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Analysis of climate variability and its economic impact on agricultural crops: The case of Arsi Negelle District, Central Rift Valley of Ethiopia

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Abstract

This study was conducted to analyze climate variability and its economic impact on agricultural crop productivity in Arsi Negelle district - Central Rift Valley region in Ethiopia. The study analyzed observed climate variability, downscaled future projection (2046–2065 periods) with reference to base line data from years 1981-2009 by using self-organising map downscaling (SOMD) technique. In addition, the study has employed Ricardian approach to analyze marginal effects of temperature and rainfall on agricultural crop productivity based on farm data generated from 174 farmers. Annual crop net revenue was regressed on climate, soil and socio-economic variables. The result obtained from metrology data indicated that in the study area, climate variability has been observed and the minimum temperature found to be more variable than maximum temperature does. While rainfall found to be more variable in Langano than in Arsi Negelle stations in the period from 1981 to 2009. Result obtained from simulation analysis for the future period indicated that significant climate variability is expected to be observed for the projection period from 2046 to 2065. Detailed analysis of rainfall projection has shown that, main rainy season is expected to decrease, while short rainy season that runs from March to May is expected to increase. Regressing of net revenue was found that climate have a significant impact on the farmers' net revenue per hectare. As a 1°C increase in temperature during the main rainy and dry seasons reduced the net revenue by 5179.65 and 704.19 Birr per hectare respectively. On the other hand, a 1°C increase in temperature marginally during the short rainy seasons was found to increase the net revenue per hectare by 1081.81 and 1542.65 Birr respectively. An increasing precipitation by 1mm during the main rainy and dry seasons reduced the net revenue per hectare by 1184.00 and 328.90 Birr respectively. Result obtained from interviewing of households indicated that farmers were aware of the occurrence of climate variability and changes hence devised adaptation strategies in response to it. The overall finding from the study suggests that there is a need to support farmers' adaptation capacity and improve their crop production efficiency to overcome future scenarios of climate change impacts.

Key words*:* Climate variability, marginal effect, downscaling, Arsi Negelle, adaptation and perception

1. INTRODUCTION

Global warming is considered to be major threat for life on our planet. Observations show that global mean temperature at the earth's surface has substantially increased over the twentieth century [IPCC, 2007].This global warming and its multifaceted impacts are affecting the whole world in various forms. Several scientific studies have suggested that developing countries in particular are suffering from the burden of the ever changing climatic conditions (UN-OHRLLS, 2009). Many low income countries are located in tropical, sub-tropical region, or in semi-arid zones, that are particularly vulnerable to shifting weather patterns and rising temperature (Joachim, 2008). Widespread research findings have revealed that climate variability and change have significant impacts on global and regional food production systems particularly on the performance of common staple food crops in the tropical sub-humid climatic zone (UN-OHRLLS, 2009). Climate variability and change have been implicated to have significant impacts on global and regional food production particularly the common staple food crops performance in tropical sub-humid climatic zone. For example, the most food insecure regions and most climate change vulnerable regions in Ethiopia are those that experience both the lowest and most variable rainfall patterns (UN-OHRLLS, 2009). Many African countries are vulnerable to climate change because their economies largely depend on climate-sensitive agricultural production system (Temesgen, 2000).This is particularly true in low-income countries like Ethiopia where adaptive capacity is low.

Ethiopia is characterized by diverse topographic features that have led to the existence of a range of agro-climatic zones each with distinctly variant climatic conditions which in turn have resulted in the evolution of a wide variety of fauna and flora and agricultural production systems. Among these agro-climatic zones, the lowland (kola) that receives the lowest and most erratic rainfall rates notably the Central Rift Valley (CRV) region experiences frequent natural hazards such as sudden flooding, recurrent droughts and chronic water stress that are aggravated by climate change and its variability. Climate variability of erratic rainfall and its uneven sequential and spatial distribution is creating frequent flooding and drought in these areas (Lai *et al*., 1998).

In the CRV of Ethiopia, fluctuations in precipitation and temperature rates are directly affecting the production and productivity of the agricultural systems (Bezabih et. al; 2010). Climate variability is indirectly affecting the agricultural production of the area through influencing the emergence and distribution of crop pests, livestock diseases, aggravating the frequency and distribution of adverse weather conditions, reducing water supplies and enhancing severity of soil erosion among other impacts (Watson et al, 1998). Climate variability and its associated impacts are inducing frequent crop failures, and declining livestock production and productivity leading to aggravated rural poverty in the region. Scientific evidences suggest that higher temperatures and changing precipitation levels as a result of the changing climate will further depress agricultural crop yields in many arid-and semi-arid parts of Ethiopia over the coming decades (Bezabih et. al; 2010). Therefore, scientific investigations and applied researches on climate variability and its economic impact on the production levels and productivity of agriculture is critical to develop effective and locally-adaptive agricultural production systems in the face of the increasing climate change and variability (Karim et. al., 1994).

The central rift valley of Ethiopia where this study was conducted is evidently the hardest hit region of the country in terms of drought (Bezabih et. al; 2010). Growing climate and land use changes as a result of the increasing climate variability such as rising temperature, erratic rainfall and the resultant water shortage coupled with the continued deforestation and mis-use of woodlands and other land resources has led to the substantial decline in agricultural productivity and rising food insecurity. Though little is known so far, evidences in the study area have shown that the increasing temperature, water shortage and the changing precipitation levels are affecting crop yields. However, despite a handful of empirical studies, in-depth analysis and well-established scientific evidences on the nature and extent of climate variability, magnitude of climate change impact on agricultural crops and the likely socio-economic consequences on the livelihoods and food security of the rural poor in the area is virtually lacking. The study is designed to investigate climate variability and its economic impact on crop yield in the Arsi Negele area. This study was therefore conducted in Arsi Negele woreda of the Oromiya National Regional State to understand and analyze climate variability and its economic impact on agricultural crop productivity.

2. METHODOLOGY

Arsi-Negelle district where this study conducted is located in West Arsi zone of the Oromia Region State about 225 km south of Addis Ababa. Geographically, it is situated in the Ethiopian central rift valley system of 7 ^{0}09'-7^{0}41' N and 38^{0} 25'-38^{0}54' E. It is bordered in the south by Shashamene district, in the southwest by Bulbula woreda which separates it from Seraro, on the west from the Southern Nations, Nationalities and Peoples Region, on the north by Adami Tullu and Jido Kombolcha with which it shares the shores of Lakes Abijatta and Langano, and on the east by the Arsi Zone (ORS, 2004). The study area covers three agro-ecological zones (low, mid and high land) based on temperature, rainfall, altitude and vegetation and that ranges from 1500-2300 m.a.s.l. (ICRA, 2002). The high altitude zone occupies the largest area followed by mid and low altitude climatic zones respectively. Average annual temperature varies from 10-25 C^{o} while annual rainfall varies between 500-1000mm (ORS, 2004).

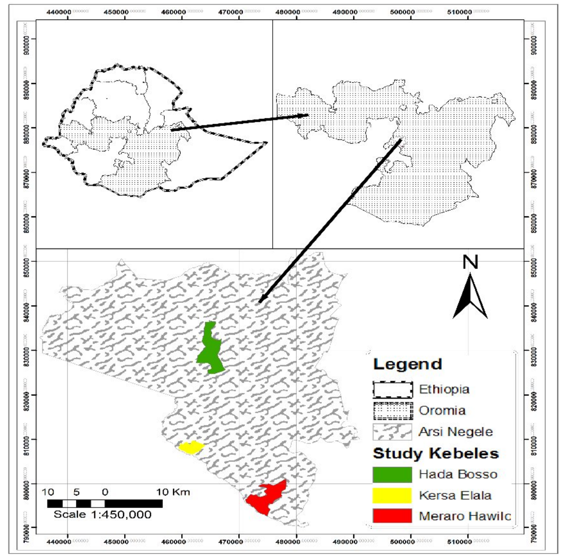

Figure 2. 1. Map of the study area

Sampling Design and Sample Size

A multi-source data collection method through stratified random sampling (SRS) was employed. In the first stage, the district was classified into three strata of Lowland (kola), Midland (woyna-dega) and Highland (dega) agro-ecological zones. From each agro-ecology one target kebele was selected in such a way that the kebeles represent the district in biophysical, agricultural and socio-economic aspects. Accordingly, Hada Boso, Kersaylala and Meralo-hawilo kebeles were selected from the three zones respectively. In the second phase the number of households in each target kebeles was identified and sample size was determined for the random sampling that were making a total of 1,740 target households. A 10% sampling intensity was used from each kebele accounting a total of 174 sample households. Proportionately distributing the sample size to the three kebeles. Finally, the respective sample households from each kebele were identified and contacted for the socio-economic study. GPS points of farmlands of each household were also located for the interpolation of the cross-section climate data at farm level.

3. Data Source and Data Collection Method

Three sets of primary data namely: climate and soil data (temperature and precipitation and soil characteristics), socio-economic and agricultural production were collected. The first group of data (climate data) was obtained from the National Metrology Agency. The second group of data (socio-economic and climate adaptation) were collected from household survey. Additionally, valuable secondary data were also collected from various sources including previous scientific studies and reports papers. Detailed description of the data collection methods are presented below.

Climate data

The observed data on climate variables mainly temperature and rainfall, from 1981-2010, of the study area was obtained from the National Metrology Agency of Ethiopia. The data were later downscaled and future projection was administered with the help of Climate System Analysis Group (CSAG) through the climate information portal (CIP) with the help of University of Cape Town, South Africa. Accordingly, monthly rainfall and temperature data were collected from all the metrological stations in the district in collaboration with the National Metrological Station. In order to impute the cross-section household farm level rainfall and temperature values, the spatial interpolation method were used using latitude, longitude, and elevation parameters of each household farm. The spatial interpolation method is a physically based interpolation scheme for arbitrarily spaced tabulated data. The Spline surface represents a thin metal sheet constrained not to move at the grid points, which ensures that the generated rainfall and temperature data at the weather stations were exactly the same as data at the weather station sites that were used for the interpolation (Yesuf et al., 2008).

Socio-economic data

An in-depth household survey by using a semi-structured questionnaire and in-person interview was employed to collect both the detailed socio-economic data. Farm households' cross-sectional data were obtained from a household survey of farmers during the 2011/12 production year in the district. Accordingly, one focus group discussion was carried out at Kebele level which contained 5-8 farmers in a particular kebele. Then one key informant discussions was also carried out at Kebele level to generate general information on the main research problem.

Following the key informant discussions, the semi-structured questionnaire already prepared for the study was amended before the actual household survey. A very important part of the data collection process was the pre-test method prior to the actual interview that helped to check the validity and appropriateness of the semi-structured questionnaire. Consequently, the questionnaire was amended and finally distributed selected respondents. The soil data for this study came from the same survey mentioned above. There are different soil types in the study areas. These soils are traditionally classified by its colors and some of the color types are sandy, clay, black and red. (FAO, 1996).

Variability, downscaling and future projection

For this study the CMIP3 archive GCMs were used where each GCM were followed by a number of simulations. The first is simulation of the 20th Century climate (1961 to 2000) forced by observed GHG concentrations. This simulation is the GCMs representation of the observed climate period. It is important to note that the values between real years and the years of the 20th century simulations will not exactly correspond, meaning that one cannot expect similarity between simulated climate data for a particular year in the 20th century simulations and observed record of climate data in that year. Similarly, simulations of future periods and GHG concentration scenarios for the study were used from two future period projections: 2046 - 2065 and 2081 – 2100. However the future development scenarios of only 2045-2065 periods are discussed. In this study, a total of 3 GCM simulations were discussed. First the time series of daily precipitation for the observed period, second the control period and third the projection period were obtained from the daily temperature and precipitation were therefore analyzed for each particular GCM. Each GCM simulation was then downscaled to the station location and climatologically summary graphs were produced. These are presented below in the form of climate projection envelopes. As mentioned above, projection envelopes capture the range of GCM responses to GHG forcing and represent the level of agreement or disagreement between the GCMs. Downscaling is based on the observation that local scale climate is largely a function of the large scale climate modified by some local forces such as topography.The downscaling methodology is used to produce the projections is called Self Organising Map Downscaling (SOMD) as it based on data clustering method. This method used in this study is developed at the University of Cape Town. It is a data description tool that extracts and displays data distribution systems (Hewitson and Crane, 2006).

Econometric model Specification

The empirical models employed for this study follow the works of Mendelsohn et al. (1994) and Ouedraogo et al. (2006). The models examine how long-term farm profitability varies with climate (temperature and precipitation) and soils while controlling for other factors. Relevant socioeconomic variables are also assessed to see the extent to which they control the impact of climate change on crop agriculture. Two main models are formulated: 'without' adaptation model and 'with adaptation models. The former include only climate and soil variables, while the latter in addition to these variables include relevant socio-economic variables such as cropland area, livestock ownership, distance to nearest market for obtaining inputs and selling products, access to extension, access to credit, household size, years of education of the household head and farming experience. These two models estimated for sample farms that represent central rift valley Ethiopia .The model without adaptation options includes only the physical variables (temperature, precipitation and soils): The model with adaptation includes the previous variables and farms characteristics(Kurukulasuriya & Mendelssohn, 2006). The dependent variable (R) indicated in equation-1 is measured as crop net revenue per hectare of cropland. Crop net revenue is the gross crop revenue which is the product of total harvest and price of the crops (Maize, Wheat, Teff, wheat, Sorghum, Barley and Haricot been (the value of crop production) total associated cost of production calculated for each agricultural household. The independent variables include the linear and quadratic terms of temperature and precipitation and only linear terms of soils and farm characteristics

Analysis of econometric Approach

For this study, a linear regression model was used to estimate the economic impact of changing climate variables on agricultural crops yield. The Ricardian approach is based on the observation of David Ricardo (1772–1823) that land rents reflect the net productivity of farmland and it examines the impact of climate and other variables on land values and farm revenues. In doing so, the model measures the contribution of each independent factor to the outcome of agriculture production and impact of climate change on agriculture (Mendelssohn et al. 1994). This approach has been found attractive because it corrects the bias in the production function approach by using economic data on the value of land. So, the Ricardian approach accounts for the direct effects of climate on the yields of different crops (Mendelsohn et al. 1994). It is also attractive because it includes not only the direct effect of climate on productivity but also the adaptation response by farmers to local climate. Following Mendelsohn et al. (1994), the approach involves specifying the productivity function of the form (Gujarati DN, 1995).

$$R = \sum P_i Q_i (X, F, Z, G) - \sum P_x X \quad .....(1)$$

where R is net revenue per hectare, Pi is the market price of crop i, Q_i is output of crop i, X is a vector of purchased inputs (other than land), F is a vector of climate variables, Z is a set of soil variables, G is a set of economic variables such as market access and Px is a vector of input prices. The farmer is assumed to choose X to maximize revenues given the characteristics of the farm and market prices. The standard Ricardian model relies on a quadratic formulation of climate

$R = B0 + B1F + B2\,F^2 + B3\,Z + B4\,G + u$…… (2)

Where u is an error term, and F and F^2 confine levels and quadratic terms for temperature and precipitation. The introduction of quadratic terms for temperature and precipitation reflect the non-linear shape of the response function between revenues and climate. From the available literature, we expect that farm revenues will have a concave relationship with temperature. When the quadratic term is positive, the revenue function is U-shaped, but when the quadratic term is negative, the function is hill-shaped. For each crop there is a known temperature where that crop grows best across the seasons, though the optimal temperature varies by crops. Crops consistently exhibit a hill-shaped relationship with annual temperature, although the peak of that hill varies with each crop. The relationship of seasonal climate variables, however, is more complex and may include a mixture of positive and negative coefficients across seasons (Mendelsohn et al. 1994 and Greene, WH. 2003). From equation (2), we can derive the mean marginal effect of a climate variable on farm revenue. Thus, the expected marginal effect of climate variable on farm revenue evaluated at the mean is:

$E[dV/df_i] = b_{1,i} + 2 * b_{2,i} * E[f_i]$ …… (3)

The original Ricardian studies used land value for the dependent variable. In many developing countries, however, land value is not available. Annual revenue per hectare can be used instead, since land value is the present value of future revenue (Dinar *et al.*, 1998).

Statistical analysis

Appropriate statistical software's such as STATA11 and Microsoft Excel were used to analyze the data from the household socio-economic survey in order to underlying socio-economic variables determining the perception and traditional knowledge of the local communities on climate change and its impacts as well as their adaptation measures. Finally, the results of the data analyzed were summarized and presented in various forms including: frequency tables, percentages, histograms, graphs, software outputs as well as narrative summaries as shown in the next section.

4. Result and Discussions

4.1 Monthly observed rainfall and temperature variability at study area

Rainfall and temperature are the key indicators and elements of climate system. In addition changes and variations succeeded rainfall and temperature variations have adverse influence on ecosystem. Ethiopia's rainfall condition shows high spatial and temporal variability. The highest mean annual rainfall (more than 2,700 millimeters) occurs in the southwestern highlands, and it gradually decreases in the north (to less than 200 millimeters), northeast (to less than 100 millimeters), and southeast (to less than 200 millimeters) (World Bank, 2012).

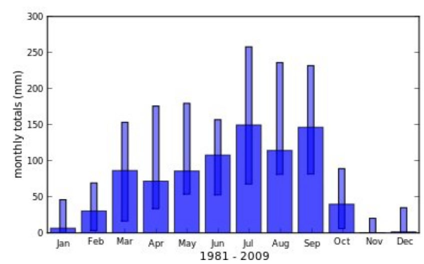

Figure4. 2: Observed monthly rainfall total climatology with inter-annual range for Arsi Negelle station.Wide bars indicate the median monthly rainfall for the observed period. Narrow bars indicate the 10th to 90th percentile range of monthly rainfall for each month during the observed period.

From the above figure-4.2, one can see that the monthly variability of rain fall in the last 28 years. For instance the cumulative average rainfall in July was about 150mm.The highest rain fall was observed to be about 250mm in the same month; and the lowest amount of rainfall has been recorded to be about 70 mm but it varied between 70 and 250mm during the same period. That means there was no time that has shown a record below 70mm.The variability of rainfall during the time period was very high because in some of the months there was no recorded rainfall data. For example, the months of January and February had deficient precipitation, and November and December did not receive any precipitation at all. When the variability is taken in to consideration, and the amount of rainfall recorded in growing season July to August, there was better rainfall and this condition helps the area to have high moisture content and that contributed to growing crops (ICRA, 2002).

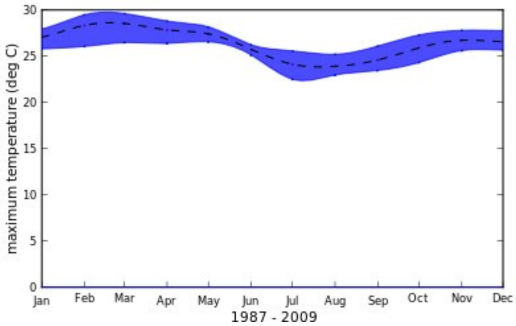

Figure 4.3: Annual cycle of observed monthly mean maximum daily temperatures (°C) for Arsi Negelle station

The blue envelope represents the 10th percentile to 90th percentile inter-annual range. (Dashed line) represents observed monthly mean of the daily maximum temperatures for the observed period.

As illustrated in figure-4.3, the highest maximum temperature was observed between February and March; the dot line represents average temperature of each month. The average maximum value of the mentioned months was about 27 °C but the variability of the maximum temperature in the same months was between 26 °C to 30 °C. Relatively, the lowest average temperature was observed during July and August. From figure-4.2, it was observed that in main rainfall season during the last 28 years on average, there was better rainfall. The variability of temperature in autumn season was high; it ranged from 23 °C to27 °C while in figure-2, the rainfall values were not observed. This is to be expected that given the uncertainties how rainfall patterns will change with rising temperatures and such situation has caused the scarcity of moisture. When there is lack of enough moisture for plant growth, forage for livestock and crop production is affected. (Cooper et al; 2008 and ICRA, 2002).

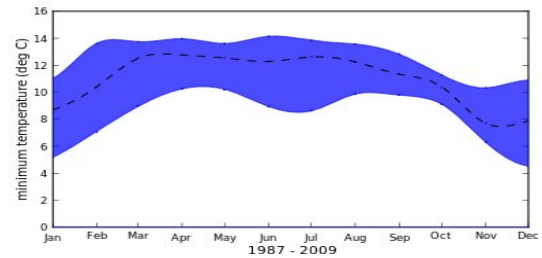

Figure4. 4: Annual cycle of monthly mean minimum daily temperatures (°C) for ArsiNegelle station. Observed monthly mean of the daily maximum temperatures for the observed period (Dashed line). Blue envelope represents the 10th to 90th percentile range of inter-annual variability

Figure-4.4 shows that the blue envelopes are relatively wider than that of figure-4.3. This implies that there was high minimum temperature variability than maximum temperature. For example, high minimum temperature was observed in February which was about 14°C and on average low minimum temperature was observed in November and December that was about 8 °C. Likewise the variability of minimum temperatures were influenced strongly by nocturnal cloud cover, which results in higher minimum temperatures variability observed in February from 5 °C to 14 °C while probably clear night skies results in lower minimum temperatures in December from 4.5 °C to 9 °C. This is more probably due to the seasonal effect. (Hewitson, B.and Crane, R.; 2006).

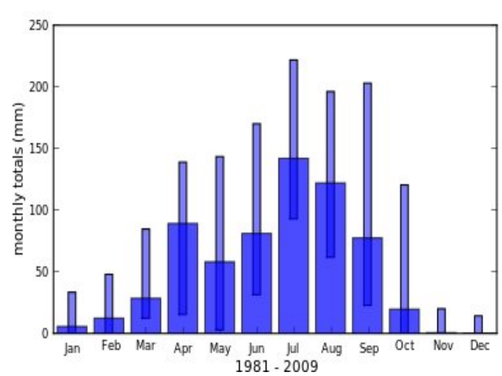

Figure 4.5: Observed monthly rainfall totals climatology with inter-annual range for Langano station . Wide bars indicate the median monthly rainfall for the observed period. Narrow bars indicate the 10th to 90th percentile range of monthly rainfall for each month during the observed period.

The monthly rainfall variability for Langano station is given in figure-4.5. The figure depicted the monthly variability of rain falls of the period in the last 28 years. The July cumulative average rainfall was about 150mm, but the highest extremes rainfall was known to have taken place that was about 230mm in the same month, and the lowest amount of rainfall has been recorded to be about 100 mm but it varied between 100 and 230mm during the time period. That means there was no time that has showed a recorded below 100mm. January and February had deficient precipitation, and November and December did not receive any precipitation. In this regard the pattern of summer rainfall for in both Arsi Negelle and Langano station had different variability. Generally sufficient summer rain fall is very important because since the area is agro ecologically low land and may have relatively high evaporation problem because of temperature increase in low land area than high land areas (ICRA, 2002).

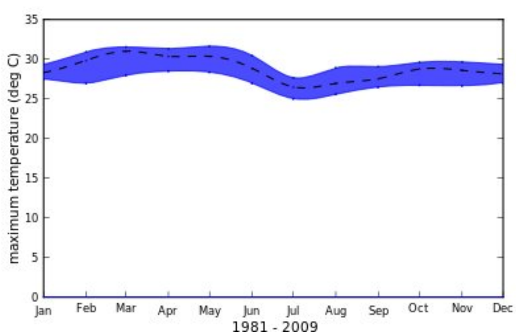

Figure4. 6: Observed monthly mean of the daily maximum temperatures for Langano station (Dashed line) represents observed monthly mean of the daily maximum temperatures for the observed period. Blue envelope represents the 10th to 90th percentile range of inter-annual variability.

The variability of maximum temperature of Langano station is represented in blue envelopes (Figure 4.6). For example, the highest maximum temperature was observed in March. The average maximum value of the mentioned months was about 31 ^{o}C but the variability of maximum temperature in the same month was between 27 ^{o}C to 31 ^{o}C. When compared to the variability and magnitude of the temperature of both stations; Langano station increased by 3 ^{o}C than Arsi Negelle stations particularly in March. According to (Cooper et al; 2008) findings, relatively highlands are colder than the lowlands because the higher the elevation, the colder it becomes.

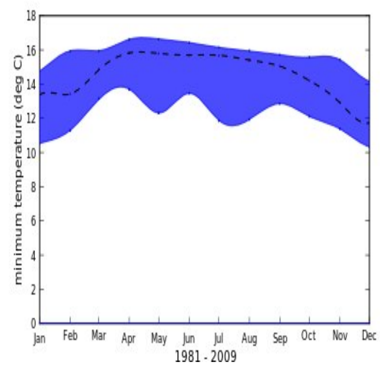

Figure 4.7: Observed monthly mean of the daily maximum temperatures for the observed period

The average high minimum temperature was observed between April and May which was about 15^{o}c and low minimum temperature was observed in December and it was about 12 ^{0}C .The variability of minimum temperatures were influenced strongly by nocturnal cloud cover, which results in higher minimum temperatures variability in February from10.5 ^{o}C to 16^{o}C while clear night skies probably resulted in lower minimum temperatures in March from 13 ^{o}C to 16 ^{o}C. It is more probably due to the seasonal effect (Hewitson, B.and Crane, R.; 2006).

4.2. Downscaled monthly rainfall and temperature projections in the study area

The most widely used method for obtaining information on possible future climate change is to use coupled Global Circulation Models (GCM). Projections of future climates are produced through models based upon knowledge of how the climate system works and used to examine estimated values of climate variability. These climate models are based upon IPCC emissions scenarios (IPCC, 2001) which reflect estimates of how humans will emit CO2 in the future. Thus, the use of GCM to derive local climate values assumes that the synoptic patterns of variance in the model are comparable to those of the observed data. The downscaled precipitation needs to be viewed in the light of what the GCM parameterized precipitation in figure-4.7 indicates that the downscaling results present a different picture from observed one.

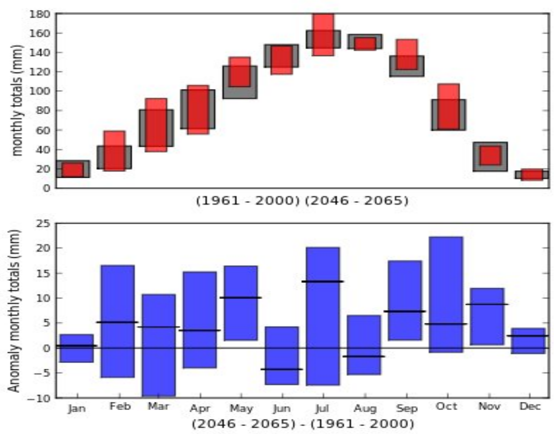

Figure4. 8: Change in monthly total rainfall (mm) for Arsi Negelle station.

Grey bars represent 10th to 90th percentile range of the control period multi-model climatologies (1961-2000). Red bars represent the same but for the future period multi-model projections (2046-2065). Anomaly plot wide bars represents 10th to 90th percentile ranges of the future - control anomalies with the median change marked as a solid black line.

As it is depicted in figure-4.8 one can deduce that the climate change anomaly from the downscaled control and future daily atmospheric data of the different GCMs. As it was shown from the above figure there is a non-perfect overlap of the two climate bars; that red bars was shifted outward. This is because of future climatic projections were expected to increases. The precipitation derived from the observed circulation may be used as the basis of comparison in order to compare the predicted precipitation to actual precipitation. Therefore- figure-4.8 showed the range of monthly projected rainfall totals variability for Arsi Negelle stations. For instance, during the control period in July, the model average rain fall is about 160mm and the future period showed 180mm and the range of monthly rainfall anomalies between the future simulation period and the control period was predicted to be about 20 mm. However, most of the models projected the future average rain fall would be more than 15mm during the July control period. The average observed monthly total values in July was about 150mm.However, the median of most GCMs simulated was about 165mm,in July month from 2045 to 2065 precipitation will increase by 15mm.

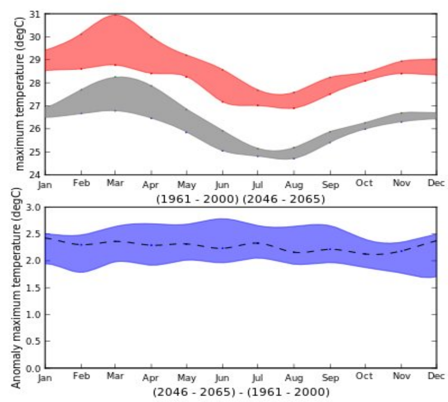

Figure 4.9: Change in monthly mean maximum daily temperature (O C) for ArsiNegele station. Grey envelope represents 10th to 90th percentile range of the control period multi-model climatologies (1961-2000). Red envelope represents the same but for the future period multi-model projections (2046-2065). (Dotted

line) represents the range of the median anomalies.

From figure-4.9 one can see the variability change of mean daily maximum temperature projections and control periods. For example, the control mean maximum temperature in July is 25 ^{O}C and the projected temperature will be 27.5 ^{o}c. Most of the models predicted that the estimated climate scenarios after 2045 maximum temperature will increase by 2.5^{O}C. From figure-4.7 it can be stated that rainfall will increase in same month by 2045 and in Jun and August the temperature will increase by more than 2 ^{o}C. According to the IPCC (2001), potential climate changes in Africa would increase in global mean temperatures between 1.5^{0}C and 6^{0}C by 2100. Current scenarios indicate future warming across the continent ranging from 2^{0}C per decade to more than 0.5^{0}C per decade. Warming expected to be greatest over semi-arid regions. However, as rainfall declines, it implies that there will be high variability and high potential evaporation (NMA, 2007).

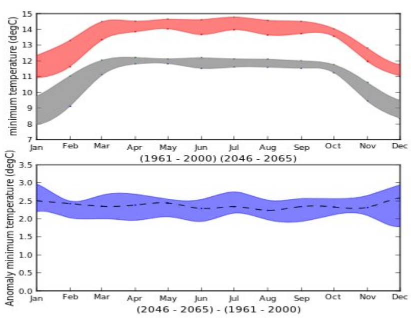

Figure4. 10: Change in monthly mean minimum daily temperature for Arsi Negelle station. Grey envelope represents 10th to 90th percentile range of the control period multi-model climatologies (1961-2000). Red envelope represents the same but for the future period multi-model projections (2046-2065). (Dashed line) represents the range of the median anomalies.

From figure-4.10, one can be observed that the variability of mean daily minimum temperature for projections and control periods. For example, in July the control minimum temperature is 12 ^{o}C and the projected temperature is 14.8 ^{o}C and the median of the models or the range of monthly mean daily minimum temperature anomalies between the future simulation period and the control period is about 2.5^{o}c. This means after 2045, minimum temperature will increase by 2.5 ^{o}C. As it shown in figure-4.9, it can be deduced that there will be more variability in the future simulation period than the observed controlled period.

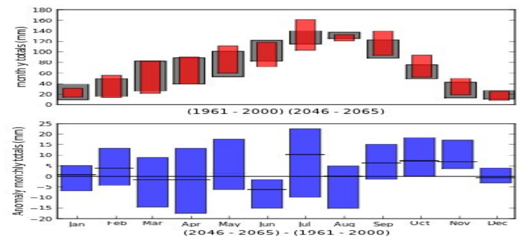

Figure 4.11: Change in monthly total rainfall (mm) for Langano station

Grey bars represent 10th to 90th percentile range of the control period multi-model climatologies (1961-2000). Red bars represent the same but for the future period multi-model projections (2046-2065). Anomaly plot wide bars represents 10th to 90th percentile ranges of the future - control anomalies with the median change marked as a solid black line.

From (fig.4.11) one can see that during the control period July average rain fall was about 140mm and the future period shows 160mm and the range of monthly rainfall anomalies between the future simulation period and the control period is about 20 mm. However, after 2045, most of the median of the models projected the future July average rain fall would be 10mm increase more than the control period. There will be some potential variability across the months. For example, in February, September, October and November indicated potential increase of precipitation but January and December showed that no variability while march, April and Jun showed precipitation will be decreased from the observed value. As result the reduction of rainfall and increasing temperature particularly in late growing season crops can be affected (Mendelsohn R & Dinar A, 2003).

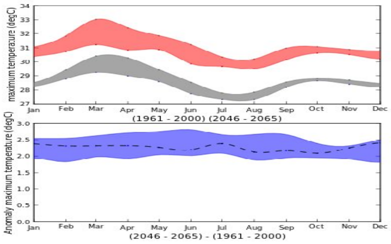

Figure4. 12: Change in monthly mean maximum daily temperature (O C) for Langano station

Top panel: 10th to 90th percentile multi-model range of monthly mean daily maximum temperatures for 20th Century (grey) and future period (red). Bottom panel: 10th to 90th percentile multi-model range of monthly mean daily maximum temperature anomalies between the future simulation period and the 20th Century simulation period.

Figure-4.12 depicted the monthly mean daily minimum temperature projections for 20th century and for the future period in the study area. For example, in March the control minimum temperature is 30 ^{0}C and the projected temperature is 33 ^{0}C and the median of the models or the range of monthly mean daily minimum temperature anomalies between the future simulation period and the control period is about 2.5^{O}C. The projected precipitation in March and April will decline while the maximum temperature will increase.

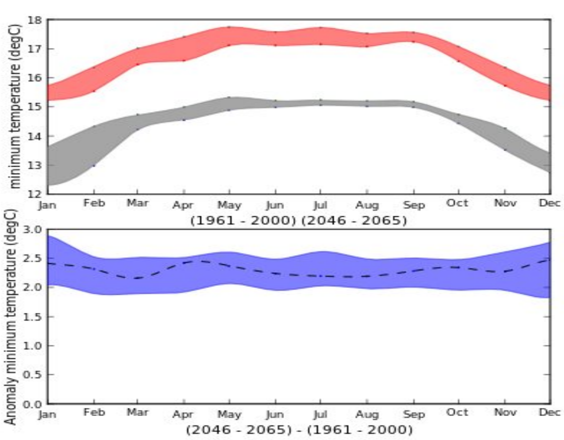

Figure4. 13: Change in monthly mean minimum daily temperature (OC) for Langano station

Figure-4.13 shows also monthly mean and daily minimum temperature projections for 20th century and for the future period. In May for instance, the control period minimum temperature is 15 ^{0}C and the projected temperature is 17.5 ^{0}C and the median of the models or the range of monthly mean daily minimum temperature anomalies between the future simulation period and the 20th century simulation period is about 2.5 ^{0}C.

4.3. Estimated marginal effect of temperature and precipitation on crop net revenues

The Ricardian approach estimates the importance of climate and other variables on the value of farmland. Net revenues were regressed on climatic and other control variables. This study explores two main sets of the Ricardian model indicated in model one and two. The first model includes only climate and soil variables and is referred to as without adaptation model. The second model includes climate, soil and relevant socio-economic variables and is referred to as with adaptation model. These additional variables are used to assess the extent to which these additional variables increase or decrease the effect of climate on crops.

The regression results indicated that most of the climatic, household and soil variables have significant impacts on the net revenue per hectare (Annex .1). This table shows that while the coefficients of dry season and main rainy season temperature are both negative, those of short rainy season and autumn season are positive. The coefficients of main rainy season are negative, whereas for dry season, short rainy season and autumn seasons are positive. The interpretations of the signs and magnitudes of impacts are further explained under the marginal analysis. For example, the coefficient of short rainy season temperature in with adaptation model is negative but the coefficient of the short rainy season temperature squared is positive. In short rainy season temperature, climate variables have a *U shaped* relationship with net revenue. This suggests that short rainy season temperature has a negative effect on net revenue until a turning point is reached, beyond that value; it has a positive impact on net revenues whereas in without the adaptation model, the coefficient of spring temperature is positive and it has a *hill-shaped* relationship with net revenue. This means, spring temperature has a positive effect on net revenue until a turning point is reached, beyond that value; temperature has a negative impact on the revenue. The coefficient of squared values tells both the direction and steepness of the curvature (a positive value indicates the curvature is upwards while a negative value indicates the curvature is downwards (Kurukulasuriya & Mendelssohn, 2006).

The estimated marginal impact analysis was undertaken to observe the effect of change in temperature and rainfall on Arsi Negelle farming. Table4.1 and 4.2 showed the marginal effects of a 1℃ increase in temperature and 1mm increase in precipitation on crop net revenues for farmer in adaptation and without adaptation model respectively. For example, with adaptation model, a 1℃ increasing temperature during main rainy season and dry seasons significantly reduces the net revenue by 5179.65 and 704.19Birr per hectare respectively (table 4.1). How- ever, a 1℃ increasing temperature marginally during the short rainy season and autumn seasons increase the net revenue per hectare by 1081.81and1542.67Birr respectively (Table4.1). During short rainy season, a slightly higher temperature with the available level of precipitation enhances germination, as this is the planting period. During autumn, a higher temperature is beneficial for harvesting. It is important to notice that most crops have finished their growing period by autumn, and a higher temperature quickly dries up the crops and facilitates its harvesting so, it has a positive effect on net revenue (Mendelsohn R & Dinar A, 2003).

Increasing precipitation by1mm during the main rainy season reduces net revenue per hectare by 1184.00Birr but 1 mm increase winter precipitation reduces the net revenue by 328.9Birr. The reduction in net revenue per hectare during the main rainy season is due to the already high level of rainfall in the country particularly in central rift valley. During this season, increasing precipitation results in flooding and damage to field crops but in Ethiopia January and February are a dry season, so increasing precipitation slightly with the already dry season may encourage diseases and insect pests. During the period of (mid-September, October and November) a 1 mm increasing precipitation increases net revenue per hectare by 227.29Birr (Table-4.1). As explained earlier, with slightly higher temperature and available precipitation (soil moisture level), crop germination is enhanced. Marginally 1mm increasing precipitation during the autumn also reduces net revenue per hectare by 358.80Birr (table-4.1). The reduction in net revenue per hectare with increasing precipitation during this season is due to the crops' reduced water requirement because it is commonly known as harvesting season. More precipitation damages crops and may reinitiate growth during this season (Kurukulasuriya, P & Rosenthal, and S. 2003).

Table 4:1 Marginal effects of climate variables on crop net revenue based on coefficients for model with adaptation (Ethiopian Birr)

Climate variables	Main rainy season	Dry season	Short rainy season	Autumn season
Temperature	- 5179.65	-704.19	1081.81	1542.67
Precipitation	-1184.00	-328.9	227.29	-358.80

For the model without adaptation, a 1℃ increasing temperature during main rainy season and dry season seasons significantly reduces the net revenue by 2010.76 and 731.11 respectively while 1℃ increasing temperature marginally during the short rainy season and autumn seasons increase the net revenue per hectare by 256.41 and 5248.54 Birr respectively (table-4.4). Increasing precipitation by 1 mm during the main rainy season and dry season increase net revenue per hectare by 143.52and22.74 Birr respectively. During the short rainy season a 1mm increasing precipitation increases net revenue per hectare by 126.00Birr. Marginally a 1 mm increasing precipitation during the autumn also reduces net revenue per hectare, by 406.00Birr. As it is explained above, the reduction in net revenue per hectare with increasing precipitation during the autumn (mid-September, October and November) is due to the crops' reduced water requirement during the harvesting season and more precipitation damages crops (Deressa et al., 2008).

Table4. 2: Marginal effects of climate variables on crop net revenue based on coefficients for model without adaptation (Ethiopian Birr)

Climate variables	Main rainy season	Dry season	Short rainy season	Autumn season
Temperature	-2010.76	-731.11	256.41	5248.54
Precipitation	143.52	22.74	126.00	-406.00

Adaptation has an advantage of the positive effects of climate change while reducing the negative ones. In table-4.3 one would expect that, inclusion of adaptation related variables (socio-economic variables) will increase the relationship between climate variables and crop net revenues for positive values and reducing the negative values. Thus including adaptation variables may help reduce the negative effects and take advantage of the positive effects of high temperatures. For example, in adaptation model, the negative effects of the dry season temperature have decreased while without adaptation model the negative effect of temperature increase from-704.19 birr to -731.11Birr respectively. However, for main rainy season temperature, the inclusion of adaptation related variables rather aggravates the negative effects of increased temperature, the estimated negative effect is -5179.65Birr whereas without adaptation model with the negative effects was estimated as -2010.76Birr reduced per hectare. According to (Dinar et al., 2008) findings, even though the adaptation related variables are important in helping to control climate effects, if

they are not properly implemented they may rather aggravate the problem. One can see that how the inclusion of socio-economic variables improved the model, as is it indicated the R-squared values from without and with adaptation models as that indicated the relative higher R-squared for the two models ranging from 22% to 50%(Annex 1&2). This implies that the socio-economic variables are important in explaining better for crop revenues.

4.4. Farmers' perceptions and adaptation to climate change

The survey instruments were designed to capture farmers' perceptions and understanding of climate change as well as their approaches to adaptations. From the three kebeles, the farmers were asked about the trends of climate parameters of temperature and rainfall is shown below.

Table 4.3: Households' perceptions on climate change over the last two decade (Percentages).

	Hadha Boso kebel (LL) (%)		Kersa Ilala kebele (ML) (%)		Meraro kebele (HL) (%)	
Directions	Rainfall	Temperature	Rainfall	Temperature	Rainfall	Temperature
Increasing	18.97	65.97	26.92	60.46	28.13	53.13

Decreasing	70.69	17.69	61.54	29.62	46.88	34.38
The same	10.34	16.34	11.54	9.92	24.99	12.49
Total	100	100	100	100	100	100

As one can see from (table 4.3), 77.59% of selected households have perceived as climate is changing while the corresponding response 22.41% of the rest didn't perceived for this climate change in the last two decades. Regarding the direction of the change of temperature and rainfall in the three kebeles, Hada Boso, Kersa and Meraro, 65.97%, 60.46%, and 53.13%, of the sample households perceive an increase temperature and 17.69%, 29.62%, and 34.38% decrease temperature respectively. With regard to rainfall as mentioned above 18.97%, 26.92% and 28.13% of respondents answered that rainfall is increasing while 70.69%, 61.54% and 46.88% of respondents answered rainfall is decreasing respectively. However, 10.34%, 11.54%, and 24.99 of Hada Boso, Kersa, and Meraro sample household did not observe any change of rainfall and temperature respectively. The agro-ecological setting of farmers influences the perception of farmers to climate change. According to Diggs (1991) findings, farmers living in drier (lowland) areas with more frequent droughts are more likely to describe the climate change to be warmer and drier than farmers living in relatively highland areas with less frequent droughts. In Ethiopia, particularly central rift valley, lowland areas are drier with higher drought frequency than other areas (Bezabih et. al; 2010). Thus, it is hypothesized that farmers living in lowland areas are more likely to perceive climate change as compared to midland and highlands. In general, increased temperature and declined precipitation are the predominant perceptions in the study areas.

4.4.1. Traditional adaptation mechanisms of climate change by local farmers

In central rift valley of Ethiopia, particularly in Arsi Negelle district, farmer's ability to adapt climate change is limited due to lack of knowledge and economic resources, and their vulnerability is put emphasis on by heavy dependence on the climate, because farmers depend on the rain fed agriculture system. Given the diversity of the constraints they faced, the general capacity to cope to climate changes is currently very low. There are no good national action plans which take into account short or long term climate changes.

The extended increasing temperature, combined with the declining of the rain fall and the frequency of the drought, as well as deforestation and land degradation of the soils, have resulted in decline of crop yields. According to Deressa et al. (2008) findings, crop yield was declined by 32.8% as result of shocks such as drought and flood etc. Farmers therefore trying to develop their own strategies to cope climate change impacts. Deressa et al. (2008) argued that adaptation to climate change is also a two-step process that involves perceiving that climate is changing, and then responding to changes through adaptation strategies. The adaptation methods most commonly cited in the literature include the use of new crop varieties irrigation, crop diversification, mixed crop, livestock farming systems, changes of planting dates, diversification from farm to nonfarm activities, increased use of water and soil conservation techniques, and trees planted for shade and shelter (Mukheibir and Ziervogel, 2007). In the case of Arsi Negelle district farmers were asked about their perceptions of climate change and their actions to offset the negative effects of climate change. As responded by farmers one can deduce that farmers actions were driven by climatic actions and the result were similar to the findings of (Mukheibir and Ziervogel, 2007).

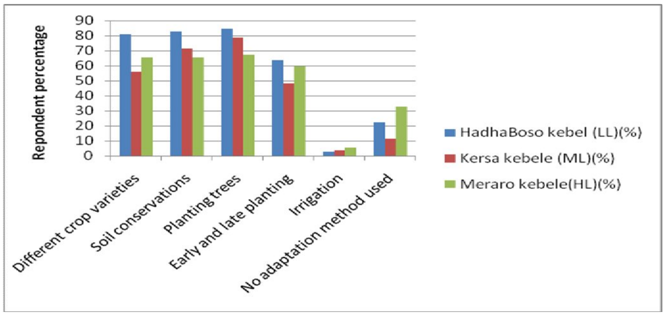

Figure 4.14: Adaptation methods in the study site

As shown in figure-4.14, most of the farmers did at least something in response to climate changes. This indicated that they are aware of the changing climatic conditions. Some farmers did not use any adaptation option. For example, 22.41%, 11.54, and 32.81% of Hadaboso, Kersa and Meraro kebeles respondents were not used any adaptation option for a number of reasons (see fig-4.15). From fig.14 one can see that the adaptation strategy in the three kebeles is most commonly used plant trees (in the three kebeles about 84.48%, 78.85%and 67.19% respectively). Other adaptation strategies farmers used were soil conservation techniques (82.76%, 71.15%, and 65.63%), using different crop varieties (81.03%, 55.77%, and 65.63%), early and late planting (63.79%, 48.08%, and 59.38%) and irrigation (2.86%3.85%, 5.44 %,) of Hadaboso, Kersa and Meraro kebeles farmers used respectively.

The various adaptation strategies being used by farmers in response to changing climatic variations in high land and the low land areas of the kebeles were as follows. In the lowland (*Kolla*) kebeles are more vulnerable to climate variability and change due to water stressed and also constraints related with alternative livelihood engagements aggravate the problem and limits their adaptive capacity. As a result the following coping strategies have been used by the community. If the drought period is short, they usually try to cope using various mechanisms being in their localities such as late and early planting, using crop diversification and sometimes irrigation and however, if the drought continues, short-term movement to the highland areas is common. Besides human population increment that cause shortage of grazing land, production of livestock per household in drought period is reducing. So, storage of crop residues (maize straw) as an emergency feed for drought periods was common practices in the area. In addition reserving some crops until the coming season, crop diversification, and using short rotation crop varieties were some of adaptation mechanisms in the study area (EARO, (2002). In highland area, farmers have used various coping strategies; some of those are as follows. Adopting of fruit trees, soil and water conservation practices, practice of using crop residues as livestock feed, community level forest conservation and management, using *Enset* crops for both source of food and feed were some of the coping strategies being used by highland farmer.

4.4.2 Major barriers and constraints to adaptations identified by local farmers

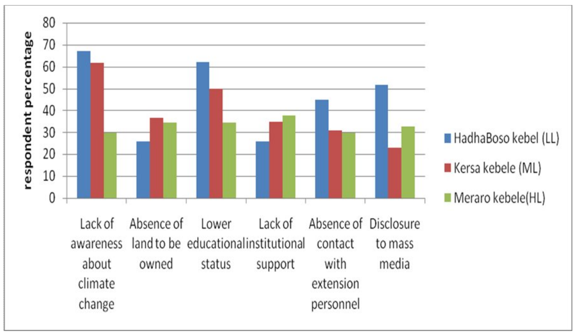

Figure 4.15: Barriers and constraints to adaptations identified by local farmers

Most of these constraints shown in the figure-4.15 were associated with poverty. Lack of information on appropriate adaptation options could be attributed to scarcity of study gape on climate change and adaptation options. Lack of money hinders farmers from getting the necessary agricultural inputs and technologies that facilitates adapting to climate change. If farmers do not have sufficient family labor or financial means to employ labor, they cannot adapt. This is true because adaptation to climate change needs some financial and technological supports. Shortage of land has been associated with high population pressure, which forces farmers to intensively farm a small plot of land. Poor irrigation potential is most likely associated with the inability of farmers to use the water that is already there due to technological incapability. The reasons of farmers not did the farm level adaptations options illustrated in figure-4.15. Lack of awareness about climate change is the major constraints

4.4.3. Major effects of climate change on agriculture in Arsi Negelle

From the figure-4.17 below, one can see that the summary statistics of the effect of climate change on agricultural practices in the three study kebeles based on the household interviewed results.

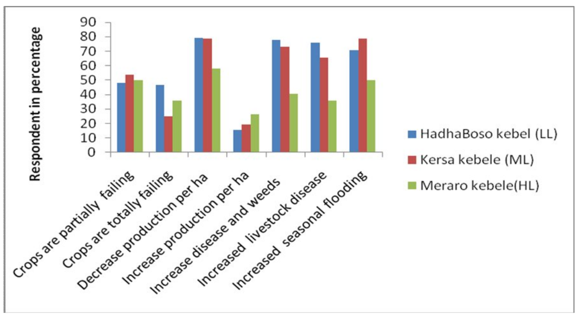

Figure4. 15: Major effects of climate change on agricultural production in study area

According to figure-4.17, the various effects faced by farmers due to climatic change are presented. For example, respondents, 48.28% lowlands 53.85% of mid land and 50.00% in highlands were answered that crops were sometimes failing. On average 46.55% of low land 25.00 % of mid land and 35.94% highland faced crops are totally failing, on average 79.31 %of lowland 78.85%of mid land 57.81%of high land responded that due to climate change, production per hectare is decreasing. As interviewed farmers claimed that there were reductions of crop yields because due to changes in rainfall temperature patterns. From the interviewed households as indicated in figure-4.17, the 15.52% 19.23% and 26.56% of respondents from low land, mid land and highland respectively answered production per ha is increasing. Thisi might be because of using different adaptation mechanizes that can increase their production against temperature and rainfall variation

5. Conclusion

The results obtained from analysis of meteorological data indicated that there has been considerable variability in climatic elements both in Arsi Negelle and Langano stations. The rate of change of maximum and minimum temperature found to vary in both stations and minimum temperature variability increased more than maximum temperature does. On the other hand, rainfall found to be more variable in Langano station than in Arsi Negelle station. The future climate scenario analysis indicates that the magnitude and variability of both maximum and minimum temperatures will increase more than the rainfall in both stations. With regard to rainfall projection at Arsi Negelle station, rainfall in the main rainy season will be decreasing meanwhile, it will be relatively increasing in the short rainy season. Whereas at Langano station, the future simulated rainfall amount during the main and short rainy seasons will decrease meanwhile the autumn rainfall will increase relatively. However, in July both Arsi Negele and Langano stations will have high precipitation as compared to other months of the year. Interpretations of results obtained from marginal analysis indicated that increasing temperature and decreasing rainfall generally have negative impact on crop productivity. However, at local level, some farmers experienced positive effects from increased precipitation while others experienced negative effects as results from interviewing farmers suggested. This is a reflection of the unclear impact of change in precipitation on crop activities in the area. It is also a reflection of the high degree of variability of the rainfall experienced in the recent past. The socio-economic and/or adaptation related variables in controlling climate effects play a crucial role for the betterment of agricultural practices. The size of cropland area is an important factor, especially for large family size households, since a larger area enable them to spread their risk from adverse climate effects and thereby to reduce the net effects from the change. Larger cropland area may provide better opportunities for efficient use of resources and the possibility of growing different crop types. Livestock farming was also found to be better practice in response to adverse climate effects because in most cases they have limited alternatives especially in dry areas. Easy accessibility of markets relatively helps farmers get higher prices for their products. This helps them to cover additional costs caused by the adverse effects of climate change. Accesses to extension and credit services have positively influenced farming activities. Most of the interviewed farmers for the studied kebeles perceived that they have observed the changing temperature and precipitation, such as reduced amount of rainfall (59.7%), increasing temperature (60%), shift in the timing of rainfall and shortened period of raining days. They also stated that these changes have been affecting their farming activities. Given this perception and depending on the farming system, farmers have practiced several adaptation mechanisms.

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List of annexes

Annex 1: Regression results of model with adaptation: climate, soil and socio-economic variables

Independent variable	coefficient	T-statistics
Summer temperature	-5525.09 *	-1.711
Summer temperature sq	172.72 *	1.82
Winter temperature	-733.3	-0.68
Winter temperature sq	14.42	1.01
Spring temperature	-1190.57 **	-2.47
Spring temperature sq	54.37 **	2.22
Autumn temperature	1538.95**	2.04
Autumn temperature sq	4.36 *	1.97
Summer precipitation	-1544.24 *	-1.74
Summer precipitation sq	180.12 *	1.54
Winter precipitation	-344.42	-0.83

Winter precipitation sq	7.76	1.07
Spring precipitation	229.46 *	1.73
Spring precipitation sq	-1.087 **	-2.11
Autumn precipitation	-473.64 *	-1.65
Autumn precipitation sq	57.42 *	1.55
Clay soil	Reference group	
Sandy soil	-216.87	-0.70
Black soil	5987.43 *	1.63
Red soil	3855.88	1.24
Land size	134.59	1.46
Livestock ownership	777.66 ***	3.32
Distance of input market	-376.04	-1.49
Distance of output market	-43.58	-0.81
Farming experience	161.41	1.02
Access to credit	18839.42***	4.71
Access to extension	6869.53 *	1.66
Family size	-565.46 *	-1.8
Year of educational household head	533.00 *	1.87
Constant	-74442.76 *	-1.88
F	6.73	
R squared	0.51	
N	**174**	

***Note*: * Significant at 10% level ** Significant at 5% level *** Significant at 1% level**

Annex 1: Regression results of model without adaptation: climate and soil variables

Independent variable	coefficient	T-statistics
Summer temperature	2134.72 *	1.69
Summer temperature sq	-61.98 *	-1.86
Winter temperature	-941.79*	-1.50
Winter temperature sq	105.34*	1.73
Spring temperature	300.75	1.39
Spring temperature sq	-22.16	-1.06
Autumn temperature	5497.96 **	2.40
Autumn temperature sq	-124.69 **	-2.07
Summer precipitation	164.16	1.30
Summer precipitation sq	-10.32	-1.00
Winter precipitation	29.78	-1.07
Winter precipitation sq	-3.52	1.30
Spring precipitation	137.06	1.01
Spring precipitation sq	-5.49	-1.40
Autumn precipitation	- 516.79 *	-1.57
Autumn precipitation sq	55.02 *	1.70
Clay soil	Reference group	
Sandy soil	-1884.35	-0.51
Read soil	4737.23	1.25
Black soil	4805.59 **	2.34

Constant	-106350.2	2.34
F	4.15	
R squared	0.22	
N	**174**	

***Note*: * Significant at 10% level ** Significant at 5% level**

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