ADDIS ABEBA UNIVERSITY, FACULTY OF SCIENCE

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Impacts of Climate Variability on Crop Production and Farmers' Adaptation Strategies in Bassona Worana Woreda, North Shoa Zone, Ethiopia

By

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A thesis submitted for the partial fulfillment of the requirements for the Degree of Masters of Science in Environmental Science.

Advisors:

Dr. Belay Simane

May, 2014

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Abstract

Climate change is expected to have serious environmental, economic and social impacts in Ethiopia. The extent of which these impacts depends on the level of adaptive capacity, particularly among rural farmers whose livelihood depends on rain-fed agriculture as a primary source of food production. The study analyzed the impact of climate change on crop production and farmers' adaptation strategies to climate change in Bassona Worana Woreda of North Shoa Zone, Amhara Regional State, Ethiopia.

This study was based on both secondary and primary data by conducting a comprehensive assessment of temperature and rainfall variations and the impacts on the most commonly grown crops. Farmers' adaptation strategies were examined based on a questionnaire designed to investigate farmers' ability to adapt to climate change. Mann-Kendall trend tests were used to examine trends of temperature and rainfall. Whereas Correlation and regression tests were carried out against dependent variables (teff, wheat, barley and sorghum) in order to examine the relationship between climate variability and crops. The study was also analyzed farmers' perception and adaptation responses to climate change. The finding of the study shows that there is significant increasing trend in the amount of annual rainfall (4.857mm/year). However, there is a significant decreasing trend of rainfall during Belg season (-2.88mm/year). Mean annual temperature and mean annual maximum temperature shows a significant increasing trend while the mean annual minimum temperature is increasing but not significant. Significant negative correlations were observed between Belg rainfall and crop

production and negative correlations between most of annual, seasonal and monthly temperatures and crop production. The survey revealed that a significant number of farmers believed that temperatures were increasing and precipitation was declining. Farmers' perceptions on whether the climate was changing were greatly influenced by incidences of drought and changes in the seasonal timing of rainfall. Farmers practiced soil and water conservation and planting trees as a major adaptation options.

The findings suggest that Ethiopia should begin to plan for climate contingencies at grassroots level. Augmenting the existing adaptation skill should be given a high priority and actions that make agriculture sectors more immune to climate should be taken in advance.

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Acronyms

BWW	Bassona Worana Woreda
CRGE	Climate Resilient Green Economy
CSA	Central Statistics Agency
CV	Coefficient of variance
DB	Debre Brehan
ENSO	El Nino–Southern Oscillation
GB	Gudoberet
GDP	Growth Domestic Plan
GHG	Green House Gas
GTP	Growth and Transformation Plan
HDI	Human Development Index
IPCC	Intergovernmental Panel on Climate Change
ITCZ	Inter Tropical Convergence Zone
LDCs	Least Developed Countries
NAPA	National Adaptation Program of Action
NMSA	National Meteorological Service Agency
PCI	Precipitation Concentration Index
RSCZ	Red Sea Convergence Zone
SOI	Southern Oscillation Index
SPSS	Statistical Package for Social Science
SRA	Standardized Rainfall Anomalies
SST	Sea-Surface Temperature
UNDP	United Nation Development Program

UNFCCC	United Nation Framework Convention for Climate Change

Chapter 1. Introduction

1.1 Background

Ethiopia is a land locked country in the Sub-Saharan Africa and agriculture is the bases for the Ethiopian Economy, providing the bases for the livelihood of a population of 77 million people (CSA, 2008). Agriculture is the main source of export earning accounting for more than 80% (Toulmin, 2009). Although the level of dependency on the environment defers from rural and urban dwellers, 85% of the population are directly dependent on land and natural resources (MoFED, 2006). Such high dependency, coupled with a lack of adequate conservation and rehabilitation intervention together with increased climate change treats have significantly affecting the livelihood of the rural population. Studies show that in 2004/2005, the total land covered by different crops was 9.8 million hectares which had increased to 11.25 million hectares by the year 2009/2010. As a result, the total average output increased from 119.1 million quintals in 2004/2005 to 191 million quintals in 2009/2010 (DPRD and MoFED, 2008). Despite this increase in food production, meeting the food demand of the growing population is still the biggest challenge for the country.

According to the 2012 UNDP Human Development index Report (World Bank, 2012), Ethiopia Human Development index Report (HDI) is 0.363, which gives the country a rank of 174 out of 187 countries. The HDI represents a broader definition of well-being and provides a composite measure of three basic dimensions of human development: health, education and income. According to the report, the HDI of Sub-Saharan Africa as a region increased from 0.365 in 1980 to 0.463 in 2011, placing Ethiopia below the regional average.

A study shows that Ethiopian Economy is highly exposed to climate variability and extremes (Conway and Schipper, 2009). Agriculture is of special concern as it is the primary source of food in Ethiopia and it is dependent on the weather.

The climate variability over Ethiopia is identified by average temperature and rainfall changes. According to IPCC (2004), observed changes in average temperature of Ethiopia between the periods of 1970 and 2004 were lying within the ranges of 0.2 and 1 degree. The NAPA (NMA, 2007) also indicates that the temperature has become warmer in the last fifty years. The minimum temperature has increased by approximately 0.37 degree Celsius per decade between 1951 and 2006. Deressa and Hassen (2009) also indicate that due to rising temperature, income per hectare will decrease by between 9.71%-303.27% by 2050 and 103.39%-418.01% by 2100 in Ethiopia. World Bank (2009) projected for a reduction in average precipitation from 2.04mm/day during the periods of 1961-1990 to 1.97mm/day in 2070 although the annual volume of rainfall in Ethiopia between 1961- 2005 remains constant (NMSA, 2007, Seleshi and Zanke, 2004 and Gebru, 2007),.

According to You and Ringler (2010), in Ethiopia climate change is expected to intensify the already high hydrological variability and frequency of extreme events, more than changes in mean annual rainfall. These two factors may have significant negative effects on the development of the agricultural sector and on the Ethiopian economy as a whole.

The impact of climate change on agriculture is estimated to be large. According to Daniel Kasshun (2008), the annual volume of rainfall in Ethiopia remains constant; however, there is a tendency for less rain to fall over the northern and eastern part of the country. Under this prospect, several studies highlight the importance of adaptation mechanisms to limit the negative effects of changes in rainfall patterns.

This research intends to investigate the effects of climate change at the grassroots level and also, the communities' perception and adaptation to changing in climate. A better understanding of their perceptions of climate change, ongoing adaptation measures, and the decision making process is important to inform policy maker, so that they may promote successful adaptation on their livelihoods.

1.2 Statement of the problem

Much of the Ethiopian central highlands are entirely dependent on rain fed agriculture which is more endangered to climate variability. This area is being cultivated for more than a century and as it is visible the expansion of cultivated area comes almost exclusively from reduction in pasture land. In most instances, this land is likely to be less fertile than existing crop land. This could enhance run off, and accelerate soil erosion and ultimately affect crop productivity. Due to the minimum temperature reaching less than 0 ºC months from October to November (NSRC, 2006), the area frequently faces frost effect on crops reached for harvest. Fluctuation of onset of short rainy season was also another perceived problem especially for local crops which requires long period (like sorghum).

In addition, growing population pressure, increasing number of livestock and the failure to return organic matter to the soil, have reduced soil fertility significantly. Moreover, crop residues are used for animal feed or fuel. Dung fuel also exports a large proportion of the nutrient and the remaining is used as fuel for home consumption. Consequently, the rate of nutrient return is very law. The straw is also used for construction and mattress. In addition, the steepness of the slope makes soil vulnerable for erosion. All these make the area more susceptible to climate change.

Accordingly, there is the need to gain as much information as possible (trend in temperature and rainfall), and learn the positions of rural farmers and their needs, about what they know about climate change and their local adaptation skills to the changing environment, in order to offer adaptation practices that meet these needs.

1.3 Significant of the Study

Analyzing the climate change (temperature and rainfall patterns/trends for the last 30 years) and impact to crop production potential at local scale will have a paramount significance to local administrators and policy makers to indicate and well aware of the potential effects of climate change on the most commonly grown crop of the area (sorghum, wheat, barley and teff). In addition, documenting farmers existing adaptation skills to the effects of climate change will have a momentous output to scale up their adaptation skills and to propose further adaptation measures. Moreover, the research will add up to the existing knowledge on climate change effect at local scale and open up further research idea.

1.4 Research Objectives

1.4.1 General Objective

The general objective of the study is to assess the effect of temperature and precipitation change on agriculture and to identify local strategies pursued for adaptation in Bassona Worana Woreda of North Shoa Zone.

1.4.2 Specific objectives

1. To analyze historical variability and trends of precipitation (rainfall) and temperature;
2. To analyze crop yield data of the area;
3. To assess the relationship of precipitation and temperature data with crop yield data; and
4. To investigate the response measures of the farmers in the face of climate change perceptions and adaptation strategies.

1.5 Scope and limitation of the study

The study is based on Meteorological data, crop production data and field survey. The report includes analysis of climate variables, crop production and adaptation strategies. Considering these the report has the following limitations:

- It is limited to a specific site- The study is bounded to only one Woreda of North Shoa Zone. With this regard, the research has focused only on the effect of local climate change on crop production.
- In terms of source, the research process has relied on the data obtained from Woreda Agricultural Office for crop data, and on two meteorological stations for rainfall and temperature records. The time frame for analysis was 8 years for crop

data and 30 and 22 years for Meteorological data of two stations (*Debre Brehan* and *Gudoberet* respectively) for both temperature and precipitation. Non-uniform temporal records have reduced the length of time and the amount of data available for making comparisons and relationships.

1.6. Thesis structure

This thesis is organized as follows. Chapter one looks into the introduction, objectives of the study and its significance. Chapter two reviews relevant literature regarding climatic change, adaptation options and national policies. The third is the materials and methods part that generally informs the ways in which this work was conducted. The fourth part is the results and discussion that bears findings of the research effort. The last and the fifth is the conclusions and recommendations.

Chapter 2. Literature Review

2.1 Climate change and crop production

Ethiopia is one of the least developed countries in the world where agriculture is the source of livelihood to a majority of the Ethiopian population and is the basis of the national economy. The sector employs more than 80 percent of the labor force and accounts for 50 percent of the GDP and 85 percent of the export revenue. Five major cereals (teff, wheat, maize, sorghum and barley) are the core of Ethiopia's agriculture and food economy, accounting for about three-quarters of total area cultivated, 14 percent of total GDP and 64 percent of calories consumed (Alemayehu *et al.*, 2011). They are mainly produced by small-scale and subsistence farmers, where they cultivate 96.3% of the total cultivated area and produced 95 % of the main crops (CSA,2008). In contrast large farms contributed only 5% of the main crop.

Many researches (Seleshi and Zanke, 2004; Woldeamlak, 2007; H. Chung *et al*., 2008; Derressa T.T. *et al.*, 2008; Conway and F. Schipper, 2010 and Dereje *et al.*, 2012) indicate that Ethiopia is the most sensitive and vulnerable country to climate change due to the fact that Ethiopia depends largely on rain-fed agriculture, which is highly sensitive to variability of rainfall across time and space. Thus, the amount and temporal distribution of rainfall and other climatic factors during the growing season are important influences of crop yields and can induce food shortages and famine. Studies shows that (Conway *et al.*, 2007) rainfall variability and associated drought have been major causes of food shortage and famine in Ethiopia which were manifested in the form of frequent drought (1965, 1974, 1983, 1984, 1987, 1990, 1991, 1999, 2000, and 2002) and flooding (1997 and 2006).

Ethiopia economy is growing at a fastest rate. Between 2005 and 2010, the country's real GDP grew by 11% per annual, with the agriculture sector accounting 8%. A 15% expansion of agricultural land and a 40% yield increase account for growth in the agricultural sector over the last five years (CRGE,2012). However, a study conducted by Alemayehu *et al*., (2011) on regional pattern and trend of crop production in Ethiopia **(Table 1)** concluded that much of the increase in production in the past decade has been due to increases in area cultivated. They also identified numerous constraints to yield and productivity growth, including relatively low levels of input use (fertilizer, pesticide, and improved seeds), low levels of irrigation, soil degradation and soil erosion, inadequate agricultural research and extension, and constraints in market development.

Table 1: Ethiopia cereal area, yield and production, decade averages and growth rates (Source - Alemayehu *et al*., 2011)

	FAO			CSA		
	Area (Million ha)	yield (tons /ha)	Production (million tons	Area (Million ha)	yield (tons/ ha)	Production (million tons)
1961/62-1969/70	6.23	0.73	4.53	--	--	--
1970/71-1979/80	5.25	0.9	4.63	--	--	--
1980/81-1989/90	4.89	1.15	5.63	4.30	1.14	4.89
1990/91-1999/00	5.87	1.18	6.88	5.60	1.20	6.67
2000/01-2008/09	8.24	1.3	10.68	7.72	1.41	10.94

A study conducted by World Bank (World Bank, 2006) indicates that Ethiopian welfare and economic productivity, which are mainly rain feed agriculture are linked to the volatile rains and the correlation between rainfall and overall GDP is strong (figure 1).

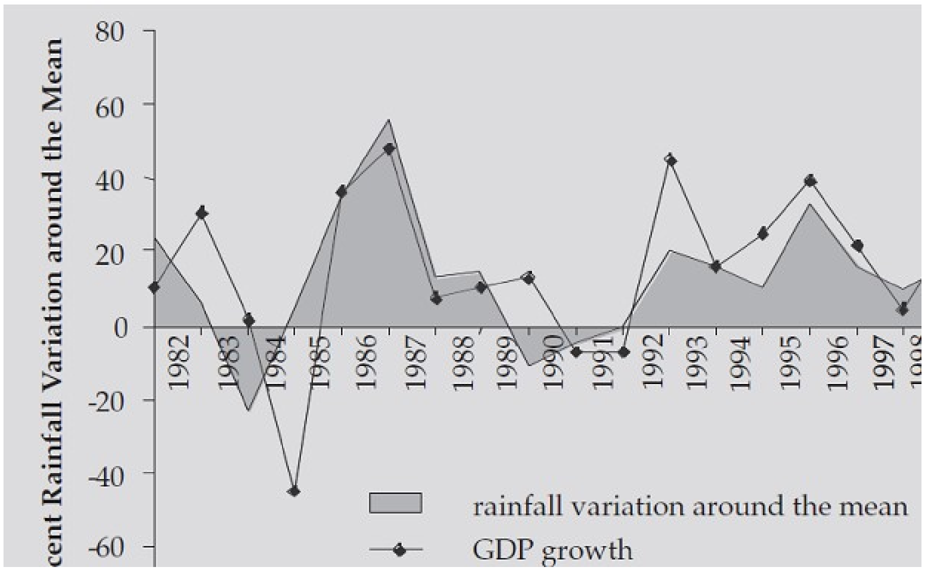


Figure 1. Rainfall and GDP growth in Ethiopia (source World Bank, 2006)

According to the World Bank study, fluctuations in cereal yield levels are extremely high and closely follow the pattern of rains. There is a significant correlation between national cereal yield and national average rainfall. National yield levels declined by as much 25 percent in 1984, 17percent in 1994, and 10 percent in 1997. Because of these fluctuations, the mean cereal yield showed little change over the years and remained at less than 12 quintals per hectare. With less than 1 percent growth rate in yield, nearly all increase in production over the years was due to expansion in the area of cropland. Expanding cropland area rather than enriching the soil of current cropland can contribute to deforestation and land degradation.

2.2 Climate change adaptation

There are numerous definition revealed for adaptation by different scholars which were then reviewed by Smith *et al*. (2000). Some of the definitions are;

Adaptation to climate is the process through which people reduce the adverse effects of climate on their health and well-being, and take advantage of the opportunities that their climatic environment provides (Burton, 1992).

The term adaptation means any adjustment, whether passive, reactive or anticipatory, that is proposed as a means for ameliorating the anticipated adverse consequences associated with climate change (Stakhiv, 1993).

Adaptability refers to the degree to which adjustments are possible in practices, processes, or structures of systems to projected or actual changes of climate. Adaptation can be spontaneous or planned, and can be carried out in response to or in anticipation of changes in conditions (IPCC, 1996).

These definitions imply that adaption refers to any societal or structural adjustment aimed at reducing the adverse effect of climate change. According to IPCC (2001) “adaptation has the potential to reduce adverse impacts of climate change and to enhance beneficial impacts, but will incur costs and will not prevent all damages”.

Adaptation is an essential ingredient both in assessments of climate impacts and in the development of adaptation policies (Smith *et al*., 2000). Its role to climate change is increasingly considered in academic research, and its significance is being recognized in international and national policy debates on climate change.

As a center of coordinating international efforts to adapt and mitigate climate change, UNFCCC were established and entered into force on 21st March 1994 and there are now 191 member countries (UNFCC, 2007). These members were committed on launching a National Adaptation Programs of Action (NAPAs). The NAPA provide a process for Least Developed Countries (LDCs) to identify priority activities that respond to their urgent and immediate needs to adapt to climate change. As of June 2010, 48 LDC have prepared and submitted their NAPA, of which 33 are in Africa.

Through the NAPA process (NMA, 2007), Ethiopia identified twenty priority project ideas that address immediate climate change adaptation needs of the country. These projects broadly focus in the areas of human and institutional capacity building, improving natural resource management, enhancing irrigation agriculture and water harvesting, strengthening early warning systems and awareness raising. The plan has legitimate issues which need to be addressed, although there are some general remarks voiced against NAPA as being a wish list or shopping list (Alemnehe, 2010). If it is implemented as per a list of ranked priority adaptation activities and projects, the NAPA could bring multiple benefits to the most vulnerable communities of Ethiopia through enhancing productivity and ecosystem resilience as well as mitigating climate related risks at local and national scale.

Apart from the NAPA, there are several local adaptation skills performed by the rural communities of Ethiopia to cope up with the change in environment. The study conducted by Deressa, *et al.* (2008), for example, identified the major methods used by farmers to adapt climate change. They undertake soil conservation, use different crop varieties, plant trees, change planting dates and irrigate their farms to reduce the negative impacts of climate change. To strength the farmer's effort, they proposed future policy which promotes soil conservation, research on use of new crop varieties and livestock species that are better suited to drier conditions, and promote irrigation can support farmers to better cope with climate change.

2.3 Climate change adaptation in Agriculture

Important adaptation options in the agricultural sector include: crop diversification, mixed crop livestock farming systems, using different crop varieties, changing planting and harvesting dates, and mixing less productive, drought-resistant varieties and high-yield water sensitive crops (Bradshaw *et al.*, 2004). Agricultural adaptation involves two types of modifications in production systems. The first is increased diversification that involves engaging in production activities that are drought tolerant and or resistant to temperature stresses as well as activities that make efficient use and take full advantage of the prevailing water and temperature conditions, among other factors. Crop diversification can serve as insurance against rainfall variability as different crops are affected differently by climate events (Adger *et al.*, 2003). The second strategy focuses on crop management practices geared towards ensuring that critical crop growth stages do not coincide with very harsh climatic conditions such as mid-season droughts. Crop management practices that can be used include modifying the length of the growing period and changing planting and harvesting dates (Orindi and Eriksen 2005).

According to Blanc (2011), Adaptation measures are commonly categorized according to their level of implementation. Farm level adaptations consist of changes in crop selection agronomic practices undertaken by farmers. Regional, national and international adaptations involve trade adjustments and modifications to public policies led by government or institutions.

Although farm level adaptation has to be supported by policies (Deressa T.T *et al.* ,2008) to have a better output for the struggle against the change in climate, they have a huge contribution to the overall national adaptation effort.

Blanc (2011) studies how climate change can be adopted at farm level. She reviewed all possible adaptation measures and come up with three main categories: Crop selection adaptation measures, crop management adaptation measures and multiple adaptation measures.

Under crop selection measures farmers can alter crop mix either by selecting better suited varieties of the current set of crops or by growing different crops. Better varieties that have properties likely to be relevant in a warming climate like late maturing, heat resistant and pest and disease tolerant can be used to achieve higher yield under changed climate conditions.

Under crop management measures farmers can modify cultivation methods to increase crop productivity and thus lessen the effect of climate change. The most commonly practices under this are fertilizer application, crop timing and water management.

The third measure - the combination of different farm level adaptation measures- is likely to increase the benefit or reduce damages from climate change on crop productivity by greater amounts than when a single measure is implemented. She supported her arguments with the study conducted by Rosenzweig and Parry (1994) which consider two farm level adaptations. Minor level adaptations include changing sowing dates, increasing irrigation levels and the use of more suitable varieties already available. Major level adaptations involve a greater shift in planting dates, new irrigation systems, increasing fertilization and development of new cultivars.

2.4. Rainfall and Seasons of Ethiopia

Ethiopia mean annual rainfall ranges from about 2000 mm over some pocket areas in the Southwest to about less than 250 mm over the Afar lowlands in the Northeast and Ogaden in the Southeast. The average annual rainfall of the country is estimated 775mm (NMSA,2001). Based on annual rainfall patterns Ethiopia seasons are classified into three periods (NMSA,1996 and Gebru, 2007). The first is the main rainy season from June to September, the second is the dry season from October to December/January, and the third is the small rainy season from February/March to May, known locally as *Kiremt*, *Bega* and *Belg* respectively. A brief description of the mechanisms for rainfall formation for each season is given below (NMSA, 1996 and Seleshi and Zanke, 2004).

During *Kiremt* the air flow is dominated by a zone of convergence in low-pressure systems accompanied by the oscillatory inter-tropical convergence zone (ITCZ) extending from West Africa through the north of Ethiopia towards India. Major rain producing systems during *Kiremt* are: the northward migration of the ITCZ; development and persistence of the Arabian and the Sudan thermal lows along 20 °N latitude; development of quasi-permanent high pressure systems over the South Atlantic and south Indian Oceans; development of the tropical easterly jet and its persistence; and the generation of the low-level 'Somali jet', which enhances low level southwesterly flow. It is to be noted that *Kiremt* rainfall covers most of the country with the exception of the south and southeast of Ethiopia.

During *Bega*, the country predominantly falls under the influence of warm and cool northeasterly winds. These dry air masses originate either from the Saharan anticyclone and/or from the ridge of high pressure extending into Arabia from a large high over central Asia (Siberia). However, very occasionally, northeasterly winds get interrupted when migratory low-pressure systems originating in the Mediterranean area move eastward and interact with the equatorial/tropical systems, resulting in rainfall over parts of central Ethiopia. In addition to this, occasional development of the Red Sea Convergence Zone (RSCZ) affects coastal areas. In *Bega*, most of the country is generally dry; the exception is the south and southeast of Ethiopia, which receives its second important seasonal rainfall in this period.

The *Belg* season coincides with the domination of the Arabian high as it moves towards the north Arabian Sea. Major systems during the *Belg* are the development of a thermal low (cyclone) over the south of Sudan, and winds from the Gulf of Aden and the Indian Ocean highs that are drawn towards this centre and blow across central and southern Ethiopia. These moist, easterly and southeasterly winds produce the main rains in southern and southeastern Ethiopia and the *Belg* rains to the east-central part of the northwestern highlands.

A study conducted by Seleshi and Zankel (2004) analyze recent changes in annual, June–September and March–May rainfall totals and also rainy days over Ethiopia and they have found that the Ethiopian Highland *Kiremt* rainfall is positively correlated to both the equatorial eastern Pacific sea level pressure and the Southern Oscillation Index (SOI), and is negatively correlated to SST over the tropical eastern Pacific Ocean. As confirmed by other studies (NMSA,1996 and Gebru,2007) this study also confirmed that warm El Nino–southern oscillation (ENSO) episodes are associated with below-average *Kiremt* rainfall over the Ethiopian Highlands. Warm SSTs over the South Atlantic Ocean tend to favor enhanced rainfall over the Ethiopian Highlands. In summary the study concluded the following:

1. There is no trend in the annual, *Kiremt* and *Belg* rainfall totals and rainy days over central, northern and northwestern Ethiopia in the period 1965–2002;
2. In contrast, the annual and the *Kiremt* total rainfall in eastern and southern Ethiopia show a significant decline since 1982; and
3. The *Kiremt* rainy days in eastern Ethiopia show a significant decline since about 1982, compared with the period 1965–81.

2.5 Temperature of Ethiopia

Universally, temperature is the quantity that tells us how hot or cold something is relative to some standard value. It is a measure of the kinetic energy of a substance, that is, the average speed of its atoms and molecules – the higher the speed, the higher the temperature and vice versa (Ahrens, 2005). In this specific study, however, the term temperature is used to designate the degree of coldness or hotness of atmosphere near the earth’s surface. This atmospheric temperature is measured in Celsius, Kelvin, and Fahrenheit scales.

Basically, temperature is governed by the solar energy coming from the sun. Nevertheless, air temperature near the earth's surface depends on such factors as the type of soil, its moisture content, and vegetation cover. When the soil is a poor heat conductor (as loosely packed sand is), heat energy does not readily transfer into the ground. This allows the surface layer to reach a higher temperature, availing more energy to warm the air above. On the other hand, if the soil is moist or covered with vegetation, much of the available energy evaporates water, leaving less to heat the air. This relationship suggests that cooler surface air temperatures saturated by water vapor above landmasses covered by vegetation than those without. This in turn has an implication on the potential of vegetation in the processes involved in convective local precipitation (Ahrens, 2005).

Another important feature of the temperature distribution (Hartmann, 1994) is the decline of temperature with height above the surface in the lowest 10-15 km of the atmosphere.

2.5 The Ethiopian Growth and Transformation Plan (GTP) and Climate-Resilient Green Economy (CRGE)

The GTP and CRGE put agriculture as a basis of economic growth. The GTP is a shift from largely depending on foreign investment to a locally driven economy. In the GTP agriculture envisaged to play a major role in earning the country's required revenue, contributing 12% to the GDP and evolves into agro industry. On the other hand, the CRGE initiative could help the country achieve its development goals while limiting 2030 GHG emissions to around today's 150 Mt CO2e – around 250 Mt CO2e less than estimated under a conventional development path. Under this document the cultivation of crops contributes to the concentration of greenhouse gases mainly by requiring the use of fertilizer (~10 Mt CO2e) as well as by emitting N2O from crop residues reintroduced into the ground (~3 Mt CO2e). In this case the CRGE well considered agriculture production as not only just affected by climate change, but also have the potential to mitigate or exacerbate climate change trends (it is a significant emitter of GHG and a potential sink for GHG). According to the CRGE (2011), the five-year growth rates (11 %) must be sustained for 15 years to become the middle income country by 2025. The growth will result in a significant shift in GDP shares where agriculture would contribute only 29% to the GDP.

Chapter 3. Materials and Methods

3.1 Description of the study area

3.1.1 Location and topography

Bassona Worana Woreda is located 10°01’–10°53’ North and 36°04’–36°26’ East in Semen Shoa Zone of Amhara Regional State in the North western part of the country which is 130 km away from Addis Ababa. The altitude of Bassona Worana Woreda ranges from 1,500 m to 3,400m above sea level. The Woreda has about 139,900 hectares of land. About 70% of the land is plain land, 23% is rugged expanse, and 7% is mountainous and hilly. The area lies in four climatic zones consisting of 50% *Dega* (cold), 38% *Woynadga* (temperate), 10% *Kolla* (arid) and 2% *Wurch* (arid cold). Bassona Worana Woreda is one of the 27 Woredas in Semen Shoa Zone of Amhara Regional State.

The higher portions of the area lie on high ground over 3400 m above sea level and constitute an undulating tract, flat and mountainous landscape. The plateau breaks up on both sides in the most spectacular fashion. To the north-west of this plateau lie a series of gorges, all belonging to the Blue Nile system opening up with extreme abruptness. The river to the east drains to Awash Tributary system (D.R. Buxton,1949)

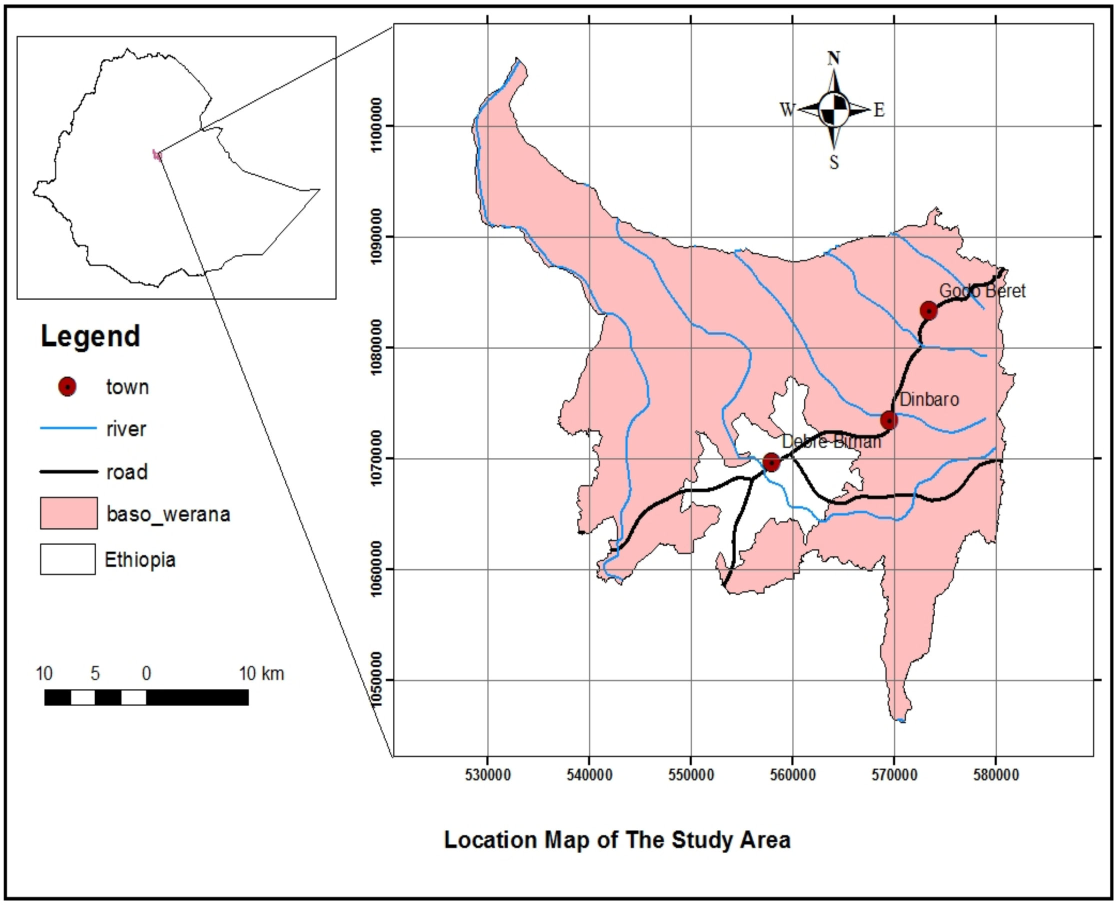


Figure 2. Location Map of Bassona Worana

3.1.2 Climate

As in the other part of the country rainfall in central highland depends on the Position of ITCZ, topography and aspect. The area receives its long rains June-September (Kiremt rain) and small rains in March/April (Belg rain).

The mean annual rainfall at Debre Brehan is 897.8 mm. It has a one-season rainfall pattern with extended rainy season from June to half of September and with the peak season is in July. However, the growing period is indicated by the graph where the graph of the rainfall is above the graph of half evapo-transpiration, i.e. from the mid of June to almost the half of October (Figure 3). The coldest month occurs in November while the hottest months are May and June . Generally, Debre Brehan fall under tepid to cool sub-moist mid highlands (SM2-8) agro-ecological zone (NSRC,2006).

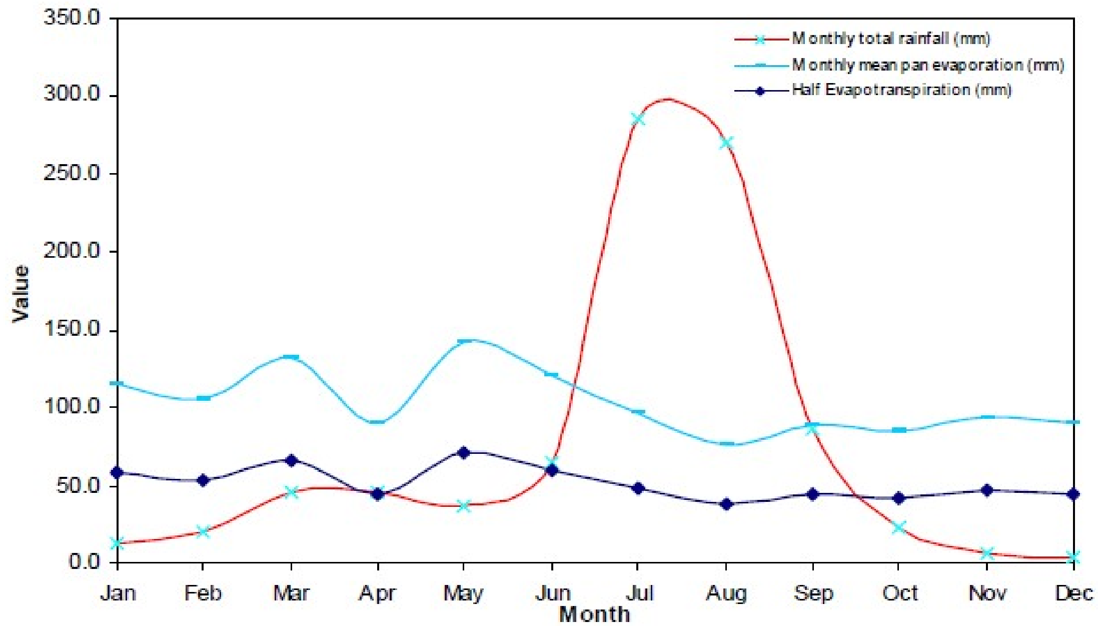


Figure 3. Precipitation, evapo-transpiration and half evapo-transpiration (source: National soil research center, 2006)

3.1.3 Agriculture and socio-economy

The Woreda has 30 rural and one urban kebeles. In 2010, the population of the Woreda reached about 128,556(48.8 % females). The population growth rate is 2.9%. Around 96% of the population depends on agriculture for its livelihood, while the remaining 4% is engaged in trading and other off farm activities. The Woreda has about 139,900 hectares of land. About 70% of the land is plain land, 23% is rugged expanse, and 7% is mountainous and hilly. An estimated 31.6% of the land is arable, 17.9% grazing land, 11.7% forest land while the remaining 38.8% is built-up area and wasteland. Agriculture is both shifting cultivation and mixed farming. According to the woredas agricultural office the dominant cultivated crops are barley, wheat, teff, sorghum, bean and lentil.

The farmland has low productive capacity resulting from removal of natural vegetation and soil erosion. The poor farming methods, deforestation and overgrazing contribute to the degraded condition of the land. As in other parts of the country, mixed agriculture is the main source of livelihood for almost all the people in the Woreda. Peoples' livelihood large depends on crop and livestock production. Crop production is very small. Livestock productivity is also low, which is associated with poor feed management practices. Agricultural in Basona Worana Woreda is subsistence farming carried out by small-scale farmers. The people use oxen plow as main means of cultivation and tools for cultivating steep slopes (locally called *Domegna*).

3.2 Data

3.2.1 Meteorological data

Monthly precipitation and temperature data was obtained from the Ethiopian National Meteorological Service Agency (NMA) from two stations – Debre Brehan and Gudoberet. The data covers the period from January 1980 up to December 2009 for Debre Brehan Station and from January 1988 up to December 2009 for Gudoberet station. The nearest Meteorological station, Debre Brehan (9^{o}40' N, 39^{o}30') is located 17 km south west of Debre Brehan town at an altitude of 2750 m above sea level.

Table 2: Location of Meteorological stations

Station Name	Class	Zone	Wereda	Latitude (º ")	Longitude (º ")	Altitude (Meters)
Debre Brehan	Principal	North Shewa	D/Berhan	09 38N	39 35E	2750
Gudoberet	3	North Shewa	Basona Worana	09 45N	39 04E	2600

3.2.2 Crop data

Time series data of the four major grown crops in the study area (teff, sorghum, wheat and barley) in terms of area coverage, production and yield were collected from the Bassona Worana Woreda Agriculture and Rural Development Office for the years 2002-2009. The study considered only the *meher* season because most of the land is cultivated during this season.

3.2.3 Socio-economic survey

The study area covered both the lowlands and the highlands that vary in altitude. Sampling was deliberately made to base this variation. The socio-economic data collection employed a two stage stratified sampling technique. The first stage - selection of representative Kebeles and the second stage - selection of households in each Kebele. Four Kebeles were selected out of the 31 rural Kebeles and 30 households were interviewed from each kebeles equally considering the variation in altitude.

Table 3: Sample selection

S.N	Kebele Name	Total households	Selected households
1	Gosehbado	953	30
2	Gudoberet	1015	30
3	Angolela	868	30
4	Debele	920	30
Total		3,756	120

Source: Bassona Worana Woreda Agriculture Office, 2010

Both open ended and close ended questions used to ask farmers on perceptions of climate change and adaptations used by farmers. Both qualitative and quantitative data relevant for the study were collected from farmers, key informants, community groups and line department experts of the various government offices. The structured questionnaires were prepared in advance and amended following the pre-testing procedure. Primary data then collected from selected sample households.

3.3 Method of Data Analysis

3.3.1 Meteorological data analysis

3.3.1.1 Rainfall

Analysis of the rainfall data involved characterizing long-term mean values, and calculation of indices of variability and trends at monthly, seasonal and annual time series. The annual and seasonal Variability of the rainfall are examined based on inter-seasonal spread of the rainfall: February-March-April-May (*Belg*) and June-July-August-September (*Kiremit* or main) rainfall. Coefficient of variation (CV) was calculated as the ratio of standard deviation to the mean in order to study monthly variability of rainfall in the study area. Precipitation Concentration Index (PCI) was used as an indicator of annual rainfall concentration (Oliver,1980). This index, described as:

$$PCI_{annual} = \frac{\sum Pi2}{\sum (pi)2} \text{ x } 100$$

Where: Pi = the rainfall amount of the i^{th} month; and

Σ = summation over the 12 months.

According to De Luis et al, (2011), PCI can be further used for predicting seasonal rainfall concentration.

$$PCI_{seasonal} = \frac{\sum Pi2}{\sum (pi)2} \text{ x } 33.3$$

PCI values of less than 10 indicate uniform monthly distribution of rainfall, values between 11 and 20 indicate high concentration, and values above 21 indicate very high concentration (Oliver,1980).

The standardized rainfall anomalies were also calculated and graphically presented to evaluate inter-annual fluctuations of rainfall in the study area over the period of observation, which is described as:

$$SRA = \frac{(Pt - Pm)}{\sigma}$$

Where SRA = standardized rainfall anomaly, Pt = annual rainfall in year t,

Pm = long-term mean annual rainfall over a period of observation and

σ = standard deviation of annual rainfall over the period of observation.

The drought severity classes are extreme drought (SRA < -1.65), severe drought (-1.28 > SRA > -1.65), moderate drought (-0.84 > SRA > -1.28), and no drought (SRA > -0.84).

Trend analysis has been done by using non-parametric Mann- Kendall test. This is a statistical method which is being used for studying the trend in environmental data time-series. Mann-Kendall test had been formulated by *Mann (1945)* as non-parametric test for trend detection and the test statistic distribution had been given by *Kendall (1975)* for testing non-linear trend and turning point. Many studies (Seleshi and Zanke, 2004; karpouzos *et al.*,2010; Al Buhairi, 2010; Drapela and Drapelova, 2011 and Mondal *et al.*, 2012) used Man- Kendall test for trend analysis.

3.3.1.2 Temperature

The standard deviation (σ) and mean (μ) of the maximum (T*max*), minimum (T*min*) and mean (T*mean*) temperatures were used to determine the variability of temperature. From the basic temperature data (T*max*, T*min* and T*mean*) standard deviation (σ) have been statistically computed for each month, year and the three seasons; *Bega, Belg and Kiremt.* Annual temperature deviation from the mean were calculated and plotted to assess below-normal and above normal temperature. Similar methodology was employed to assess the trend of temperature with that of rainfall.

3.3.2 Relation between crop production and climatic variable

Correlation and regression methods were used to examine relationships between monthly and seasonal rainfall and crop production. The patterns of inter-annual rainfall variability and fluctuations in cereal production are also presented graphically to gain a better insight of rainfall-crop production relationships in the area.

3.3.3 Socio-economic data analysis

The data collected from household survey were coded and analysed by appropriate statistical computer software using Statistical package for social sciences (SPSS 13). Descriptive statistics and correlation analysis were employed for the data analysis, where the outputs were presented in the form of tables, graphs and charts. Excel spreadsheets were also used to analyse and summarize some of the data that were not entered in SPSS.

Results from household surveys were used to verify the climate change impact and crop production, as well as to generate information on farmers' perceptions of the changes in temperature and rainfall in the district and their adaptation strategies to cope with climate change.

Chapter 4: Results and discussions

4.1 Rainfall data analysis

4.1.1 Annual, seasonal and monthly rainfall variability

4.1.1.1 Annual rainfall variability

The precipitation data were analyzed for each station separately to determine the monthly, seasonal and annual variability and spatial distribution of the study area (Table 4). The long term mean annual rainfall in the two stations varies from slightly over 900 mm in Debre Brehan (DB) Station to more than 1,190 mm in Gudoberet (GB) with a coefficient of variability (CV) 13% and 43% respectively. The CV revealed higher annual rainfall variability within the surrounding of GB station.

The area receives maximum annual rainfall of 1083.8mm and 1,919.6mm in the year 2007 while a minimum annual rainfall exhibited in 1981 (636.5mm) and 1991 (193.5mm) in DB and GB stations respectively.

Table 4: Annual, seasonal and monthly rainfall variability (1980-2009)

	Debre Brehan station		PCI	Gudoberet Station		PCI
	Mean	CV		Mean	CV	
January	12.8	1.05		21.67	1.28	
February	21.11	1.01		15.85	1.2	
March	49.28	0.84		41.1	0.97	
April	47.14	0.67		51.19	0.66	
May	41.2	0.93		43.09	0.98	
June	51.1	0.83		76.69	0.68	
July	295.92	0.29		374.61	0.49	
August	269.03	0.26		324.76	0.6	
September	82.35	0.44		141.78	0.67	
October	20.31	1.16		66.12	1.39	

November	6.23	1.95		23.83	1.75	
December	3.94	1.82		11.31	1.73	
Bega	43.29	0.75		122.93	0.996	
Belg	158.73	0.37		151.23	0.54	
Kiremt	698.4	0.19		917.84	0.44	
Annual	900.42	0.13	23.97	1192	0.43	19.97

Below 700mm rainfall were recorded in three years (1981,1984 and 1987) in DB station whereas four years (1989,1991,1992 and 1993) in GB. These all are evident of different spatial rainfall distribution within the study area even in a short distance. This might be happened because of the area topography and vegetation cover. GB station is surrounded with high vegetation cover which was planted during fuel wood plantation program at the time of *Derg* regime and also found at the edge of two tributes (Awash and Nile).

As indicated by other studies (Seleshi and Zanke, 2004; Woldeamlak, 2007; H. Chung *et al.*, 2008 and Dereje *et al.*, 2012,), the study also found out that annual total rainfall was irregularly distributed with high precipitation concentration in some part of the period (PCI 24 and 20 for DB and GB respectively).

Figure 4 presents a graphical display of the standardized rainfall anomaly of DB station for each year. DB is a principal station and more or less has the same overall characteristics as the other station in spite of different spatial distribution of rainfall.

The data shows that there were dry years with SRA below -1.28 and wet years with SRA above -0.84. Generally, extreme dry years were observed at 1981, 1984, 1987 and 1989. The variation pattern seemed to follow the El Nino and Southern Oscillation episodes (Seleshi and Zanke, 2004). The area was drier than normal during this period, with an average of 220 mm less rainfall than long term annual mean. The drier periods of below normal rainfall were evident, even at national level in the 1980s (Seleshi and Zanke, 2004). The wettest periods were in 1986 and 2007.

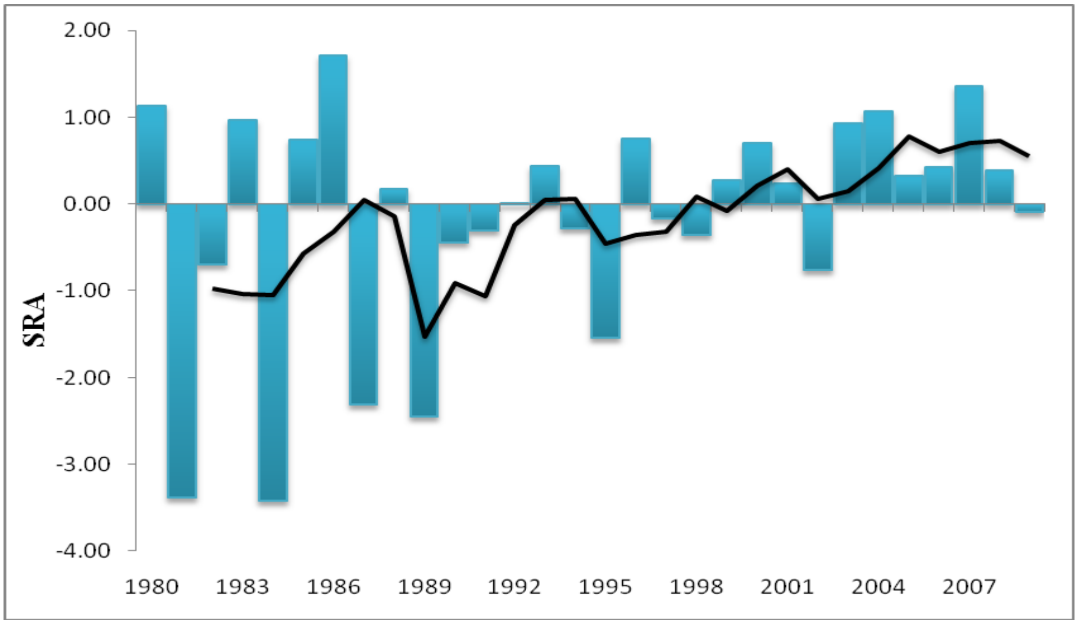


Figure 4. Standardized rainfall anomalies (1980-2009)

(Bold line- Three years moving average)

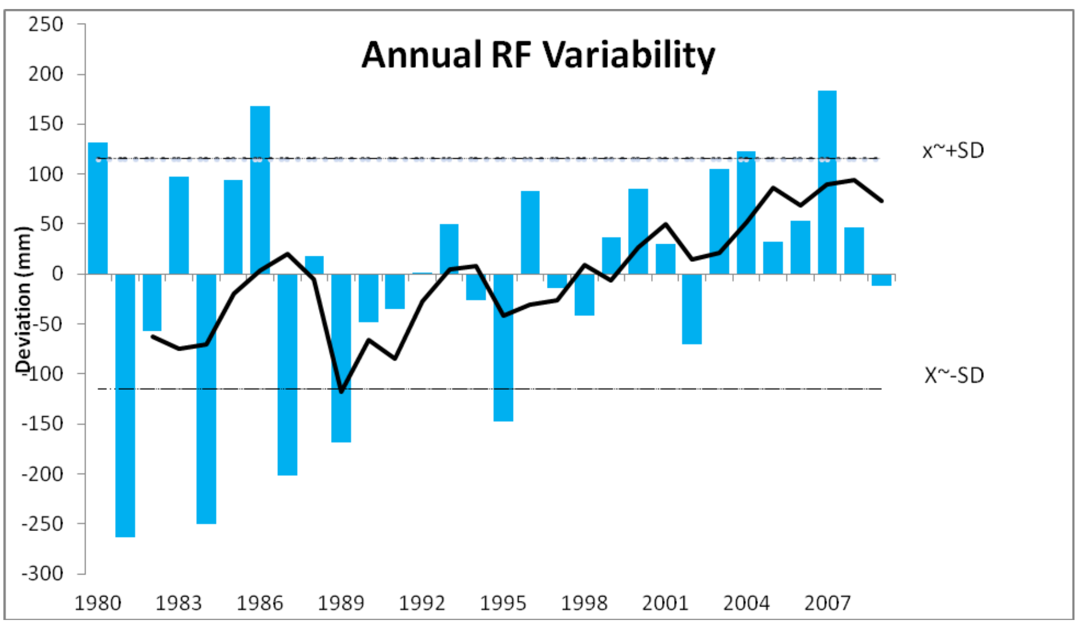


Figure 5. Annual Rainfall Variability (1980-2009)

(Bold line- Three years moving average)

Annual rainfall showed positive anomaly for the 1999–2009 decade except 2002 and 2009 when a slight negative anomaly has been occurred. During the wettest year's annual rainfall have been 1.71 times the standard deviations above the long term (1980 – 2009) average. However, annual rainfall was found 3.42 times the standard deviation below the long-term (1978–2008) average during the drier years.

The study found out that the year 1984 was driest year in Bassona Worana Woreda. The study conducted by Woldeamlak (2009) and Dereje *et al.* (2012) also noted that the year 1984 was come up with the lowest rainfall record in the Amhara region and showed the worst drought year.

As in the Amhara region, the rainfall in Bassona Worana Woreda was characterized by sporadic fluctuation of wet and dry years. The present study showed thirteen years negative deviations of areal annual rainfall of the woredas from its long-term average, most of which was occurred during the 1980s. The result agrees with the result found by Woldeamlak (2009) and Dereje *etal.* (2012). However, the rainfall showed some recovery and faintly progressed above the mean for the last decade (1999-2009). These years were the wettest years in the woredas as well as in the Amhara region.

4.1.1.2 Monthly rainfall variability

Long term monthly average is least for the month of December for all years (3.94 mm and 11.31mm) followed by November and January while maximum rainfall occurs in the month of July (295.92 mm and 374.61mm) followed by August in both DB and GB stations respectively. Almost all months nearly showed high variability of rainfall distribution except July and August (CV >50%) (Table 4).

4.1.1.3. Seasonal rainfall variability

Mean seasonal rainfall was obtained by summing the corresponding mean monthly rainfall, which was originally derived from the rainfall dataset. For example, the Belg rainfall for 2000 was obtained by summing the mean monthly rainfall records for February, March, April, and May of 2000. Mean seasonal rainfall was calculated for the *Bega, Belg* and *Kiremt* seasons of the two stations individually. .

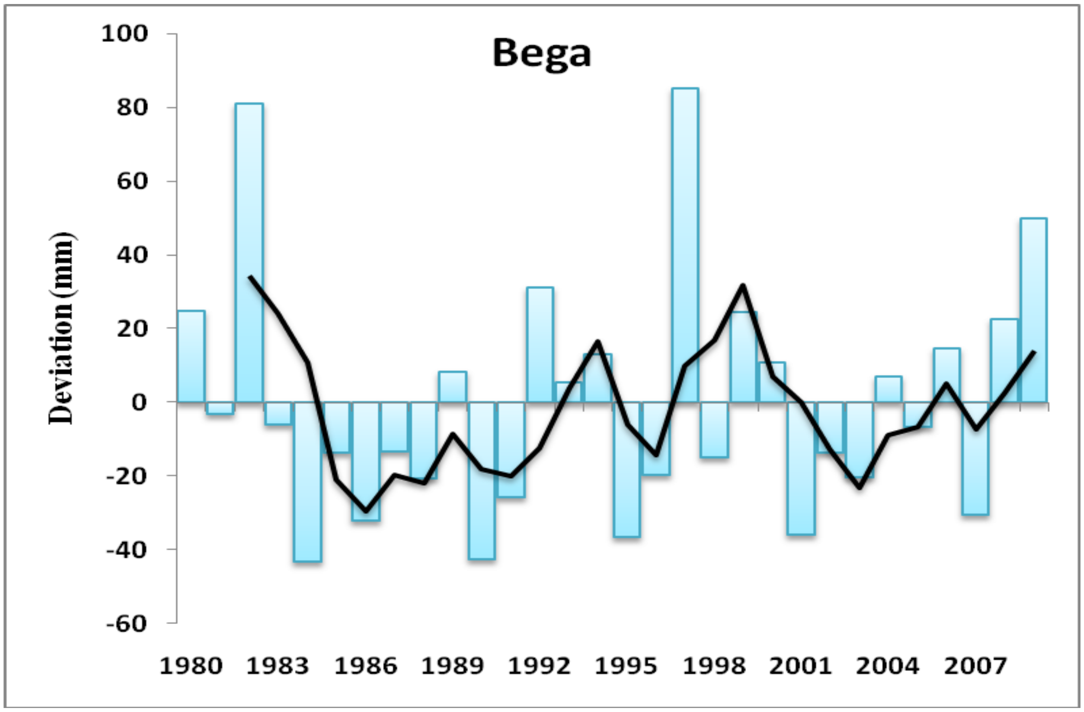
The result showed a unimodal rainfall type where nearly 77% of the rainfall was concentrated in the four months of the *Kiremt* season (June-July-August-September). The rainfall showed moderate to higher inter-annual variability as shown by the coefficients of variations (Table 4). The *Belg* (small rainy season, February-May) and the *Bega* (dry season, October-January) rainfalls are much more variable than the *Kiremt* (main rainy season, June-September) rainfall (Figure 6).

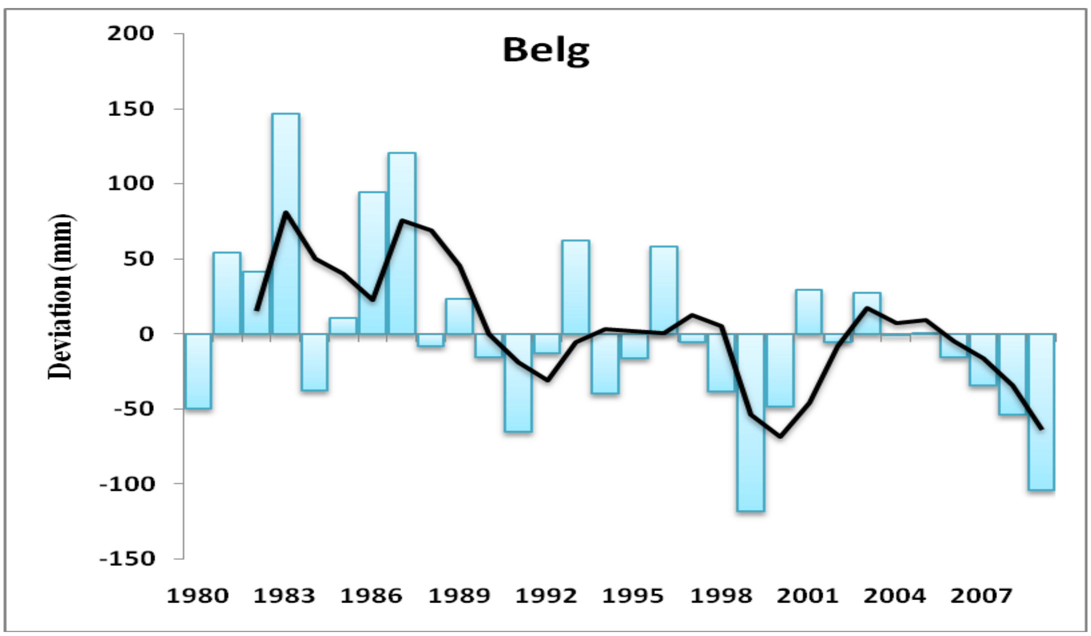
The *Belg* rainfall variability was much higher as compared to the other seasons. The biggest differences in variability were found at GB station both during the full year as well during the *Belg* seasons. The year to year variability of the *Belg* rains in Ethiopia was also high (Seleshi and Zanke, 2004). The *Belg* rains constituted about 18% and 13%

of the annual rainfall in DB and GB stations respectively. The lowest rainfall intensity for the *Belg* season was found in the month of February. According to the study conducted by Rosell and Holmer (2007), *Belg* onsets have a great impact on crop production. Dry spells- more than seven days in a row without rain during *Belg* onsets (February and March), can be devastating to the crops cultivated during the *Belg* season.

Considering *Kiremt* rainfall variability, which is directly affecting agricultural production over most parts of Ethiopia (Seleshi and Zanke, 2004), DB station exhibited a coefficient variation of 19% whereas 44% coefficient of variation were recorded at GB station.

Bega season showed high variability (CV>70%) where the months of November and December exhibited the minimum amount of rainfall. This goes in line with the idea of Woldamlak (2007) where the rainfall variability was higher in areas of low annual rainfall. According to Seleshi and Zanke (2004), the Bega season lasts from October until January and is caused by northeasterly winds, which gives the horn of Africa dry conditions. The Bega gets interrupted when migratory low-pressure systems, originating in the Mediterranean area, move eastward and interact with the equatorial/tropical systems. This results in rainfall over parts of central Ethiopia where Bassona Worana is located.


Bega
Deviation (mm)
100
80
60
40
20
0
-20
-40
-60
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007


Belg
Deviation (mm)
200
150
100
50
0
-50
-100
-150
1980
1983
1986
1989
1992
1995
1998
2001
2004
2007

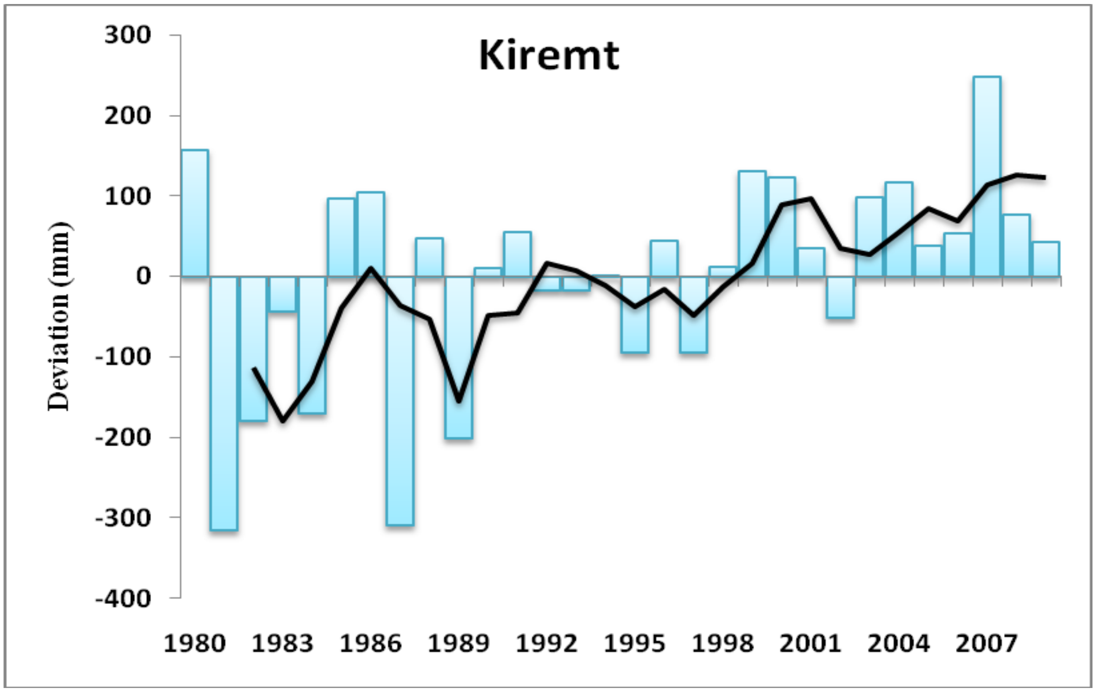


Figure 6. Seasonal rainfall variability deviation from the long term mean (Bold line-Three years moving average)

4.1.2 Annual, seasonal and monthly rainfall trend

Trend analysis of the study area were carried out for 30 (DB station) and 22 (GB station) years of precipitation data. Mann-Kendall and Sen's Slope Estimator were used for determining the trend. Table 5 provides the calculation of the Mann-Kendall statistics (S), *P*-value and sen's slope (b) derived from each stations.

Table 5: Monthly, seasonal and annual rainfall trend

	Debre Brehan station			Gudoberet Station		
	S	***P* value**	**B**	**S**	***P* value**	**B**
Annual	99	0.081*	4.857	115	0.01**	43.183
Bega	38	0.509	0.508	77	0.031**	7.833
Belg	-117	0.038**	-2.88	63	0.081*	5.805
Kiremt	129	0.022**	6.3	101	0.004***	34.425
January	50	0.377	0.023	44	0.224	0.688
February	-58	0.306	-0.333	-20	0.589	-0.15
March	-136	0.016**	-1.4	26	0.481	0.9
April	40	0.486	0.558	104	0.004***	3.025
May	-57	0.321	-0.591	47	0.194	1.662
June	102	0.071*	1.05	93	0.008***	4.318
July	215	<0.0001***	5.563	57	0.116	7.613
August	11	0.86	0.343	81	0.023**	15.863
September	-39	0.502	-0.548	121	0***	9.41
October	-52	0.363	-0.2	73	0.042**	3.5
November	94	0.074*	0	76	0.03**	0.7
December	63	0.252	0	44	0.207	0.1

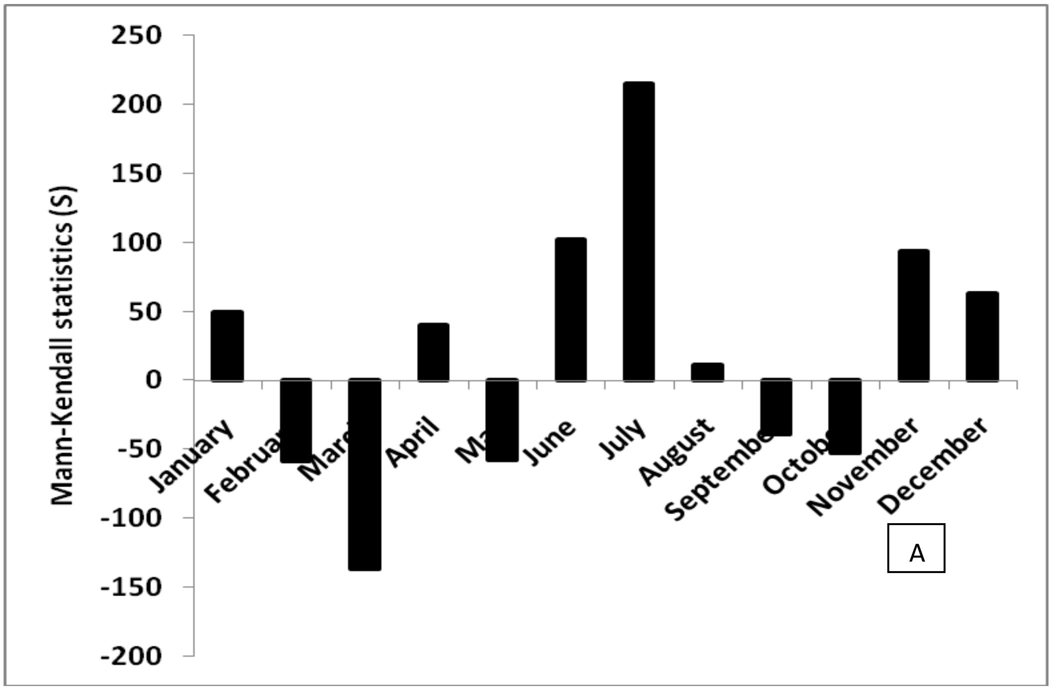
*Significant at 0.1 level; **Significant at 0.05 level; ***Significant at 0.01 level

In the Mann-Kendall test the *P*-value revealed significant level whereas Mann-Kendall statistics (S) and Sen's slope revealed the direction of the trend for annual, seasonal and for months from January to December.

The result showed that there is a decreasing of rainfall trend for the months of February, March, May, September and October in DB station and an increasing trend in GB station except for the month of February. The down ward trends for all months were not found statistically significant except for the month of March (DB station). On the other hand, upward trend were found statistical significance for most of the months. Especially the month of July which is the major contributor to *Kiremt* rainfall (40-42%) possesses an upward trend with a statistical significance level of 0.01 at DB station.

Regarding the seasonal analysis, the following remarks are noted. *Bega* revealed an upward trend in both stations which is statistically significant for GB station. *Kiremt* rainfall showed an increasing trend with statistical significant in both stations. The *Belg* rainfall exhibited a downward trend statistically significant at 0.05 at DB station and an upward trend statistically significant at 0.1level at GB station. Overall the annual rainfall trend revealed an increasing trend in both stations statistically significant at 0.1 and 0.05 levels (DB and GB stations respectively).

Unlike studies of Woldeamlak and Conway (2007) in drought prone areas of Amhara region (Northwestern Ethiopia), Seleshi and Zanke (2004) in central, northern, and northwestern Ethiopia and Conway et al. (2004) in the central Ethiopian highlands and Conway (2000) in northeastern Ethiopian highlands, this studies found that there is a significant and clear trend in the annual rainfall pattern.



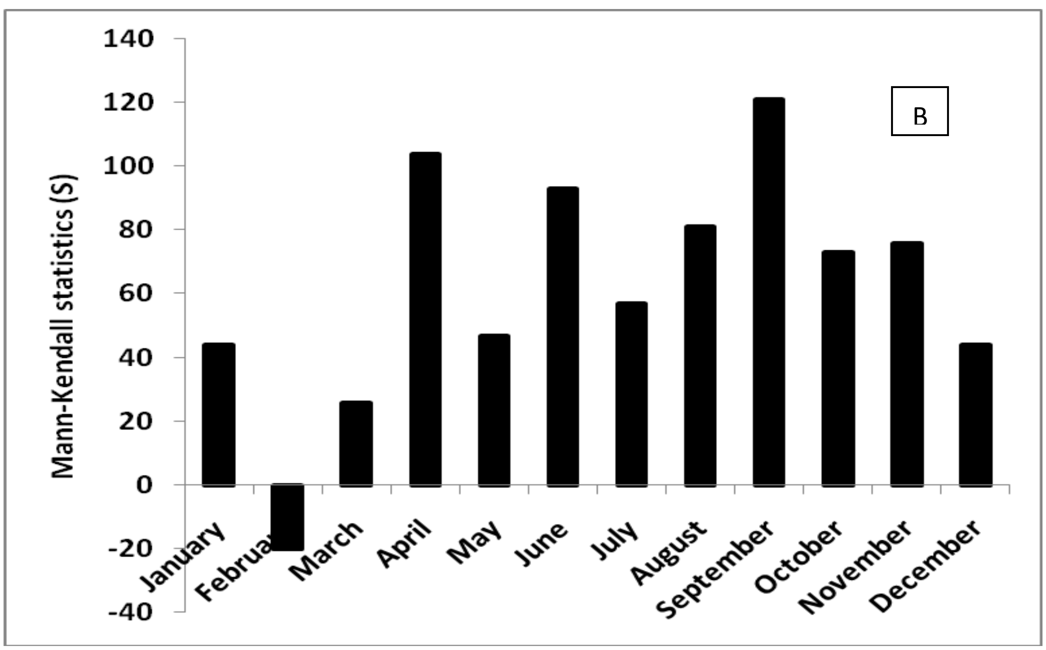


Figure 7. Mann-Kendall rainfall trend analysis of DB station(A) and GB station (B)

4.2 Temperature data analysis

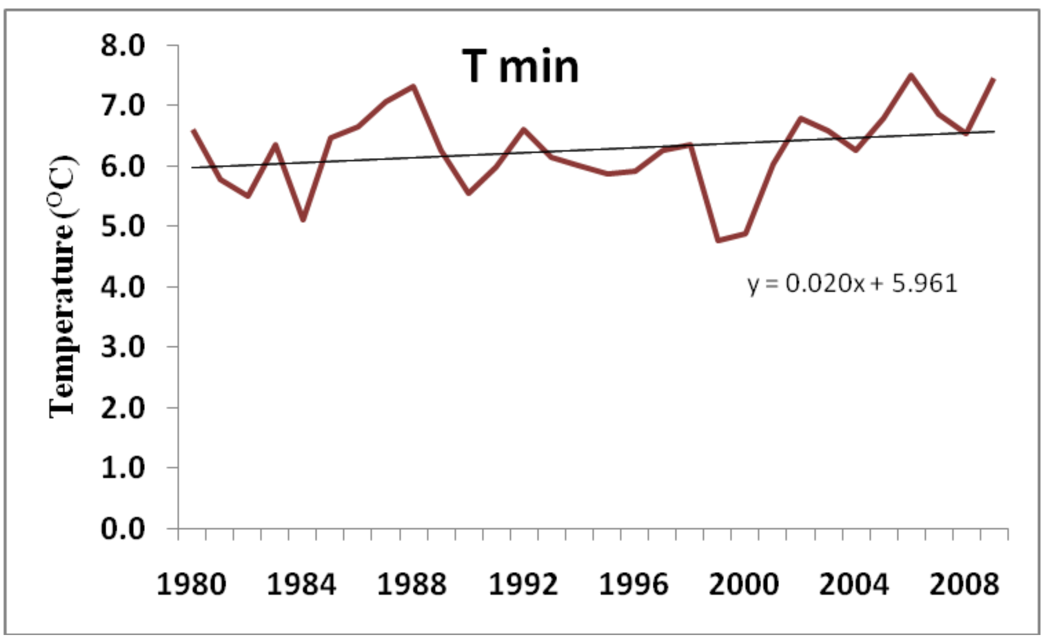
4.2.1 Temperature variability

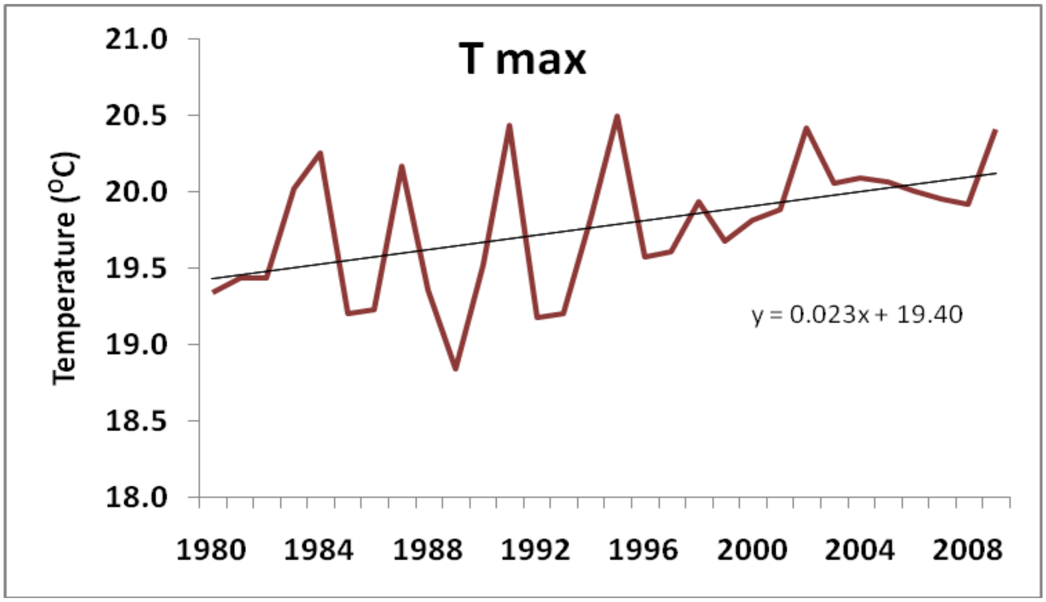
The standard deviation (σ) and mean (μ) of the maximum (**Tmax**), minimum (**Tmin**) and mean (**Tmean**) temperatures are specified in Table 6. From the basic temperature data, (**Tmax**), (**Tmin**) and (**Tmean**) temperature, along with their standard deviation (σ) have been statistically computed for each month, year and the three seasons; *Bega*, *Belg* and *Kiremt*. DB station, as a principal, was used to analyze the variability and trends of temperature.

Table 6: Monthly, seasonal and annual temperature mean (μ) and standard deviation (σ)

	T min (°c)		**T max** (°c)		**Tmean** (°c)	
	Μ	Σ	μ	σ	μ	Σ
January	4.55	2.07	19.64	0.96	12.09	1.13
February	6.12	2.69	20.45	1.04	13.28	1.35
March	7.72	1.61	20.81	0.95	14.26	0.94
April	7.80	1.05	20.68	1.16	14.24	0.67
May	7.36	0.95	21.51	1.02	14.43	0.60
June	7.41	0.97	21.79	1.14	14.60	0.64
July	8.86	0.53	18.71	1.27	13.79	0.61
August	8.91	0.64	18.25	0.70	13.58	0.43
September	7.22	0.70	18.78	0.58	13.00	0.41
October	3.55	1.22	18.61	0.68	11.09	0.69
November	2.24	1.64	18.80	0.62	10.52	0.95
December	3.05	2.16	19.05	0.56	11.05	1.18
Annual	6.28	0.68	19.78	0.44	13.03	0.42
Bega	3.40	1.12	19.04	0.50	11.23	0.64
Belg	7.25	1.17	20.86	0.79	14.05	0.73
Kiremt	8.09	0.44	19.40	0.56	13.74	0.35

Table 6 reports the temperature characteristics in the study area and it is clear from the table that, the mean monthly temperature was highest in June 14.60 ^{o}c and lowest in November 10.52 ^{o}c. However, the mean maximum temperature for June was 21.79 ^{o}c. On average, November was the coldest month of the year and June was the warmest (only slightly warmer than May). The lowest mean monthly temperature occurred in December 1998 (8.1 ^{o}c) and the warmest month ever recorded was March 1988 (17.5 ^{o}c). **Tmin** of December and November were exhibited a maximum variability (CV of 71% and 73% respectively) whereas the **Tmax** for all months was below 10%. The temperature for the average annual mean temperature is 13.03 ^{o}c with a CV 3% while the annual mean maximum temperature reached 19.78 ^{o}c (CV 44%) and the annual mean minimum temperature was 6.28 ^{o}c (CV 68%).





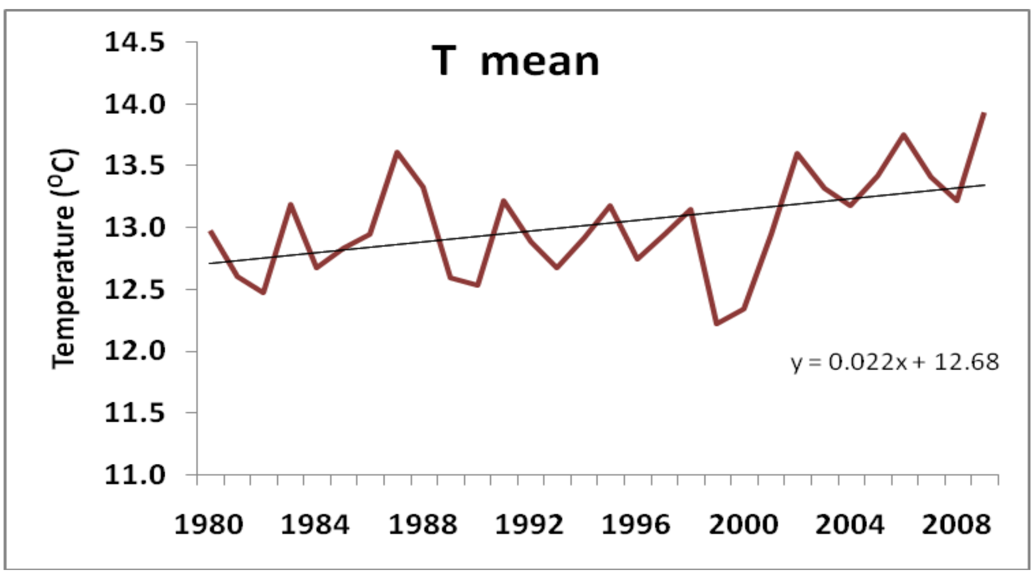


Figure 8. Temperature variability of T min, T max and T mean with linear trend line

4.2.2 Temperature trend

The results of the Mann–Kendall test statistics (S), significance level *p*-value and the Sen's slope (b) corresponding to the temperature variables trend are presented in Table 7. The statistically significant levels, high 0.01, medium 0.05 and low 0.1 were used.

Table 7: Temperature trend analysis

	T_{min} (°c)			T_{max} (°c)			T_{mean} (°c)		
	S	P value	B (°c/year)	S	P value	b (°c/year)	S	P value	b (°c/year)
Jan	79	0.166	0.061	93	0.101	0.026	119	0.035**	0.034
Feb	36	0.532	0.023	87	0.126	0.034	73	0.201	0.029
Mar	-69	0.228	-0.024	121	0.032**	0.044	25	0.671	0.004
Apr	21	0.724	0.01	69	0.228	0.039	89	0.117	0.025
May	13	0.832	0.004	133	0.018**	0.05	133	0.018**	0.03
Jun	133	0.018**	0.056	65	0.256	0.027	171	0.002***	0.042
Jul	138	0.009***	0.035	-95	0.078*	-0.034	-20	0.724	-0.005
Aug	105	0.063*	0.02	-1	1.000	0	43	0.457	0.01
Sep	-3	0.972	-0.002	133	0.018**	0.023	91	0.109	0.012
Oct	68	0.188	0.037	130	0.015**	0.039	138	0.006***	0.042
Nov	16	0.769	0.013	-22	0.681	-0.005	20	0.710	0.009
Dec	18	0.752	0.013	87	0.107	0.022	42	0.446	0.02
Annual	91	0.109	0.020	149	0.008***	0.023	147	0.008***	0.022
Bega	73	0.201	0.036	87	0.126	0.021	131	0.020**	0.033
Belg	7	0.916	0.004	131	0.02**	0.043	105	0.063*	0.029
Kiremt	105	0.063*	0.022	59	0.304	0.015	107	0.058*	0.013

There were warming trends in minimum, maximum and mean temperature during all seasons. The *Bega* mean temperature shows an increasing trend which is statistically significant at 0.05 level. **T max** and **T mean** also shows an increasing trend. However, these warming trends are not statistically significant. The *Belg* season of **T max** and **T mean** shows an increasing trend significant at 0.05 and 0.1 level respectively while **T min** shows warming trend but not significant.

The mean annual temperature and the mean annual maximum temperature shows an increasing trend, which is statistically significant at $P < 0.01$ level, while the mean annual minimum temperature is increasing but not significant. The linear trend of mean annual temperature has slope of +0.022 ^{o}c per year and this warming trend mainly comes from the mean annual maximum temperature.

The mean temperature shows an increasing trend for all months except July. Statistically significant increases of mean air temperature were noted for January and May at $P < 0.05$ and for June and October were noted at P < 0.01. **T min** shows a warming trend practically for all months except March and September and a significant trend were recorded for June, July and August at 0.05, 0.01 and 0.1 level respectively. Fig 6 shows increasing and decreasing trends of monthly and annual temperature for **T min** and **T max**. Fig 5 also shows the linear trend with a slope b for mean annual, mean annual maximum and mean annual minimum temperature.

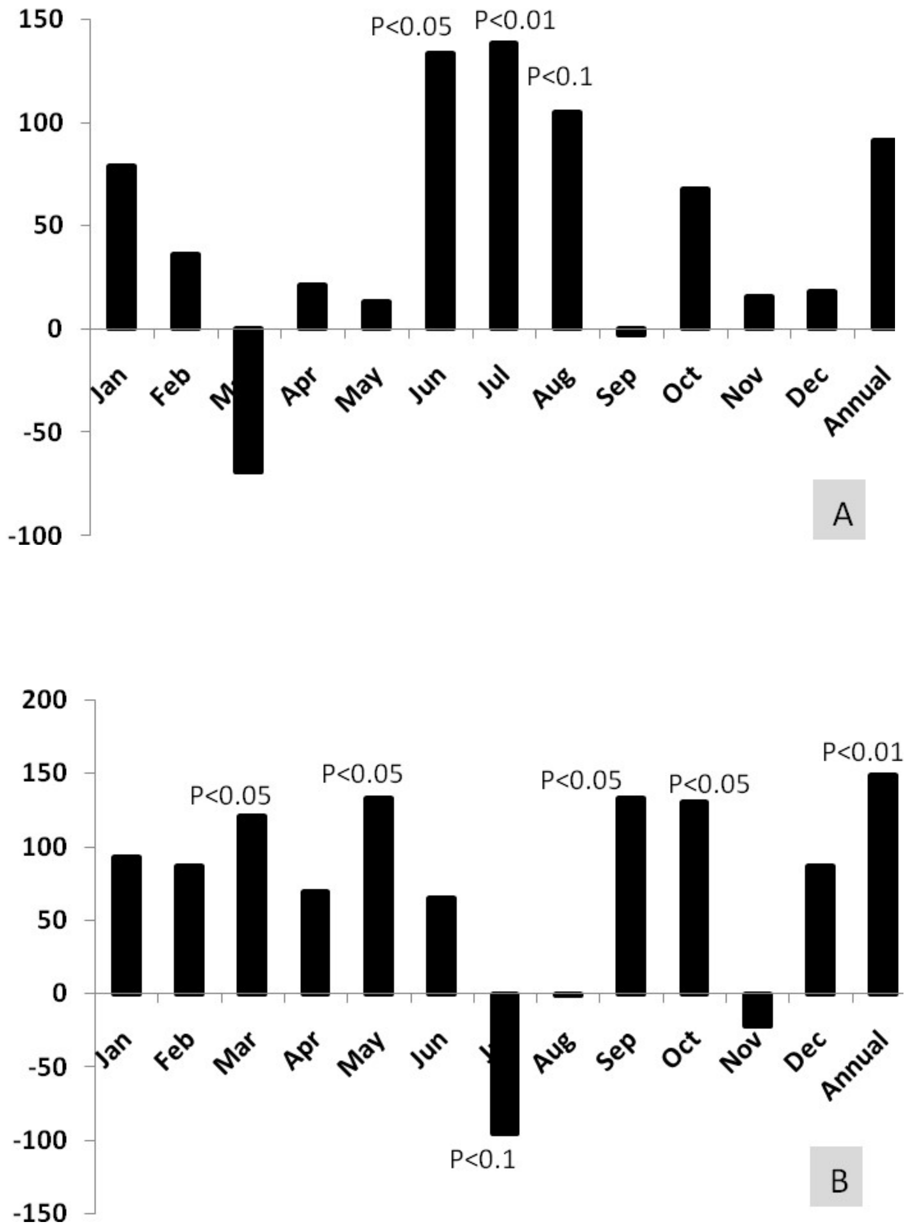


Figure 9. Monthly and annual T min (A) and T max(B) temperature trend with Mann–Kendall test statistics (S)

4.3 Climate variability (rainfall and temperature) and crop production relationship

4.3.1 Crop production trends

Table 8 presents a summary of area, total production, and yields (productivity/hectare) of cereals in BWW of North Shoa Zone, Amhara Regional State during the years 2002 - 2009.

Table 8: Summary statistics in area cultivated (ha), production (Qt) and yield (Qt/ha) of cereals in BWW.

	Area		Total Production		Yield (productivity/ha)	
	Mean	CV (%)	Mean	CV (%)	Mean	CV (%)
Teff	2411.16	0.27	36319.69	0.35	14.81	0.1
Wheat	5673.49	0.17	140445.54	0.41	24.07	0.3
Barely	7151.51	0.13	155282.88	0.29	21.34	0.17
Sorghum	3318.39	0.6	76173.50	0.49	24.87	0.18

Total main cereal production of the area was nearly 565,000 quintal in 2009, an increase of 65% compared to production in 2002. Total area allocated to main cereals, however, expanded by 3% over the same period although there were fluctuations within the years. It was obvious that in the highland areas there is no room for expanding cultivated land because most of lands suitable for crop production were used for cultivation. As a result, agricultural intensification can be considered as a main actor for increasing crop production. For example, wheat yield reached 38 Qt per hectare in 2009, exhibiting a 115 percent growth over eight years.

The main cereal according to land use was barely (39% of total main cereal land), followed by wheat (31%), sorghum (18%), and teff (13%). In terms of volume, barely also ranked first with 155 thousand Qts of output, followed by wheat, sorghum, and teff. The difference in area and output ranking indicates that sorghum yields are higher than yields of other cereals (25 Qts per hectare compared to 24 for wheat, 21 for barely and 15 for teff) despite the fact that sorghum exhibits the largest year-to-year variability in terms of area cultivated, total production and yield compared to the other cereals.

According to Alemayehu *et al.* (2011), in Ethiopia during the years 2005- 2008 cereals were grown on 73.4 percent of the total area cultivated, by a total of 11.2 million farmers. Together, these holders produce a yearly average of 12 million ton of cereals, which is 68 percent of total agricultural production. The five major cereals are teff, wheat, maize, sorghum and barley. Teff accounts for 28 percent of total cereal area. The BWW, as expected, has a very small contribution to the national crop production. For example, the total contribution to the national crop production for teff, wheat, barley and sorghum during the years 2002 -2009 was 0.2%, 0.6%, 1% and 0.4% respectively.

4.3.2 Crop production and rainfall

Table 9: Pearson correlation coefficient of cereal production with monthly, seasonal and annual rainfall

	Teff	Wheat	Barely	Sorghum
Annual	0.028	-0.155	-0.171	-0.017
Belg	**-0.859**	**-0.886**	**-0.887**	0.555
Kiremt	0.446	0.236	0.242	-0.331
May	0.011	0.078	0.124	-0.505
June	-0.335	-0.526	-0.482	0.168
July	0.509	0.687	0.680	-0.495
August	0.315	0.033	0.021	0.034
September	-0.206	-0.417	-0.412	-0.018

*Bolds are significant at 0.05 level

Table 9 revealed the correlation coefficient between rainfall (for growing periods of crops under study) and crop production. From table 8, mean annual rainfall is weakly positively correlated with teff and negatively with the rest of the crops under study. The implication of this is that annual rainfall has a minor contribution or effect to the overall production of teff, wheat, barley and sorghum. Rather inter-annual variability of rainfall is the major determinates of crop production. Similar to this finding, a study conducted on impact of rain fall variability on crop production in Ethiopia also pointed out that inter-annual rainfall variability has significant and negative impacts on the out puts of crop production in Ethiopia. He also pointed out that what matters most in crop production is not the amount of rainfall but how that level diverges from the mean rainfall which is supposed to be the optimal level. When the rainfall diverge from the mean value (both upward and downward), the level of production has significantly diminished to all crop types unanimously (Kassahun, 2011).

Belg rain is negatively correlated with teff (-0.859), wheat(-0.886) and barely (-0.887) which are statistically significant at 0.05 level. On the other hand, sorghum is positively correlated (0.555) with *Belg* rains but not statistically significant. Sorghum production is particularly related to the *Belg* rains. This is because of the fact that sorghum is sown in late April or early May, which makes the *Belg* rainfall critically important. Sorghum production is more strongly correlated with *Belg* rainfall than the *Kiremt* rainfall, as noted above. The correlation coefficient between crop yields and *Kiremt* rainfall revealed that a positive correlation was observed for teff, wheat and barley whereas a negative correlation for sorghum. The result shows teff production is more strongly correlated with *Kiremt* rainfall than *Belg* and annual rainfalls. This might be happened because of farmer's traditional farming system where they usually sow teff between end of June and July, after the vertisol soil (most of them) have adequate moisture and hence its influence might be relatively high. Sorghum, however, tolerates end of season dry spells (shortage of rainfall in September) (Woldeamlak, 2007).

4.3.3. Crop production and temperature

The data analysis for temperature and crop production also revealed that temperature and crop productions are mostly negatively correlated. A rise in temperature loosely translates to a decrease in crop production. Table 10 shows a correlation coefficient of cereal production with T min and T max.

Table 10: Pearson correlation coefficient of cereal production with T min and T max monthly, seasonal and annual average temperature

	Teff		Wheat		Barely		Sorghum	
	T min	T max	T min	T max	T min	T max	T min	T max
Annual	0.219	-0.242	0.701	0.167	0.525	-0.223	0.608	-0.121
Belg	-0.461	-0.312	0.009	-0.002	-0.051	-0.170	-0.031	-0.146
Kiremt	-0.117	-0.176	-0.046	0.161	0.042	-0.145	0.121	-0.215
May	-0.302	0.423	-0.104	0.046	0.131	-0.058	-0.084	0.165
June	**0.802**	-0.005	0.605	0.408	**0.824**	0.040	**0.833**	0.107
July	-0.023	-0.172	0.054	-0.407	-0.015	-0.428	0.230	-0.459
August	0.092	-0.043	0.184	0.226	0.146	0.291	0.164	0.137
September	-0.703	0.060	-0.687	0.553	-0.594	0.386	-0.634	0.280

*Bolds are significant at 0.05 level

Maximum annual average temperature has positive weak correlation with wheat (0.167) and negatively correlated with teff (-0.242), barely (-0.223), and sorghum (-0.121). High temperature encourages evapo-transpiration, affecting plant growth in the absence of adequate soil moisture. As a result, increases in temperature might result in increases or decreases in yield, depending on the optimum temperature for crop development and the amount soil moisture. Wheat is in favor of maximum annual average temperature even if it has insignificant correlation. In contrast in the IPCC report (IPCC, 2007), it was stated that even moderate increases (1-2°C) are likely to have a negative effect on yield for major cereals like wheat with further warming having increasingly negative effects showing decreases in wheat yield in low latitude regions of approximately 50% for an increase in local temperature of about 5°C.

Minimum annual average temperature is positively correlated with all the crops under study. This might be directly attributed to the decrease of frost which farmers claimed as one of the constraints of crop production but it might needs further in-depth research. T min of the month June positively correlated to all crops under study but significantly correlated with teff, barely and sorghum. This might be attributed due to abundant soil moisture.

4.3.4. Regression analysis for the crops and climatic variables

The regression analysis computed for the crops as dependent variable and annual or *Kiremt* rainfall as independent variable revealed a very small coefficient of determination (2 and 10% average for annual and *Kiremt* respectively). Whereas the multiple linear regression analysis with production data of cereals as dependent variables and area cultivated, and *Belg* and *Kiremt* rainfalls as independent variables clearly reveals the significance of fluctuations in cropped areas and rainfall variability as the major determinants of food production in the study area. In this regards teff, wheat, barley and sorghum, have coefficient of determination of 0.97, 0.91, 0.90 and 0.86 respectively. This indicates that 97, 91, 90, and 86 % of the variance in teff, wheat, barley and sorghum can be, respectively explained by the climatic parameters under study. The implication is that 3, 9, 10 and 14% of the variance in teff, wheat, barley and sorghum can be, respectively explained by other factors not included in the study. Climatic variables therefore, have impact on selected crop yield over the years under study. Other factors, such as labor, solar radiation, type of soil, soil fertility and farm methods and management may also be responsible for crop yield variability.

4.5 Climate change perception and adaptation options

4.5.1 Characteristics of the respondents

The socio-economic factors that were likely to affect the perception and adaptation abilities of respondents include gender, age, occupation, marital status, family size and land size are presented in table 11.

Table 11: Background characteristics of respondents

	Male		Female		Total Percent
	Frequency	percent	Frequency	Percent	
Age					
20-30	2	1.7%	0	0%	1.7%
31-40	19	15.8%	1	0.8%	16.6%
41-50	30	25%	10	8.3%	33.3%
51 and above	46	38.3%	12	10%	48.3%
Total	**97**	**80.8%**	**23**	**19.2%**	**100%**
Occupation					
Farming	93	77.5%	23	19.2%	96.7%
Farming and trade	2	1.7%	0	0%	1.7%
Farming and handcrafts	2	1.7%	0	0%	1.7%
Total	**97**	**80.8%**	**23**	**19.2%**	**100%**
Education					
Church school	8	6.7%	0	0%	6.7%
Adult education	46	38.3%	7	5.8%	44.1%
Formal education	31	25.8%	3	2.5%	28.3%
Illiterate	12	10%	13	10.8%	20.8%
Total	**97**	**80.8%**	**23**	**19.2%**	**100%**
Marital status					
Single	8	6.7%	2	1.7%	8.4%
Married	80	66.7%	7	5.8%	72.5%

Divorced	5	4.2%	9	7.5%	11.5%
Widow	4	3.3%	5	4.2%	7.5%
Total	**97**	**80.8%**	**23**	**19.2%**	**100%**
Household size					
1-3	15	12.5%	11	9.2%	21.7%
4-6	52	43.3%	12	10%	53.3%
7-10	30	25%	0	0%	25%
Total	**97**	**80.8%**	**23**	**19.2%**	**100%**
Land holding size					
0.25-0.5ha	12	10%	6	5%	15%
0.5-1ha	36	30%	11	9.2%	39.2%
1-2ha	38	31.7%	3	2.5%	34.2%
2ha>	11	9.2%	3	2.5%	11.7%
Total	**97**	**80.8%**	**23**	**19.2%**	**100%**

According to Deressa T.T *et al.* (2009) household characteristics have significant impact on adaptation to climate change. The study underlines that education, gender and age of the household head and household size can profoundly affect the probability of adapting to climate change. For example, a unit increases in age of the household head results in a 0.5% increase in the probability of planting trees and a 0.06% increase in irrigation. Male-headed households were 9% more likely to conserve soil, 11.6% more likely to change crop varieties and 10% more likely to plant trees. Therefore analyzing the characteristics of the respondents is significantly important in order to understand the choice of farmers adaptation to climate change.

As depicted in Table 11 majorities of the respondents (80.8%) encountered during the survey were male while 19.2% were female. All of the respondents are followers of Ethiopian Orthodox church. The age class, 51 and above, was the highest age category (48.3%) followed by age category of 41-50 (33.3%). Most of them (72.5%) were married with the family size being in the range 4-6 (53.3%) while 8.4% of the respondents are single. Most of the respondents (96.7%) engaged in farming activities as their primary occupation. Others integrate agricultural activities with other means of earning (trade and handcrafts) to supplement their incomes.

Table 11 further shows the educational level of the respondents were 79.2% are literate of which 6.7% attend church school, 44.1% adult education and 28.3% attend formal education. There are more educated men than women. From the total male respondents 87.6% of male are literate. Only 13 percent of men report no education versus 57 percent of women.

4.5.2 Climate change perception

Farmer perceptions regarding long-term changes in temperature and precipitation are presented below. The results indicate that most farmers perceive that overall temperatures are increasing. On the other hand, the overall perception on long term changes in precipitation is that the precipitation is getting decreasing.

4.5.2.1 Temperature

As depicted in figure 10, about 100 percent of the respondents perceived the change in the number of hot days over the last 20 years. 98.3 percent of them (118 farmers) said that the number of hot dates for the last 20 years were increased while only 1.7 percent of them perceived a decreased in temperature. About 95.8 percent of the farmers interviewed perceived long-term changes in temperature. Most of them (95 percent or 114 farmers) recognize the temperature in the area were increased. Only 0.8 percent noticed the contrary, a decrease in overall temperature. On the other hand only 4.2% of them have not noticed any changes in the temperature. These results appeared to agree with the Meteorological record trends of temperature (Section 4.2.2). The increase in temperature has a positive outcome as explained by DB Research Center. They side that in the previous year's most of the crops, especially wheat and barley, were hit by frost. But now a days due to an increase in temperature and a decreased in frost farmers in the high land areas are getting a fair yield.

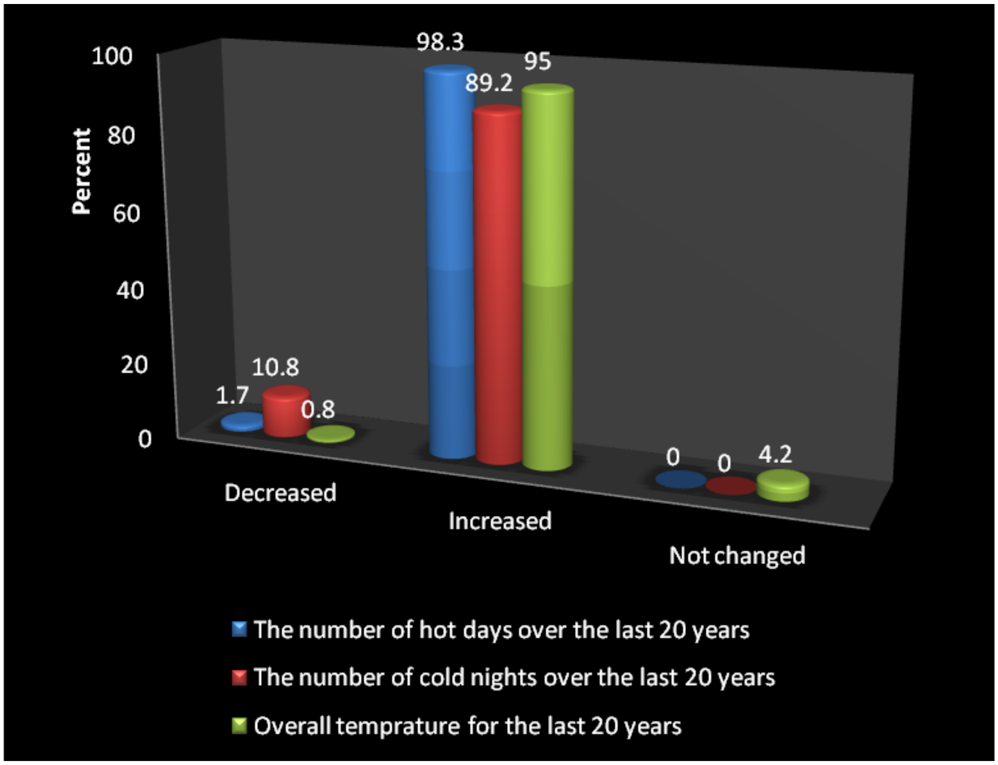


Figure 10: Farmers perception on change in temperature

4.5.2.2 Precipitation

One hundred percent of the respondents observed changes in the distribution of *Belg* and *Kiremt* rainfall patterns over the past 20 years (Figure 11) whereas 98.3 and 78 percent of the respondents observed changed in the *Belg* and *Kiremt* time of rainfall respectively (Figure 12). About 96 percent of farmers perceived a decreased in *Belg* rainfall distribution or a shorter rainy season and about 80 percent of them noticed a decrease in the distribution of Kiremt rainfall. Almost 97 percent of the informants noticed that *Belg* rain was being late while 75 percent of respondents observed that the main rainfall season, *Kiremt*, is coming late. Their perception is inconsistent with the Meteorological data of precipitation. This could be attributed because of irregular distribution of seasonal rainfall across the area. This incident explained by farmers that the long rainy season, *Kiremt,* most of the years *Bega*n in late June and was already over by the end of August but usually should continue until mid September.

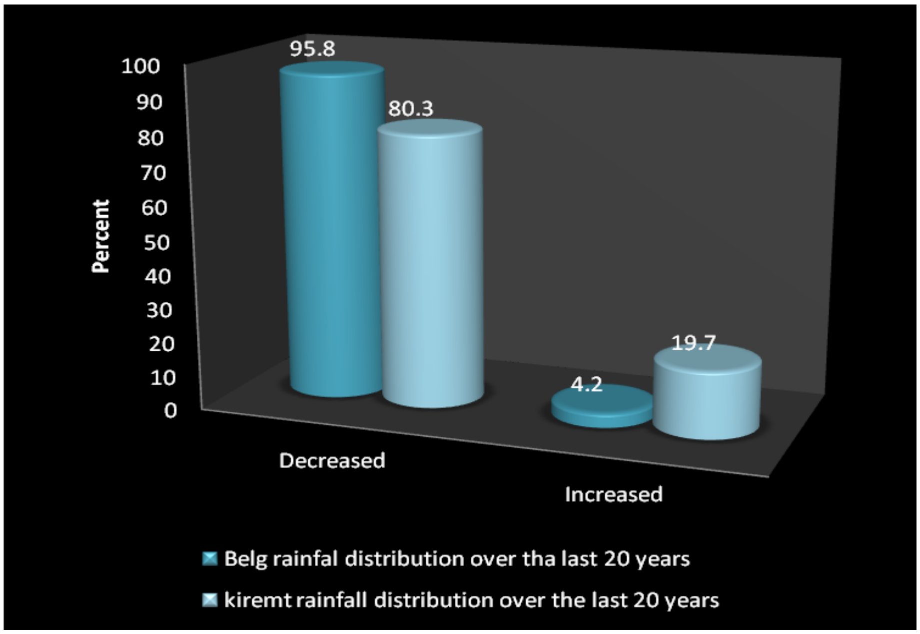


Figure 11: Farmers perception on the distribution of precipitation

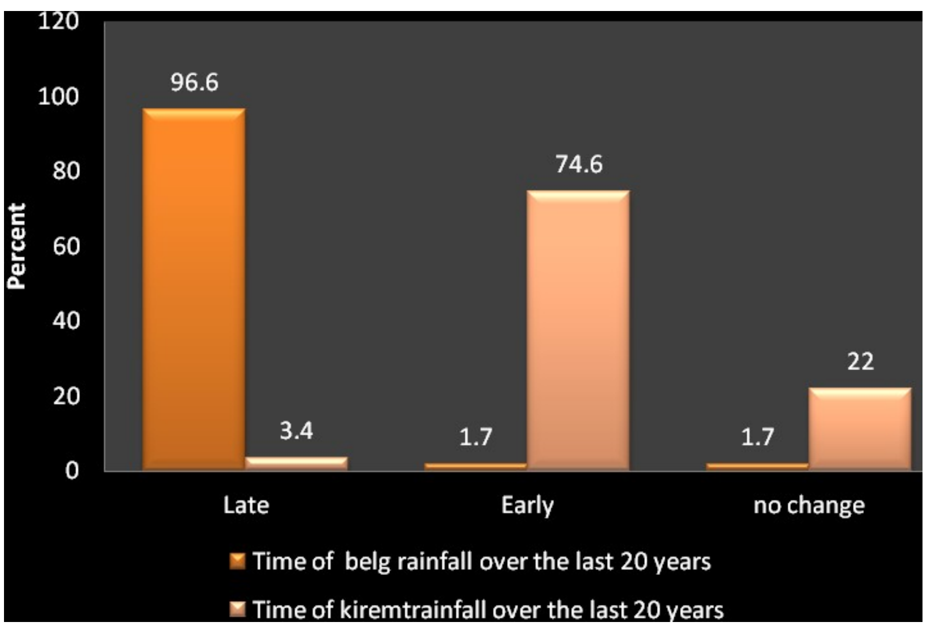


Figure 12: Farmers perception on time of precipitation

4.5.3 Farmers' Adaptation to Climate Change

During the study exercise farmers identified the most challenging constraint for crop production and found out that reduced soil fertility (23%), lack or delayed of short rainy season (26%) and shortage of rainfall (19%) are the three main restraint. Farmer's ability to adapt those challenges is limited by their lack of economic and technical resources, and their vulnerability is heightened by heavy dependence on the climate because of the rain fed system. The very primitive farming methods, the low technical capacity on how to protect the soil against degradation and erosion and the very limited and inaccessible irrigation in the area makes farmers entirely dependent to plant crops once during the rainy seasons. Figure 13 presents various adaptation strategies being used by farmers in response to changing climatic and other socioeconomic based on the survey observations.

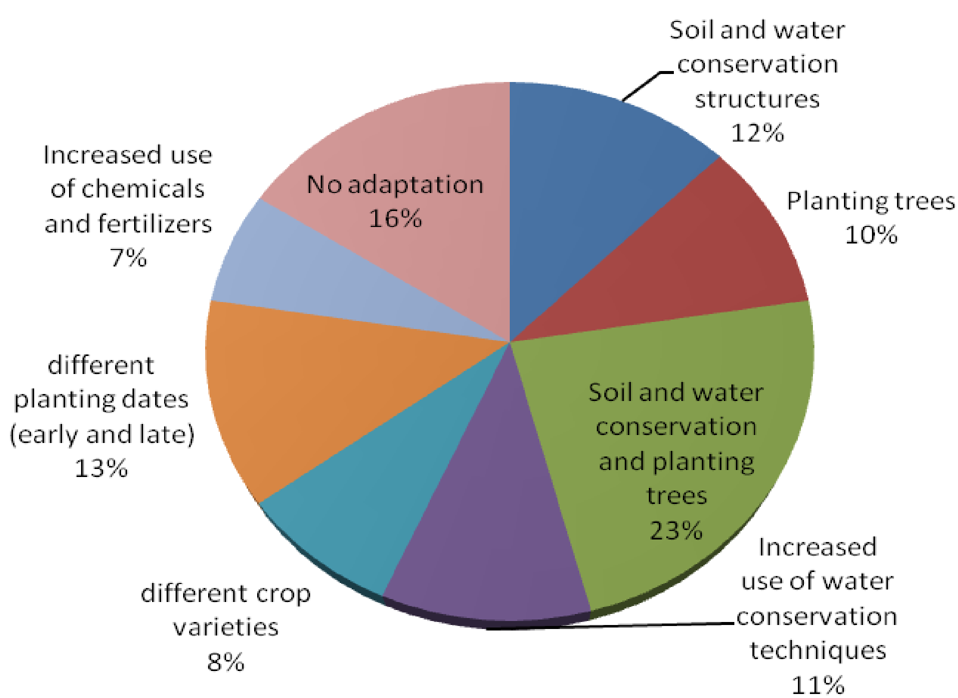


Figure 13. Farmers' adaptation options

As shown in the figure 84% of the farmers did at least something in the response to climate changes. More than 23% of the farmers were of the view that their solution to climate change depended on the application of soil and water conservation and planting trees and 13 % of them on timing the planting period to coincide with the onset of the rains (early and late). Other adaptation methods farmers used are soil and water conservation alone (12%), tree planting alone (10%), increased use of water conservation techniques (11%), different crop varieties (8%) and increased use of chemicals and fertilizers (7%).

Soil and water conservation and tree planting activities has been carried out in the study area as a primary method of climate change adaptation because most of the area is highly degraded to the level that rock-out crops are seen and taken as a viable strategy in attempt to conserve and rehabilitate the degraded area. From the observation, the amount of soil and water conservation activities implemented and the number of trees planted varies from household to household depending on labor availability and land size.

Conclusions and Recommendations

Agriculture is major source of income in Bassona Worana Woreda. Although it is the main source of income, it is not sufficient to feed their family throughout the year because of less agriculture land and less crop production. Almost 35% of them owned 0.5ha -1ha land for both agriculture and grazing with a family size of 4-6 in average. Poor economic condition and low human development in terms of education, health and other physical infrastructure is another social characteristics feature of the Woreda.

This study has presented analyses of historical rainfall and temperature data and relationships between rainfall and temperature change and effects in crop production and farmers choice of adaptation. Over the 30 years examined, rainfall in DB station is characterized by large inter-annual variability with a substantial increase in the amount of annual rainfall (4.857mm/year). However, there is a noticeable, long-running trend of decreasing rainfall during *Belg* season (-2.88mm/year). It has been also witnessed a large spatial distribution of rainfall across the area due to topographic and vegetation effect.

The analysis of past temperature records shows a clear warming trend. The mean annual temperature and the mean annual maximum temperature show an increasing trend, which is statistically significant while the mean annual minimum temperature is increasing but not significant. The maximum temperatures were increasing slightly more (0.023^{0}C/year) than the minimum temperatures (0.020°C/year).

With regards to effect of climate variables on crop production, annual rainfall has a minor contribution or effect to the overall production of teff, wheat, barley and sorghum.

Rather inter-annual variability of rainfall is the major determinates of crop production. In addition a rise in temperature loosely translates to a decrease in crop production.

In the study area farmers are able to recognize that temperatures have increased and there has been a reduction in the volume of rainfall and they have pursued different strategies to reduce vulnerabilities from climate related disaster where soil and water conservation and planting trees are the dominant option practiced by them.

To support farmer's struggles against climate change, there is a need to integrate planning processes at all levels that will enable farmers to meet the objective of limiting the negative effects of climate change, and thereby reduce their vulnerability. In general, climate change should be considered in long-term planning horizon to maximize adaptive capacity.

Based on the information obtained from individual survey and community group discussion the following recommendations are also made in order to assist farmers for their struggle against climate change and to diversify their livelihood options.

- The establishment of nurseries for indigenous trees and useful multipurpose trees and distribution of seedlings to farmers to plant in their homesteads should be given high consideration in terms of area coverage and diversification of species.

- Awareness creation and environmental education programs among community members need to be strengthened.

- Both non-governmental and governmental organization needs to lobby at national, regional, zonal and woreda level in promoting conservation activities in the woredas for minimizing the unforeseen effects of climate change.

- During the group discussion, farmers were complaining on the loss of drought-tolerant and early maturing varieties that are not only important but also necessary for resilience against recurrent drought and climate change. Responsible body should facilitate in identifying the land race and re-introduction of the landraces by consulting with Institute of Biodiversity Conservation and the zonal agriculture offices.

- One of the most abundant species in the Gosebado kebele, which were found during study observation is *Becium grandiflorum*(locally called *Muatish)*, an important honey bee forage species which indicates the potential of the area for honey bee production. Promotion of honey bee production (both with improved and intermediate beehives) in the Woreda could be used as alternatives to diversify the livelihood and adaptation options.

Finally, this research and findings hopefully will induce further research in the area and the author recommend rigorous study on climate change impact and effect on crop production. Such analysis is important for building confidence in determining the impacts of climate change on agricultural production and food security.

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ANNEX

1. **Questionnaire**

Part 1. Identification of the study site

1. Woreda_________________
2. Kebele __________________
3. Village __________________

Part 2. Characteristics of the interviewee and his/her household

1. Sex a) Male b) Female
2. Age _____________________
3. Religion a) Orthodox b) Catholic c)Protestant d) Islam
   e) Other (Specify)______________________
4. Occupation a) Farming b) Commerce c)Handicraft d)House wife f) Not working g) mixed/more than one activity
5. Education a)Illiterate b)Literate
6. If literate a)church school b)Quran c)Literacy campaign
7. Marital status a) single b)Married c)Divorced d) widow
8. Household size ____________________________

Part 3. Wealth and economic status of the interviewee

1.What is the size of your land holding for crop production and grazing?

1. <o.25 ha 2. 0.25-0.5ha 3. 0.5- 1.0ha 4. 1.0ha-2.0ha 5. >2ha

2. How many of the following domestic animals do you own?

Milk cow _____________________

Oxen/bull_____________________

Horses/donkeys/mules_______________________

Goat______________________________

Sheep____________________________

Chicken ___________________________

3. What is the status of your house?

1. house with corrugated iron sheet 2. House with roof thatched grass 3. Both

4.What are the main source of income for the household? In rank order

1.Sales of cash crops

2. Sales of surplus food crops

3. Sales of livestock or their products

4. Trade

5. Handicrafts

6. Others _______________________

5. How much do you earn per year?

1. from crop production

2. from sales of livestock or their products

3. Others __________________________

Part 3. Climate change knowledge and adaptation

1. How long have you lived here?

1. 10 years 2. 15 years 3. 20 yeas 4. More than 20 years

2. Do you know about climate change?

1. yes 2. No

3. If your answer for question number 2 is yes, how do you get the information?

1.Governmnet extension agent 2. Mass media

3. Empirical/experience/talking to elders 4. Others

4. What is your perception about the change in temperature?

4.1 Has the number of hot days stayed the same, increased, or declined over the last 20 years?

1. Temperature decreased 2. Temperature Increased 3. Temperature stayed the same

4.2 Has the number of cold nights stayed the same, increased, or declined over the last 20 years?

1. Decreased 2. Increased 3. stayed the same

5. Over the last 20 years the temperature in the middle of the day

1. Decreased 2. Increased 3. stayed the same

6. Has the temperature overall

1. Decreased 2. Increased 3. stayed the same

7. What is your perception about the change in the amount of rainfall during the Belg (short rainy) season? (has the number of rainfall days stayed the same, increased, or declined over the last 20 years?)

1. Rainfall decreased 2. Rainfall increased 3. Rain fall stayed the same

8. What is your perception about the change in the distribution of rainfall during the Belg (short rainy) season over the last 20 years?

1. Delayed 2. Early 3. Same as before

9. What is your perception about the change in the amount of rainfall during the Kiremt (Long rainy) season? (has the number of rainfall days stayed the same, increased, or declined over the last 20 years?)

1. Rainfall decreased 2. Rainfall increased 3. Rain fall stayed the same

10. What is your perception about the change in the distribution of rainfall during the Kiremt (long rainy) season over the last 20 years?

1. Delayed 2. Early 3. Same as before

9. Are there any changes to the intensity of rains?

1. Heavier 2. Less intensive 3. Same as before

Part 4. Crop Production Determinants

1. What is the state of your land 20years ago?

    1. land slope ____________________

    2. Soil depth _____________________

    3. Soil Fertility ______________________

2.What was the state of the land 20 years ago?

2.1 Land slope	1. Decreased	2. Increased	3. Same
2.2 Soil depth	1. Decreased	2. Increased	3. Same
2.3 Soil Fertility	1. Decreased	2. Increased	3. Same

3. What crops do you grow? How much land do you have under each crop?

1. Teff __________________	5. Lentils _____________________
2.Wheat___________________	6. Beans ______________________
3. barley ____________________	7. Chickpea ____________________
4. Sorghum __________________	8. Others______________________

4. Please list the type of crops planted during the Belg seasons?

5. Which crops would you like planting most? Please list in order of importance

1. Teff __________________	5. Lentils _____________________
2.Wheat___________________	6. Beans ______________________
3. barley ____________________	7. Chickpea ____________________
4. Sorghum __________________	8. Others______________________

6. What is the trend in the amounts of crop production for the last 20 years?

    1. decreased   2.increased   3. Stayed the same   4. Others

7. Has modern fertilizers and improved seed utilization changed in the last years?

1. decreased 2. Increased 3. no use of any fertilizer 4. The same as before

8. What kind of agricultural inputs do you used?

8.1 Seed 1. Improved 2. Local 3. Both

8.2 Fertilizer 1.DAP 2. Urea 3. Both 4.Organic fertilizer 5. Other

8.3 Labor 1.Human 2.Oxen 3.Both

9.Is there any change to the agricultural inputs you used today and 20 years ago? What other mechanisms do you used to enrich the fertility status of the land?

10.What are the main constraints to crop production?

1. Diseases 2. Pests 3. Weeds 4. Lack of rain 5. Too much rain 6. Changes in seasonality (e.g. late small rains or main rains) 6. Temperature change

11. Which crops are more sensitive to changes in climate? Why?

12 Which are not sensitive and why?

13. Is there any crop species disappearing from your area?

1. yes 2. No

14 If yes what is the name of the crop?

15. If your answer to question number 13 is yes what do you think the reason behind?

Part 5. Adaptation strategies

13. Do you think that the decline in the productivity of your agriculture is due to climate change? If so, how?

1.shortage of growing season

2.Exessive rain fall

3.Shortage of rainfall

4. season fluctuation

5. higher temperature

6. Lack/delayed short rainy season

7. Soil fertility reduction

14. What measures/techniques are you using to adapt to any of the above changes?

1. Soil and water conservation structures

2. Planting trees

3. Soil and water conservation and planting trees

4. Increased use of water conservation techniques

5. different crop varieties

6. different planting dates (early and late)

7. Increased use of chemicals and fertilizers

8. No adaptation