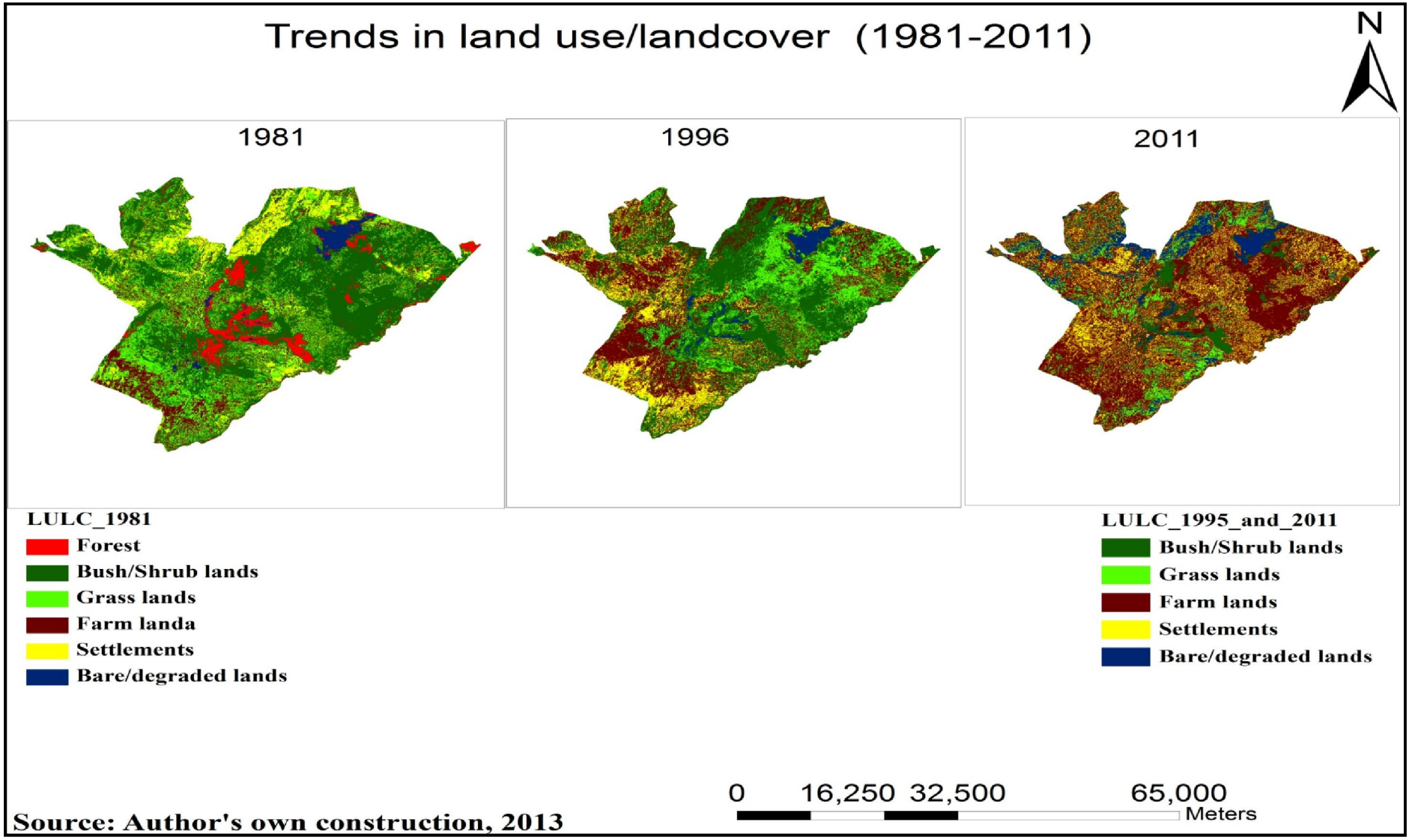
4.3. Trends of Land Use/ Land Cover Change (1981-2011)

Three Land Sat satellite imageries Namely 1981 TM, 1996 TM and 2011 ETM with spectral resolution of 28, 28 and 15 meters, respectively have been analyzed to observe the trend of the land use/land cover of the area. Six major land use classes for the years 1981 and five major land use classes for the years 1996 and 2011 were identified. These are forest, bush/shrub lands, grass lands, farmlands, settlements and bare/degraded lands. Forest land uses were totally cleared with in fifteen years in the study area. Compared to 1981 as shown in figure 13, bush/shrub lands and grass lands were decreased dramatically in 1996. In contrast to this, farmlands and settlements were increased. In 2011 compared to 1996, bush/shrub lands were decreased in similar pattern whereas farmlands and settlements were increased. Further, the coverage of bare/degraded lands was also increased of the expense of the other land covers. In 2011 the rate of increment was higher for farmlands than any other land use. Moreover the forest lands which were found in the area in 1981 were totally changed in to another type of land cover in the years 1996 and 2011.

The condition is worse for bush/shrub lands and grass lands ecosystem than any other land covers. The analyzed Land Sat satellite image in 2011 showed that only small coverage of bushes/shrubs and grass lands were found in the study area as indicated in figure 13.

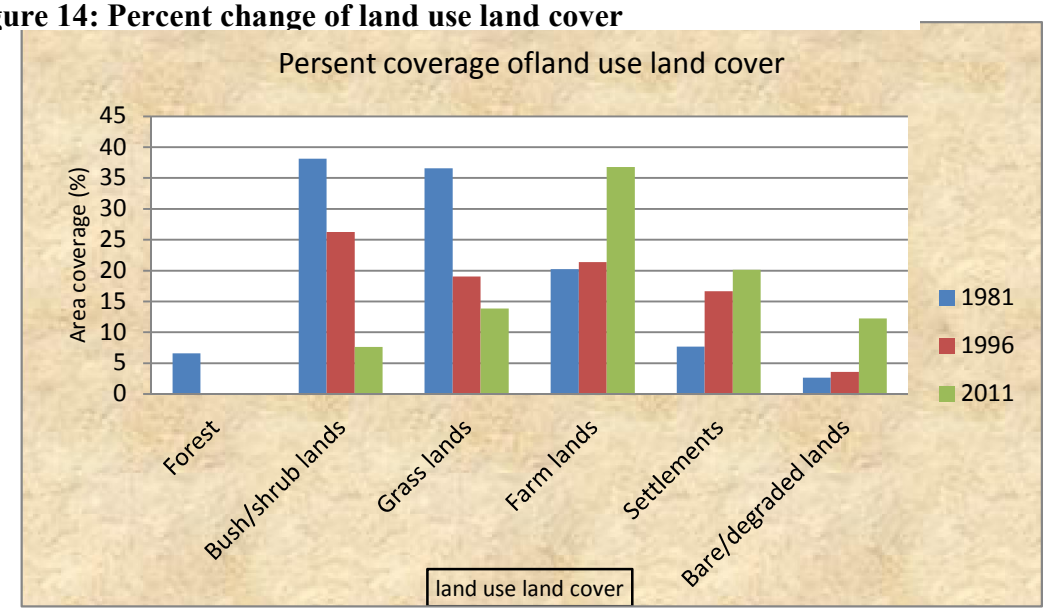
The dominant land use categories in 1981 were bush lands which occupied about 38% of the study area followed by grass lands with 37% area coverage. Farm lands and settlements covered 20% and 8 % of the area respectively while bare lands occupied only 3% and 7 % of the area was covered by forests.

Figure 13: Land use land/cover trend of Boset woreda



The trend of the land use/land cover continued in the same manner in 1996. However, farm land, settlement and bare/degraded lands shown an increasing trend while bush /shrub lands and grass lands showed a significant reduction. Forests were totally cleared form the area.

Figure 14: Percent change of land use land cover



Source: Author's own construction, 2013

In 2011, the two categories continued to dominate the area (farmlands with 37 % and settlements with 20 %). Bare/degraded lands also increased from 4 % in 1996 to 12 % in 2011.

In all these years, these lands, which are very crucial for the sustainability of agriculture, have been replaced by farm lands, settlements and bare/degraded land. As a result, the area is becoming prone to frequent drought and flood. Furthermore, due to the pronounced reduction of grazing lands; pastures become the main problems of farmers. In many areas, the shrinking of pastures has led to overgrazing, which has devastating consequences on livestock. Moreover, due to the destruction of the forest and bush/shrub lands, soil degradation and gully formation is becoming a common phenomenon in the study area. Farmers in this area have explained that, in the past years most of the lands were covered by either bush or grasses but now all are gone and the land is bare. As a result, many gullies have been developed in the area and their farm lands are shrinking. Moreover, different studies such as Vincent et al. (2012) and Mekonen et al. (2013), showed that, the change in land use/land cover have a negative impact on agriculture resulting land degradation, soil erosion and drought. Another

study conducted by Gizachew (2010) also confirmed that the changing of the land cover especially from forest or bush lands to other types of lands resulted flooding.

4.4. Farmers' Perceptions on Local Climate Variability/Change and Perceived Impacts

4.4.1. Farmers' perceptions on local climate variability/change

All participants of FGDs, key informant and expert interviewees recognized that there have been changes in the amount, timing and distribution of rainfall in the study area over the past 30 years. Table 6 presents perceptions of farmers' to climate variability/change. Farmers of the area were aware of the fact that the local climate has been changing as compared to the situation in the past thirty years. 95.7% and 93.1% of the respondents claim that there has been an overall increase in temperature and decrease in rainfall, respectively over the past three decades. They also perceived that rainfall has become more variable and erratic as compared to the situation in the past. They reported that in some years the rain starts late and stops early (41.6%) or ends late (58.5%) as compared to past experiences.

Table 6: Perceived changes in climatic elements and related hazards

Perceived changes	Name of Kebeles					Total (%)
	Qombe Gugisa	Ararso Bero	Merqo Oda Lega	Dengore Tiyo	Qawa Hara Mirqasa	
	Respondents (%)	Respondents (%)	Respondents (%)	Respondents (%)	Respondents (%)	
Increasing in temperature	100.0	88.7	93.1	98.8	98.1	95.7
Decreasing in temperature	0.0	11.3	6.9	0.0	0.0	3.6
Increasing in rainfall	2.9	15.1	10.3	1.2	1.9	6.3
Decreasing in rainfall	97.1	84.9	89.7	97.6	96.3	93.1
The rain comes late and ends early	51.5	28.3	34.5	47.6	46.3	41.6
The rain comes late and ends late	57.1	66.0	62.1	50.0	57.4	58.5
The rain concentrates in some days with high intensity	80.0	100.0	93.1	76.2	85.2	86.9
Decreasing in "belg" rain	74.3	85.2	77.4	82.8	77.4	79.4
Increasing in flood and drought occurrence	74.3	83.0	79.3	73.8	83.3	78.7

NB: Multiple responses

Source: From Author's field survey, 2013

During the focus group discussion, the farmers pointed out that when the rain comes late and ends early, the crops cannot get enough rain and time to give the intended product and

sometimes it leads to total failure of crops. On the other hand when the rain ends late, it extends the harvesting time and resulting in spoilage of products. Farmers also perceived that there have been declining/failure of "belg" rain in the last decades. 94.8 % of the respondents reported that the amount of "belg" rainfall decreased and sometimes almost failed over the past thirty years. Their observations were confirmed by agricultural experts in the area and recorded data (Table 5). Increasing incidence of flood and drought were also the major challenge of the farmers in the study area. 78.7 % of the respondents claimed that there is a large difference in the occurrence of these events compared with the past years. The perception of the increase in drought occurrence was asserted by the meteorological drought computed from meteorological data (Figure 6).

The key informants also pointed out that the pattern of climate in the Woreda has changed. For instance, one farmer key informant explained:

> *I lived here in Boset Woreda for about 48 years. I can tell you that climate of the area was different from that of today. For example, before ten or fifteen years, at least we received enough amount of rain to harvest during the "meher" season and there was "belg" rain which was helpful to prepare our agricultural land for the next harvesting time. However, these days there is no enough rain and if it comes, it is very intense and stayed for short period which resulted in flood. For the "belg" rain, most of the time it does not come or is not enough to wet the farm land. As a result, there is an increase in weeds during the harvesting season.*

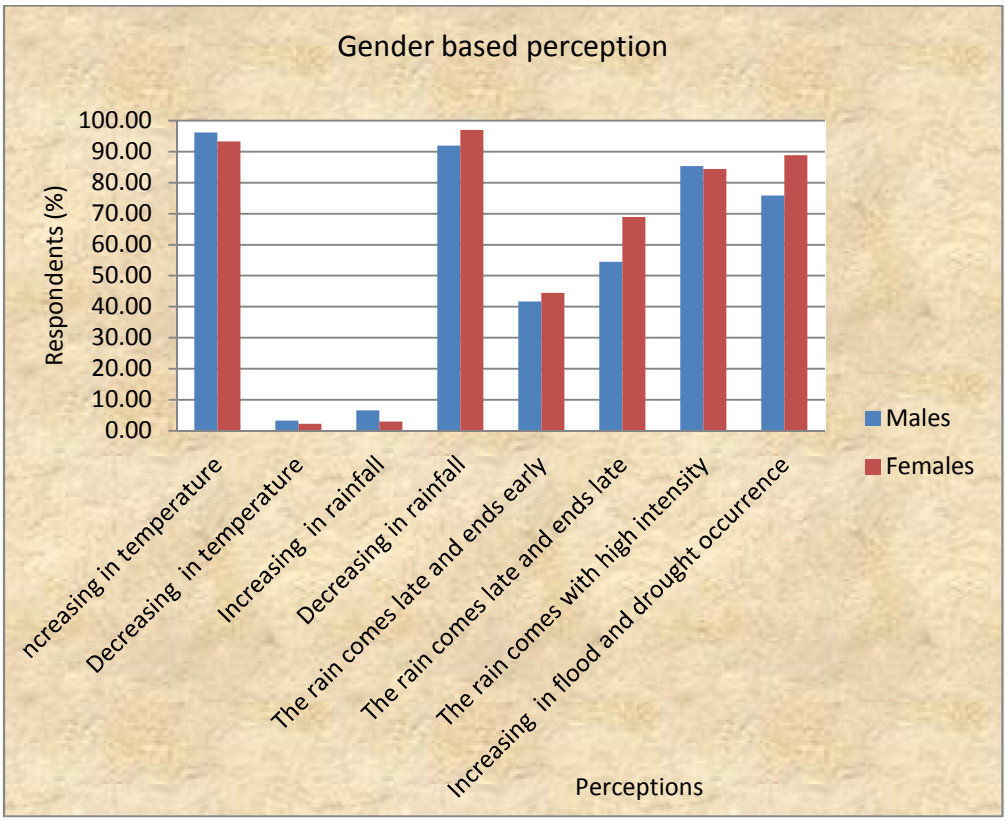
Similar findings were reported by previous studies (Dejene, 2011, Yohannes et al., 2009, Woldeamlak et al. 2011). Dejene (2011) in his study conducted in Central Tigray, Ethiopia found that 90% of the respondents observed changes in rainfall patterns in the past 20 years in the area, and 70% have noticed a decrease in the amount of rainfall. About 20% of the informants noticed a change not in the total amount of rainfall but in the timing of the rains, with rains coming either earlier or later than expected. The finding of Yohannes et al. (2009), also reveals that most of the pastoralist communities in the three different locations (Somali region, Afar region and Southern Omo Zone) surveyed for his study, feel that the dry season has become longer and that the short and main wet seasons fail more often. Besides, the start of the rains has also become more unpredictable, as they may come early or late. The rains may stop very early and be more erosive because there is less vegetation cover. Similarly, in their study conducted in Abaya and Baro-Akobo River Basin, Ethiopia, Woldeamlak et al.

(2011) found that an increase in temperature and declining rainfall amount were reported to be the predominant perceptions among their surveyed households.

4.4.1.1. Gender based differences in perception

Regarding the perception of climate change between men and women households, there is no difference on their perception of the change. The result showed that both women and men perceived that there is an increase in temperature and a decrease in rainfall amount in the study area. Besides; they have equally sensed the frequent occurrence of drought and flood with very little differences.

Figure 15: Gender based climate change perception



NB: Multiple responses

Source: From Author's field survey, 2013

4.4.2. Perceived Impacts of Climate Variability/Change in the Area

Almost all of the respondents in the study area recognized that climate variability/change has been affecting the area in different ways. In terms of ranking, most of the respondents (97.9%) observed that reduction of production has been the foremost effect of climate

variability/change in their Woreda. The second and third impacts mentioned by the respondents were increase in incidence of plant diseases (88.8%) and insects (87.8%). Other effects of climate variability/change, such as increase in incidence of animal diseases (62%), weeds (76.7%) and flood and drought (58.6%) were also impacts which were spotted by the respondents.

With regard to the impact of climate variability on livestock, 82% of the respondents reported that livestock numbers have decreased in the area. 52% of the respondents indicated that the main reason for the decrease in the numbers of livestock per households had been shortage of animal feed and water, while 30% claimed that the reason was due to the death of livestock due to animal diseases. The land use/land cover trends of the area (Figure 13) are also supported the idea of the farmers related to shortage of forage for animals as the coverage of bush and grasslands were replaced by farmlands and settlements. During the FGDs, the members explained that the decreasing number of livestock especially oxen make the farming activity difficult as they are dependent on them for the preparation of farm lands.

Table 7: Perceived impacts of climate variability/change

Perceived impacts	Name of Kebeles					Total (%)
	Qombe Gugisa	Qawa Hara Mirqasa	Merqo Oda Lega	Dengore Tiyo	Ararso Bero	
	Respondents (%)	Respondents (%)	Respondents (%)	Respondents (%)	Respondents (%)	
Reduction in crop production	100.0	90.7	100.0	98.6	100.0	97.9
Increased incidence of insects	94.3	79.6	94.3	79.3	91.7	87.8
Increased incidence of plant diseases	91.4	88.9	91.4	82.8	89.3	88.8
Increased incidence of animal diseases	74.3	74.1	74.3	55.2	32.1	62
Increased incidence of weeds	82.9	68.5	82.9	65.5	84.5	76.7
Increase in incidence of flood and drought	48.6	68.5	48.6	72.4	54.8	58.6

NB: Multiple responses
Source: From Author's field survey, 2013

The FGDs and key informants also revealed that all the above mentioned impacts were common to the area and their occurrence has been increasing from time to time. Though the Woreda has only one growing season, "meher", the presence of "belg" rain is very crucial and its shortage or absence has adversely affected land preparation for "meher" crop productions and increased the incidence of weeds. Besides, the fluctuation and irregularity of

the rain increased the frequency of pests and disease occurrences. One of the members of the FGDs said that:

> *The unpredictability of the rain affects all of us as our life is totally dependent on the availability of enough rain water for our crops and livestock. These days being a farmer is very difficult and disappointing. You cannot get what you are expecting at the end of the harvesting time either due to the shortage of rain or crop diseases and pests. Besides you have to suffer with your livestock whenever there is shortage of water and pasture/ forage for them.*

Flood occurrence has also become one of the hazards in the study area as a result of deforestation and the erratic nature of the rain. Floods were most common among those who lived at the foot of sloppy areas and on hillside of rugged terrain.

Agricultural experts support the idea raised by all groups. They explained that livestock diseases and crop pests and insects were not new for the study area. However, climate variability/change results an increased frequency of occurrence of pests and diseases in recent years. This argument is supported by different research findings as small increase in temperature and change in precipitation can result in measurable impacts on crop production, pests and diseases (IPCC, 2007; Ana, 2006, Mendelsohn et al. 2000).

4.5. Agricultural Vulnerability to Climate Variability/Change

For this analysis, PCA was run on the indicators listed in table 3. The PCA of the data set on vulnerability indicators revealed ten components with Eigen values greater than one. These ten components explain 69% of the total variation in the data set (Appendix I). Based on earlier arguments for the use of PCA in constructing indices, the first principal component, which explained the majority of the variation in the data set, was taken. As can be observed from the factor scores in appendix II, the first PCA was positively associated with the majority of the indicators identified under adaptive capacity and negatively associated with almost all the indicators categorized under exposure and sensitivity.

Thus, for the construction of the vulnerability indices, indicators of adaptive capacity, which are positively associated and the indicators of sensitivity and exposure which are negatively associated with the PCA, were selected. The relationship between the indices and

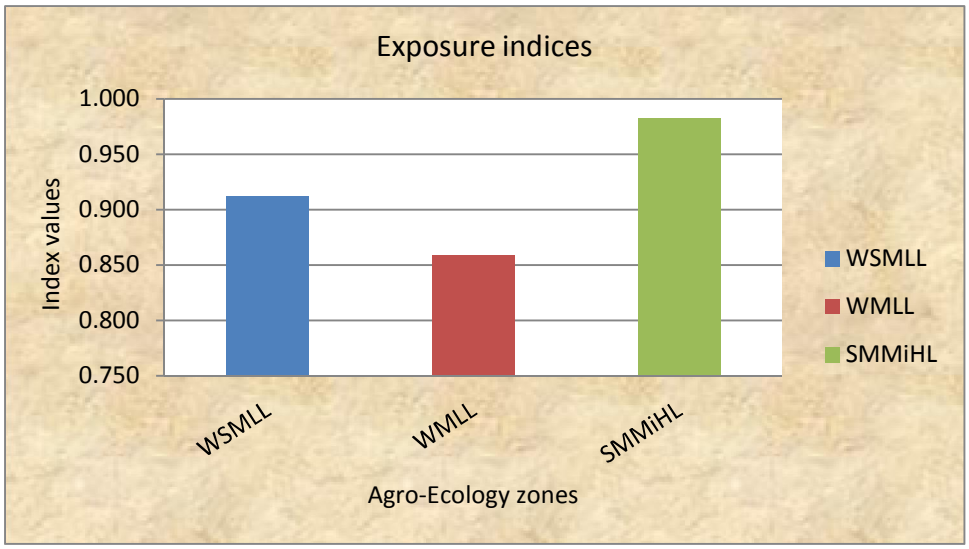
vulnerability is that the higher the value of the vulnerability index, the lesser the vulnerability and vice versa.

4.5.1. The Three Dimensions of Vulnerability

4.5.1.1. The Exposure Index

The three agro-ecology zones of the Woreda were almost similarly exposed to increasing in temperature and decreasing in rainfall amount (Figure 16). However, their exposure to flood and drought occurrence were different. The SMMiHL agro-ecology zone was highly exposed to climate variability as most affected by flood and the WMLL was less exposed to this event. Though the WSMLL agro-ecology zone was not as such affected by flood, the frequent occurrence of drought compared to the other zones made it the second exposed to climate variability/change.

Figure 16: The exposure indices across the agro-ecology zones



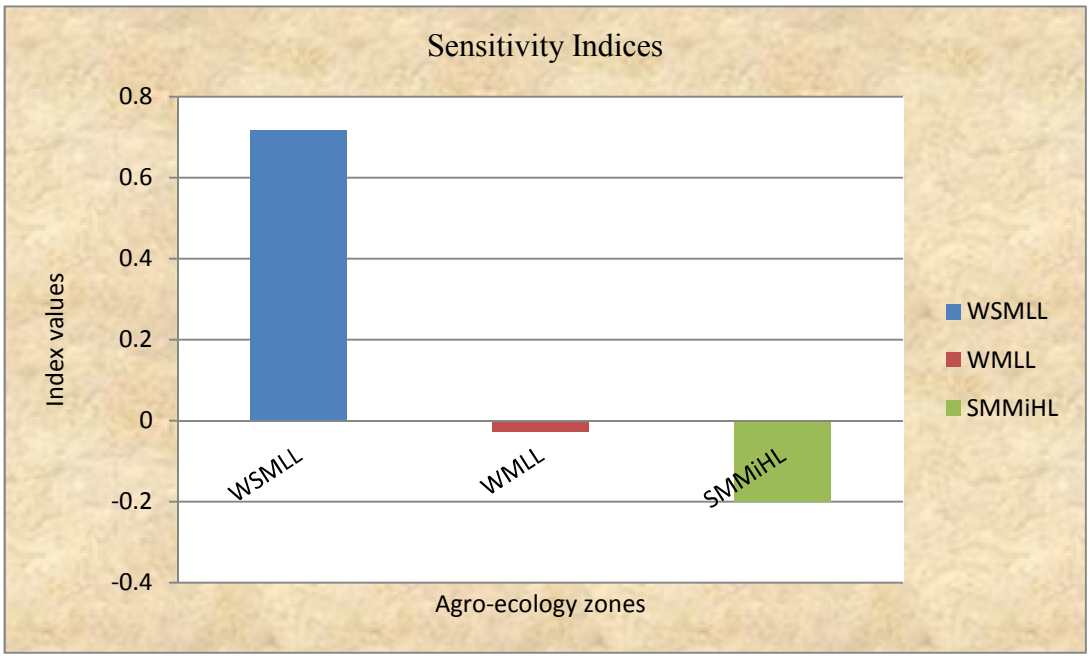
Source: From Author's field survey, 2013

4.5.1.2. The Sensitivity Index

The overall sensitivity of the agriculture sector across the three agro-ecology zones has been presented in figure 17. The most sensitive agro-ecology zone in the Woreda was WSMLL, mainly due to less availability of water for the animals and limited usage of improved seeds and both chemical and organic fertilizers. According to the study conducted by Serigne et al (2006), agricultural production can be boosted in a significant way through the use of high

yielding varieties together with organic and inorganic sources of fertilization; they further stated that the usage of organic fertilizer increases the water holding capacity of the soil in addition to helping the crops to give more products. Thus, failure to do so makes agriculture more vulnerable to drought and other climate related events. Besides, most of the farmers in this agro-ecology zone grow only one crop type per growing season and was highly dependent on rain fed agriculture with very limited irrigation activities. Gina et al. (2008) stated, if we compare two agricultural regions that grow the same crops and have similar climates, their exposure to climate variability might be similar, but their sensitivity could be very different; i.e. areas with irrigation practice would have low sensitivity to short-term precipitation variability, whereas a rain fed system would have greater sensitivity to the same exposure.

Figure 17: The sensitivity indices across the agro-ecology zones

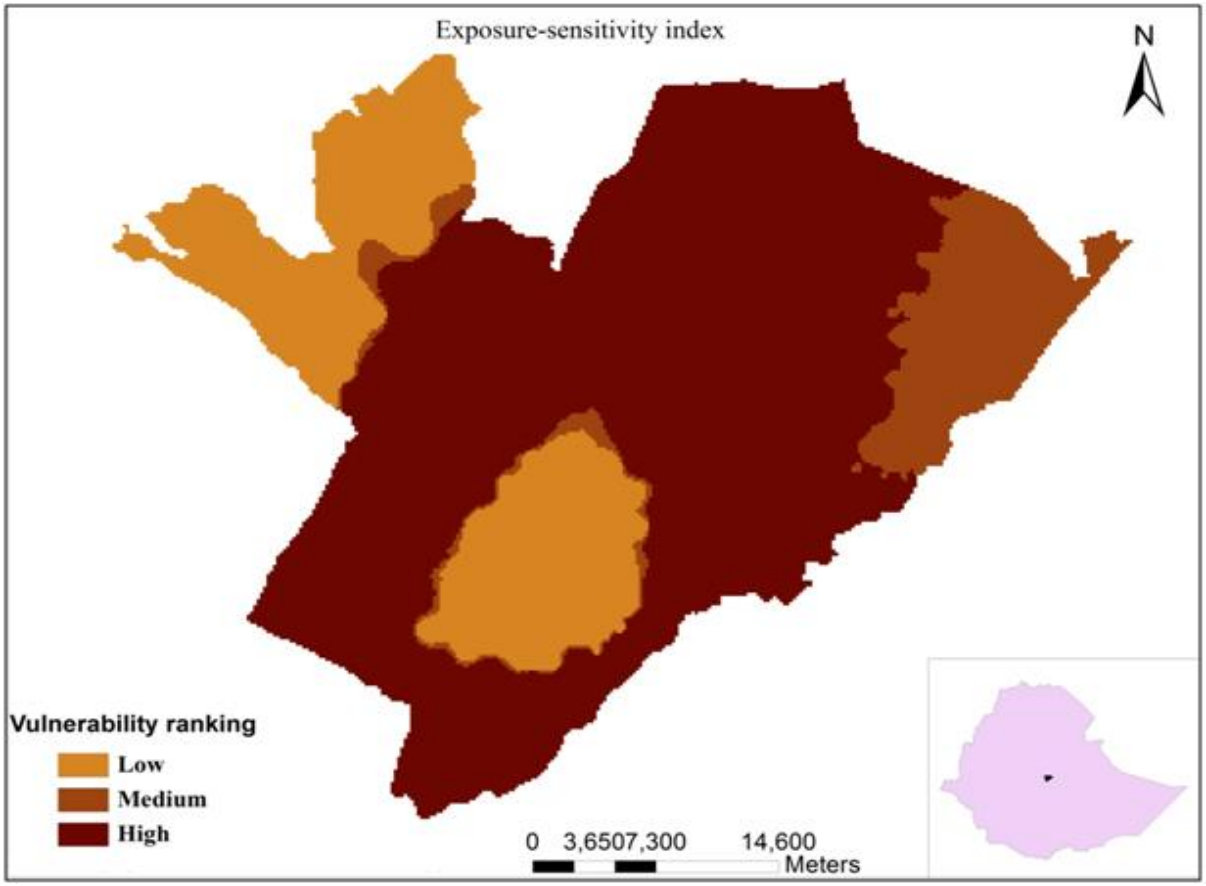


Source: From Author's field survey, 2013

Although agriculture was highly dependent on rainfall, the availability of pasture and water for the animals and the higher usage of fertilizers make the SMMiHL agro- ecology zone less sensitive than the WSMLL. The least sensitive agro-ecological zone was WMLL. The reason for this is that there were no problems related to water and pasture land compared to the other agro-ecological zones. The relying of agriculture on irrigation in this zone also made less sensitive to climate variability.

The combined effect of the sensitivity and exposure indicators give us the potential impact of climate variability/change on the three agro-ecological zones. The WSMLL agro-ecology zone has the largest potential impacts (Figure 18). This is because this zone has both the largest exposure and sensitivity. With less sensitivity and intermediate exposure compared to the other zones, the WMLL zone faced the least potential impact. The SMMiHL zone has the second highest potential impact due to its high exposure to climate change.

Figure 18: Map of exposure-sensitivity indices across the agro-ecological zones



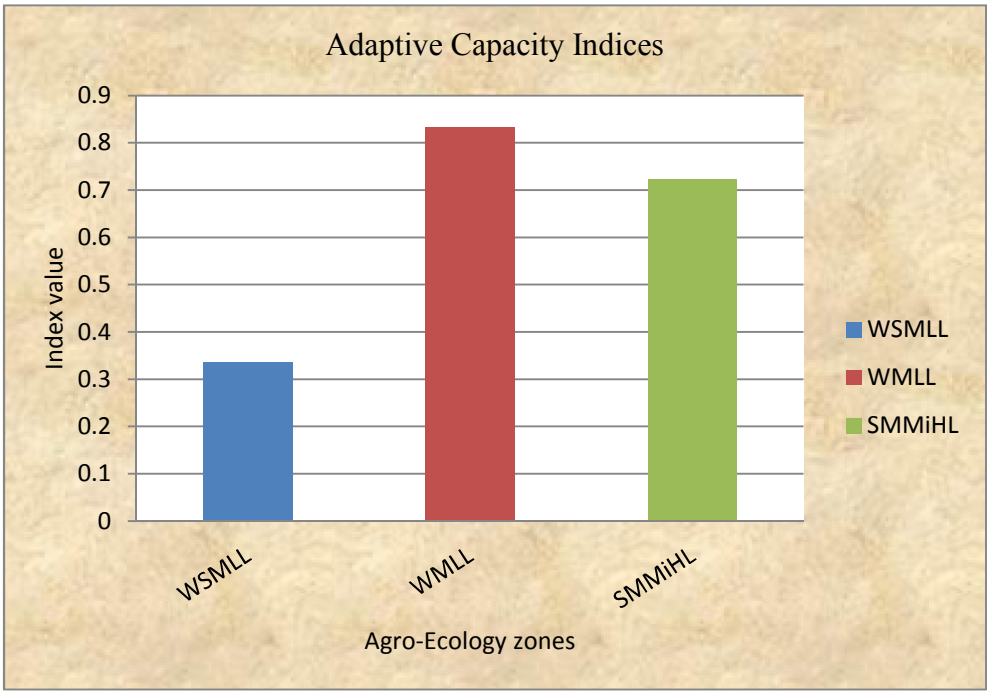
Source: From Author's field survey, 2013

4.5.1.3. Adaptive Capacity Index

Figure 20 presents the adaptive capacity of the three agro-ecological zones. Adaptive capacity was highest in the WMLL zone with 0.834 index value. High livestock and farm land ownership, good microfinance activities (saving money and get loan), and high irrigation practice made this zone with high adaptive capacity. The SMMiHL (0.723 index value) has better adaptive capacity than the WSMLL (0.335 index value). The combined effects of large household size, low microfinance access, market problems and its distance from the service

giving units like health centre, veterinary services and drug stores made WSMLL agro ecological zone the least on its coping power.

Figure 19: Adaptive capacity indices across the agro-ecology zones

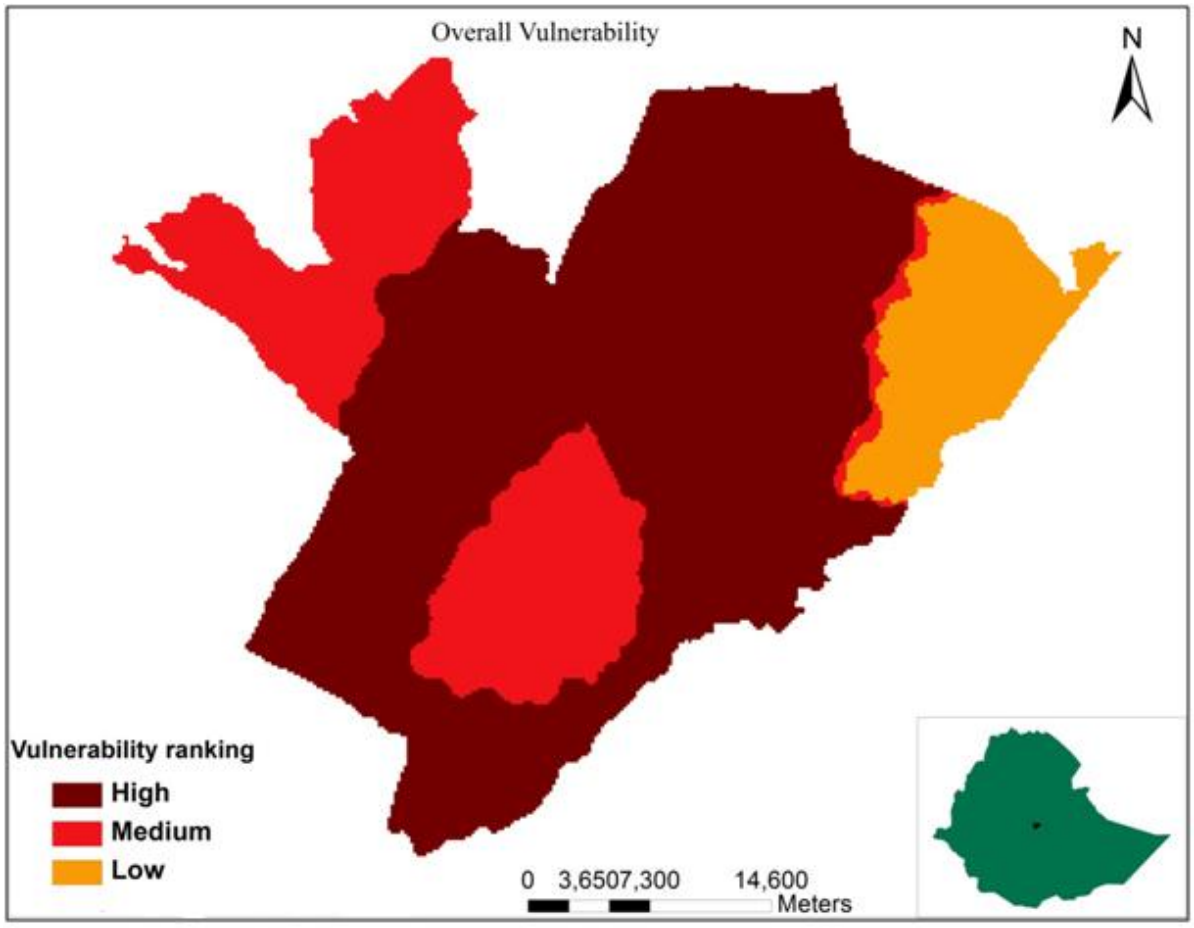


Source: From Author's field survey, 2013

4.5.1.4. Overall Vulnerability Index

The agricultural vulnerability map was prepared by integrating all the three indices: exposure, sensitivity and adaptive capacity. Comparing agro-ecology zones based on their potential impacts and adaptive capacities, keeping in mind that these parameters increase or decrease vulnerability, respectively, the WSMLL was the most vulnerable zone and the WMLL was the least vulnerable one. The WMLL zone has the lowest vulnerability due to its low potential impact and high adaptive capacity. In contrast, because of its combined high sensitivity and exposure and low adaptive capacity, the WSML zone has the highest level of vulnerability.

Figure 20: Map of the overall vulnerability indices across the Agro-ecology zones



Source: Author's own construction, 2013

Figure 20 illustrates the results of the vulnerability index for each agro-ecology zone in the Woreda. The results show that less dependency on the rainfall and high irrigation practice, availability of grazing land and water for the animals, accessibility of both formal and informal microfinance and high ownership of farmland and livestock make the WMLL agro ecology zone less vulnerable to climate variability/change with an index value of 0.325. Though agriculture is highly dependent on rainfall, large farmland and livestock ownership, good access to micro finance, the presence of service giving structures in the nearby areas made the SMMiHL less vulnerable with index value 0.3 than the WSMLL (index value -0.179) agro-ecology zone. However less usage of organic fertilizer, high dependency on rainfall, and non- existence of irrigation activity played a significant role for its high vulnerability with compared to WMLL agro-ecology zone. The most vulnerable agro-ecology zone was the WSMLL because of its high dependency on rain fed agriculture, unavailability

of pasture and water for animals, less irrigation practice and its poor access to service giving areas like veterinary, health and drug centers.

Despite the fact that there were differences in the vulnerability level of these three agro-ecology zones, they have common futures that make them equally vulnerable to climate variability/change. All of the zones have large household size, and most of the farmers grow one crop in their farm land per growing season. Studies conducted by Gerald (2010), Shengcai et al. (2011) and Temesgen (2010) confirmed that an agricultural region growing more diversified crops will be less sensitive to climatic variations. Moreover, most of the households were highly dependent on agricultural income, as they have less households' involvement in non-agricultural income earning activities. According to the study conducted by Abate (2009) diversification of income sources from non-farm activities are potential adaptation options to reduce vulnerability associated with climate change and climate extreme events. Likewise, low accessibility of improved seeds also contributed for the vulnerability of the agriculture to climate change. Most of the respondents and FGDs complained that they cannot get improved seeds, which are good on resisting the existing drought and pests. However, the seeds are not accessible and if so are not affordable.

4.6. Adaptation Strategies

Adaptation improved society's ability to cope with changes in climatic conditions across time scales; ongoing from short term to the long term (Dejene, 2011). In response to the above mentioned perceived changes, farmers in the study area have been undertaking a number of adaptation measures (Table 8). The adaptation measures which were taken by the five kebeles were almost the same. On average 75.7%, 73.4%, 79.4%, and 71.2% of the respondents undertake adaptation measures of planting trees, practicing natural resource conservation measures, borrowing money (credits), and sought off-farm activities (like petty trading, daily labor, fuel wood and charcoal selling), which are the major one, respectively.

Table 8: Adaptation measures taken by farmers

Adaptation Measures	Name of Kebeles					
	Qombe Gugisa	Qawa Hara Mirqasa	Merqo Oda Lega	Dengore Tiyo	Ararso Bero	
	Respondents (%)	Respondents (%)	Respondents (%)	Respondents (%)	Respondents (%)	Total (%)
No adaptation	7.3	11.4	9.6	6.4	17.5	10.4
Planting trees	85.7	66.7	71.7	72.4	82.1	75.7
Natural resource conservation practice	85.7	61.1	71.7	72.4	76.2	73.4
Use different crop Varieties	60.0	51.9	54.7	58.6	61.9	57.4
Early or late planting	42.9	31.5	35.8	37.9	44.0	38.4
Sale livestock	62.9	66.7	26.4	51.7	40.5	49.6
Borrow money	74.3	85.2	77.4	82.8	77.4	79.4
Saving money	65.7	66.7	62.1	60.7	43.4	59.7
Seasonal migration	0.0	10.3	0.0	0.0	0.0	2.1
Sought off-farm Activity	65.7	79.6	71.7	72.4	66.7	71.2
Use irrigation	42.9	20.4	0.0	0.0	0.0	12.66

NB: Multiple responses

Source: From Author's field survey, 2013

The FGDs and key informants also revealed that all the above mentioned coping strategies have been applied by them to solve problems related to climate shocks. Changing cultivation or type of crop cultivated by following changes in the trend of precipitation is being practiced. Apart from the common crop varieties, some households have also started growing early maturing seeds. However, adaptation strategy related to fuel wood and charcoal selling is becoming almost impossible due to the scarcity of wood in the area. The scarcity of wood is related to the change in land use/ land cover change in the area (Figure 13). Seasonal migration was mentioned as a means by 10.3 % of respondents from Qawa Hara Mirqasa kebele and all of them were pastoralists.

The interviewed government officials confirmed that the households borrow money from formal and informal sources as a means of coping strategy. They said that Oromia Credit and Savings Share Company has been providing credits for a few years now, helping farmers buy agricultural inputs, livestock and create an asset. As learned from the farmers and credit association managers, the farmers organized themselves so that the members are responsible for an individual's credit. The credit is granted during the months of January and February

each year, around the commencement of “belg” season, and the deadline for paying back is December, after crop is harvested.

Regarding natural resource conservation practices, the Woreda agricultural bureau and World Vision Ethiopia in collaboration with local government officials have been trying to involve communities on conservation practices. On the other hand, farmers are expected to involve in this practices in order to get different supports from their locally existing organization. Both the FGDs and key informants agreed that at first they were not willing to do what they were asked by the officials, however after some awareness creation by the agricultural bureau, they believe in the importance and now they are witnessing the success.

Irrigation practice has been considered as an adaptation option by respondents from Qombe Gugisa (42.9 %) and Qawa Hara Mirqasa (20.4%) kebeles.

About 10.4% of the respondents did not undertake adaptation measures in response to impact of climate variability/change. The major reasons which were mentioned by the respondents for not taking any adaptation measures were not knowing what to do and shortage of land and money.

Studies conducted by different researchers also found the same results on adaptation measures undertaken by farmers in different parts of Ethiopia. A study carried out by Muluneh and Demeke (2011) at Woreilu Woreda, North Eastern Ethiopia; found that farmers have taken adaptation measures like sowing variety of crops, changing harvesting season and diversifying income sources to cope the changing climate. The findings of Temesgen (2010) also showed that farmers in the Nile Basin of Ethiopia applied different adaptation strategies which include; planting trees, soil conservation, use of different crop varieties, changing planting date and irrigation.

However, the currently available coping mechanisms are not sufficient to solve the problems they are facing due to different reasons. 89% of the households interviewed and FGDs explained that absence/shortage of selected crop varieties, prolonged water shortage and unpredictability of the climate limited the feasibility of coping strategy. They further stated that in some years, though they applied different strategies, it was almost impossible to cope with the existing problem.

Chapter Five

Conclusions and Recommendations

5.1. Conclusions

This paper studied the vulnerability of smallholder agriculture to climate variability and change in the Boset Woreda of Oromia region, Ethiopia. For this study, 256 households were questioned from the three agro-ecological zones. Socio-economic and bio-physical data were directly collected from farmers and other stakeholders. Focused group discussions and key informant interviews were also carried out in order to get detailed information. Other supporting data were gathered from different sources including books, journals, and unpublished materials available at the Woreda administrative and agricultural bureau. Data for the study were also gathered from various organizations like The Agriculture Bureau of the Woreda and East Shewa Zone, CSA, Ministry of Water and Energy of Ethiopia and NMA.

According to the result of the study, the frequency of climatic variability/change is increasing both in terms of extreme weather frequency and gradual changes, and consequently aggravating the vulnerability of agriculture to these events. Rainfall has generally been declining over the last 30 years in the study area, while both minimum and maximum temperature trends have increased. Analysis of belg and meher drought trends also indicated a degree of increase in frequency. Farmers in the area also agreed with the metrological data. About 95.7% and 93.1% of the respondents claim that there has been an overall increase in temperature and decrease in rainfall, respectively over the past three decades. They also perceived that rainfall has become more variable and erratic as compared to the situation in the past. They reported that in some years the rain starts late and stops early (41.6%) or ends late (58.5%) as compared to past experiences. 78.7 % of the respondents indicated that there is a large difference in the occurrence of flood and drought with compared to the past years. Likewise, there is no significant gender based difference in perception of climate variability/change.

The multi-temporal analysis of satellite imageries data clearly indicate that in 1981 about 81% of Boset Woreda was under forest, bush/shrub and grass lands. But, in 1996 and 2011 these figure of coverage was reduced to 45% and 21 %, respectively.

As a result of these changes, farmers in the study area were affected in different ways. 97.9% of the respondents said that reduction of production has been the foremost effect of climate variability/change in their Woreda. The second and third impacts mentioned by the respondents were increase in incidence of plant diseases (88.8%) and insects (87.8%). Other effects of climate variability/change, such as increase in incidence of animal diseases (62%), weeds (76.7%) and flood and drought (58.6%) were also impacts which were spotted by the respondents. However, there are local coping mechanisms that are used to reduce the climate change impacts. On average 63 % of the farmers used one or more of adaptation mechanisms such as planting trees, practicing natural resource conservation measures, using different crop varieties, early or late planting, selling livestock, borrowing money, using irrigation, saving money and sought off-farm activities, though, the coping mechanisms are not sufficient to tackle the challenges.

The study also analyzed the vulnerability of smallholder agriculture to climate variability/change by developing vulnerability indicators and comparing these indicators across three agro-ecological zones. The vulnerability analysis followed the IPCC definition of vulnerability, which explains it as a function of exposure, sensitivity and adaptive capacity. The socio-economic and bio-physical (environmental) factors of each agro-ecology zones were included in developing the vulnerability indicators. The socio-economic factors include; wealth, access to different infrastructure and institutions, availability of technology and income diversification, level of crop diversification, availability of water, grazing land and drug for animals, usage of chemical and organic fertilizer on their land. The bio-physical factors include change in temperature and rainfall and irrigation activity. These factors further divided into three groups to reflect exposure, sensitivity and adaptive capacity. The method of principal component analysis was employed to give weights to the different factors of vulnerability.

Vulnerability was calculated as the net effect of sensitivity and exposure on adaptive capacity. Hence, result indicated that warm sub-moist lowlands agro-ecology zone found more vulnerable followed by sub-moist mid highlands and warm moist lowlands agro ecology zones. The vulnerability of warm sub-moist lowlands agro-ecology zone is due to its high dependency on rain fed agriculture, unavailability of pasture and water for animals, less irrigation practice and its distance from service giving areas like veterinary, health and drug centers. Likewise, less usage of organic fertilizer, high dependency on rainfall, and non-

existence of irrigation activity make sub-moist mid highlands relatively more vulnerable with compared to the warm moist lowlands agro-ecology zone. Unlike the two agro-ecological zones less dependency on the rainfall and high irrigation practice, the availability of grazing land and water for the animals, accessibility of both formal and informal microfinance and high ownership of farmland and livestock make agriculture in the warm moist lowlands agro ecology zone less vulnerable to climate variability/change.

5.2. Recommendations

Investments in improved agricultural productivity such as land resource management, on-farm technology, access to extension services, transport, fertilizers and improved seed varieties, should be implemented in order to enhance the resilience of agriculture.

Integrated rural development schemes aimed at reducing the sensitivity of the agriculture to the changing climate and increasing adaptive capacity of the farmers should be the focus of governmental and non-governmental organizations so as to get sustainable result on the alleviation of the problem of the farmers.

Irrigation activities should be implemented in the areas where there can be irrigable river or ground water. Furthermore, to reduce the impact of drought on agriculture different water harvesting techniques should be introduced.

Market problem is one of the challenges in which the farmers are facing; particularly those who are practicing irrigation activities. Thus, different strategies must be developed in order to help the farmers to sell their products before they lost all the products.

Natural resource management particularly soil and water management strategies are necessary in the study area as they are useful for sustainable crop production and the techniques used have a great potential in buffering against drought and floods, which are more frequent in the area

There should be a development of appropriate strategies for reducing vulnerability of agriculture to climate extremes by helping farmers use their local knowledge in combination with introduced innovations to enhance local adaptations to climate change and variability

Additional meteorological stations are needed to exactly predict the climate change Variations with full confident level since the available climatic stations are not enough.

Although the result of this study indicate vulnerability of agriculture using socio-economic and biophysical factors, future research should focus on the contribution of land degradation to agricultural vulnerability to climate variability/change.

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Appendices

Appendix I: Factor scores from PCA and associated statistic

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	4.558	16.278	16.278	4.558	16.278	16.278	3.702	13.221	13.221
2	2.679	9.568	25.845	2.679	9.568	25.845	2.496	8.914	22.136
3	2.183	7.798	33.644	2.183	7.798	33.644	2.244	8.014	30.149
4	1.998	7.135	40.779	1.998	7.135	40.779	2.177	7.775	37.924
5	1.643	5.870	46.648	1.643	5.870	46.648	1.690	6.035	43.959
6	1.416	5.056	51.704	1.416	5.056	51.704	1.668	5.958	49.917
7	1.385	4.947	56.651	1.385	4.947	56.651	1.472	5.258	55.175
8	1.265	4.519	61.170	1.265	4.519	61.170	1.464	5.228	60.403
9	1.117	3.988	65.158	1.117	3.988	65.158	1.220	4.359	64.762
10	1.091	3.895	69.053	1.091	3.895	69.053	1.201	4.291	69.053
11	.996	3.556	72.609						
12	.921	3.290	75.898						
13	.886	3.164	79.062						
14	.842	3.006	82.069						
15	.739	2.638	84.706						
16	.688	2.456	87.162						
17	.672	2.401	89.563						
18	.654	2.334	91.897						
19	.536	1.913	93.810						
20	.533	1.903	95.713						
21	.422	1.507	97.220						
22	.354	1.265	98.485						
23	.309	1.102	99.587						
24	.116	.413	100.000						

Appendix II: Factor scores of the first Principal component

Indicator variables	Mean	Standard deviation	Factor score
Change in temperature	1.12	.356	-0.186
Change in precipitation	2.01	.149	0.116
Change in drought occurrence	1.02	.182	-0.042
Change in flood occurrence	1.04	.256	-0.056
Crop diversification	1.92	.789	-0.012
Chemical fertilizer usage	1.20	.402	-0.157
Availability of improved seeds	1.58	.496	0.398
market problem	1.75	.432	0.389
razing land availability for your animals	1.03	.165	-0.017
water availability for your animals	1.49	.870	0.620
Natural resource management activities	1.06	.241	0.063
Organic fertilizer usage	1.25	.432	-0.010
Household size	5.62	1.166	0.055
Farm land ownership	1.06	.241	0.063
Livestock ownership	1.02	.129	-0.020
Livelihood activities	2.97	.257	0.020
Other income source other than Agriculture	1.76	.428	-0.016
Economic support from relatives/family members	1.82	.389	0.012
Health service	3.77	1.106	0.946
Veterinary service	3.77	1.106	0.946
Kms travel to get pesticide and insecticide	3.77	1.106	0.946
irrigation practice	1.69	.465	0.224
access to loan	1.40	.492	0.137
Saving money	1.53	.500	0.369
Drug availability for animals	1.07	.757	-0.026
Educational Level	2.87	.627	-0.013

Appendix III: Questionnaires for sample households, FGDs and key informants

This questionnaire is prepared for an academic purpose for the fulfillment of MA Degree in the Department Geography and Environmental Studies. The objective of the study is to assess the vulnerability of small holder agriculture to climate variability/ Change. Your response is very important for the success of the study. Hence, you are kindly requested to fill the questionnaire without hesitation. Your name will not be mentioned to others. I would like to thank you in advance for all your cooperation.

Code _____ Kebele _____ Date of interview _____

Choose the best answer

1. Sex
   1. Male 2. Female
2. Age
   1. 18-25 years 3. 31-35 years 5. >40 years
   2. 26-30 years 4. 35-40 years
3. Marital status:
   1. Married 2. Unmarried 3. Divorced 4. Widowed
4. Educational level
   1. Read and write 3. Primary school 5. Higher education
   2. Illiterate 4. Secondary School
5. Do you have children?
   1. Yes 2. No 3. If yes, how many?
6. Household size
   1. 1 3. 3 5. 5
   2. 2 4. 4 6. >5
7. Livelihood activities
   1. Farming only 2. Animal husbandry 3. mixed farming
   4. Other (specify _____)
8. Do you or your family member(s) has/have another source (s) of income other than agriculture?
   1. Yes 2. No
9. If your answer is yes what kind?
   1. Petty Trade 3. Daily labor work
   2. Firewood/ Charcoal selling
   4. If other specify _____
10. Do you have any family member(s)/ relative(s) who support you economically?
    1. Yes 2. No
11. Do you own farm land?

1. Yes 2. No

If yes how much hectare of land? _____

12. How many crops do you grow per growing season per agricultural land?
1. 1 2. 2 3. 3 4. More than 3

13. Do you have problems related to insects and pests?
1. Yes 2. No

14. If your answer is yes, are these problems common to the area?
1. Yes 2. No

15. Are their occurrences the same as before (five or ten years before)?
1. Yes 2. No

16. Do you use pesticide and insecticide on your farm?
1. Yes 2. No

17. If your answer is yes for Q-16, do you get them whenever you want?
1. Yes 2. No

18. If your answer is yes for Q-16, do you get them in enough amounts?
1. Yes 2. No

19. Does the supply source of pesticide and insecticide near to your home?
1. Yes 2. No

20. If it is far how many kms do you travel to get them?
1. <1 kms 3. 2-4 kms 5. >5kms
2. 1-2 kms 4. 4-5kms

21. What kind (s) of livestock do you have?
1. Cattle 3. Goat 5. Poultry
2. Sheep 4. Camel 6. All
7. Other specify _____

22. Do you use chemical fertilizers on your farm land?
1. Yes 2. No

23. If your answer is No Why?
1. I can't afford to buy it 3. I don't believe in its importance
2. I use natural fertilizer
4. Other, specify _____

24. If your answer is yes, is it available as the amount you want?
1. Yes 2. No

25. Is it affordable?
1. Yes 2. No

26. Where do you get seeds to plant?
1. From my reserve 2. From relatives 3. Agricultural Bureau
4. Other specify _____

27. Is there any supply for improved seeds?
1. Yes 2. No

28. Where do you go when your livestock get sick?
1. Veterinary surgeon 3. Other specify _____
2. Traditional doctor

29. Do you get drugs easily for your animals when they get sick?
1. Yes 2. No
30. Is there a market place near?
1. Yes 2. No
31. Have you ever experienced any problem related to market due to its distance from your home?
1. Yes 2. No
32. If yes, what kind of problems did you face?
1. Spoil of products 2. Selling products in low price
3. Unable to sell products when there is emergency (need money)
4. Others, specify _____
33. Do you practice irrigation?
1. Yes 2. No
34. If yes do you get enough water for your plants whenever you want to water them?
1. Yes 2. No
35. Have you experience problems related to market for your products produced using irrigation?
1. Yes 2. No
36. Are there available grazing lands for your livestock in the nearby areas?
1. Yes 2. No
37. If your answer is yes, are they accessible?
1. Yes 2. No
38. Are there available water sources for your livestock in the nearby areas?
1. Yes 2. No
39. If your answer is yes, are they accessible?
1. Yes 2. No
40. Do you practice any natural resource management activities?
1. Yes 2. No
41. Do you use organic fertilizer on your farm land?
1. Yes 2. No
42. Do you have access to loan?
1. Yes 2. No
43. If your answer is yes who can give you the loan?
1. Community organization 3. Relatives
2. Friends 4. Banks
5. Other, Specify _____
44. Do you save money?
1. Yes 2. No
45. If your answer is yes where do you keep it?
1. At home 3. With friends
2. with relatives 4. In the Bank
5. Other specify _____
46. How do you characterize the weather conditions of this area in terms of its temperature
1. Very Hot 2. Hot 3. Very cold 4. Cold

5. Moderate

47. How do you characterize this area in terms of its rain fall?
    1. Receives high rain fall
    2. Receives low rain fall
    3. Receives moderate rain fall
    4. Varies from time to time
48. Do you know what climate change mean?
    1. Yes
    2. No
49. If yes how do you express it? (You can choose more than one answer)
    1. change in temperature trends
    2. Change in rainfall patterns
    3. Change in frequency of drought and floods
    4. Other, specify _____
50. Is there any change on the temperature and rainfall amount with compared to before ten or twenty years?
    1. Yes
    2. No
51. If yes, how? (You can choose more than one answer)
    1. Increasing temperature
    2. Decreasing temperature
    3. Increasing rain fall
    4. Decreasing rainfall
    5. The rain comes late and ends early
    6. The rain concentrates in some days with high intensity
    7. Others, specify _____
52. Have you ever faced any climate related impact in your life time?
    1. Yes
    2. No
53. If yes, how do you explain the impact? (You can choose more than one answer)
    1. Considerable reduction in crop production
    2. Reduction in the length of crop growing period
    3. Increased incidence of insects
    4. Increased incidence of plant diseases
    5. Increased incidence of animal diseases
    6. Increased incidence of weeds
    7. Others, specify _____
54. What do you do to cope with the above situation (s)? (You can choose more than one answer)
    1. No adaptation
    2. Planting trees
    3. Soil conservation
    4. Use different crop Varity
    5. Early or late planting
    6. Sale livestock
    7. Borrow money
    8. Food aids
    9. leaving the place for sometime (migration)
    10. Sought off-farm activity
    11. Use irrigation
    12. Water harvesting practices
    13. Others, specify _____

Interview questions

For FGDs and key informant interview

1. What is/are the main livelihood of the people in this area?
2. How do you characterize the weather conditions of this area in terms of its temperature?
3. How do you characterize this area in terms of its rain fall?
4. Is there any change with compared to the temperature and rainfall amount before ten to twenty years?
5. If yes, how do you characterize it?
6. Do these changes affect the farmers? If yes, would you please explain the extent of climate change and variability impact on crop and livestock in this area?
7. What are the local coping mechanisms used to reduce the impacts?
8. How much is the average land holding size of the farmers?
9. Is there enough pasture land for animals?
10. If yes, are they accessible? If not why?
11. Do the farmers get enough fertilizer for their land? If not why?
12. Are there different organizations which are working with the farmers?
13. If yes, what is their role on helping the people to cope the impacts of climate change?
14. Are pests and diseases major problems in the area?
15. If yes, do their frequency of occurrence show any change from year to year? If yes, what do you think is the reason?
16. Do the farmers get enough pesticides and drugs (easily) for their crops and animals?
17. If not why?
18. Is there any clinic in the nearby for the animals? If not, what do the people do when their animals get sick?
19. Are there market problem in the area? If yes could u please explain what the problems are?
20. Are there any natural resource management activities held in the area? If yes what are the main targets of the activities and if not why?
21. Do the farmers have access to improved seeds?

Thank you!