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The Impact of Climate Variability on Food Security and Coping Mechanisms of Farmers in Boricha District Southern Ethiopia

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Abstract: The rapid growth of greenhouse gas emissions as a result of human activities such as burning fossil fuels is raising the Earth's temperature and leading to climate change. This results in variability in precipitation, the prevalence of more extreme weather events, and shifting seasons. The accelerating pace of climate change, combined with population growth, will also threaten food security. Climate change will result in irreparable ecological degradation and possibly the reduction of agricultural productivity in many parts of the World with serious consequences for food security. This paper investigated the impacts of climate variability on food security and coping mechanisms of farmers in Boricha district of Ethiopia by using meteorological, agricultural and socio-economic survey data. The study employed various data analysis methods such as computing the coefficient of rainfall variability, estimating the impact of rainfall and temperature change on agricultural productivity, and analyzing coping strategies of the local communities in response to climate extreme events. The coefficient of rainfall variation results show that rainfall variability has significant and negative impacts on agricultural productivity in the Boricha district. Moreover, linear regression model outputs for the relationship between rainfall and crop yields indicate that rainfall variability has been significantly affecting agricultural productivity in the district. Results from the multinomial logistic model for multi-choice coping/adaptation mechanisms also show that different socio- economic factors such as education level and age of household head, family size, farm income and livestock ownership affect how households cope with extreme climate events. This research suggests that policies should introduce adaptation measures outlined by existing rural communities such as inter-cropping, livelihood diversification and early maturing crops to incorporate indigenous knowledge to ensure food security and sustain the economic growth of the country.

Keywords: Climate Change, Food Security, Coping Mechanisms, Agricultural Productivity, Impact, Regression Models, Boricha

1. Introduction

The environment of our planet is in a state of continuous change at alarming rate. United State Global Change Research Program (USGCRP) [20] stated that climate system is highly variable, with conditions changing significantly over the span of seasons, from year to year, and over longer timescales. Many scientific observations indicate that the Earth may be undergoing a period of relatively rapid change on timescales of decades to centuries, when compared to historical rates of change. Much scientific evidences also indicate that these changes are the results of both natural and human-related influences.

Humans are relatively new comers in the vast scale of the Earth's geological history, but we have become agents of environmental change, at least on timescales of decades to centuries. Although some early societies had negative impacts on their surroundings, others lived in relative harmony with nature. In modern times, however, growing human populations and the power of our technology have heightened concern about what we are doing to our environment [2].

Human influences include industrial activities which emit a variety of atmospheric pollutants, burning of fossil fuels which lead to emission of greenhouse gases (GHGs), alteration of the land's surface for example due to deforestation, burning of biomass and vegetation which also produce GHGs and particulate soot, agricultural practices which produce methane (CH_4) and nitrous oxide (N_2O). These human activities have significantly altered the atmosphere, particularly its composition resulting in increased acidity in the atmosphere, production of pollutants, elevated level of GHGs and threats to the ultraviolet-filtering ozone layer in the stratosphere. These gases also produce a greenhouse effect by allowing incoming solar radiant energy to penetrate to the Earth's surface while reabsorbing infrared radiation emanating from it and not letting this radiation to scape to the outer atmosphere [12].

Of all the climatic factors, the seasonal and inter-annual variations in precipitation and temperature are most crucial for rain-fed agriculture and also for runoff irrigated production. Spatial and temporal variation in precipitation plays a great role for both rain-fed and irrigated agricultural systems [3]. The day-to-day variability of rainfall associated with weather is also the major risk factor for agricultural productivity. Moreover, the variability in rainfall intensity and duration makes agricultural production and productivity very difficult in relation to long-term climate variability to anticipate [3]. African agriculture is already under stress as a result of population increase, industrialization and urbanization, competition over resource use, degradation of resources, and insufficient public spending for rural infrastructure and services [11]. The impact of climate change is likely to exacerbate these stresses even further.

A number of countries in Sub Saharan Africa already experienced considerable water stress as a result of insufficient and unreliable rainfall, changing rainfall patterns, inadequate storage and uneven distribution of rain during the year. For Africa, it is estimated that 25% of the population approximately 200 million people currently experience water stress, with more countries expected to face high risks in the future. This may, in turn, leads to increased food and water insecurity for at risk populations, undermining socio-economic growth [15, 17].

Over 80% of Ethiopia's 80 million people live in rural areas and are heavily dependent on rain-fed agriculture. This makes them extremely vulnerable to changes in weather conditions. Over the last four decades, there have been a number of severe famines at least partly triggered by droughts in Ethiopia [1]. Therefore, Ethiopia is likely to be vulnerable to climate change. The Government of Ethiopia's National Adaptation Plan of Action (NAPA) process of 2007 identified arid, semi-arid and dry sub-humid areas of the country as being most vulnerable to drought. The vulnerability assessment based on the existing information and a rapid assessments carried out under the Ethiopian National Meteorological Agency [14] has indicated that the most vulnerable sectors to climate variability and change are agriculture, water and human health.

This study therefore was conducted to examine the impact of climate variability on food security and livelihoods, with particular emphasis on the effects of rainfall and temperature variation on crop and livestock productivity and socio-economic impacts, as well as investigation of the coping capacity of the farmers in the Boricha district of southern Ethiopia.

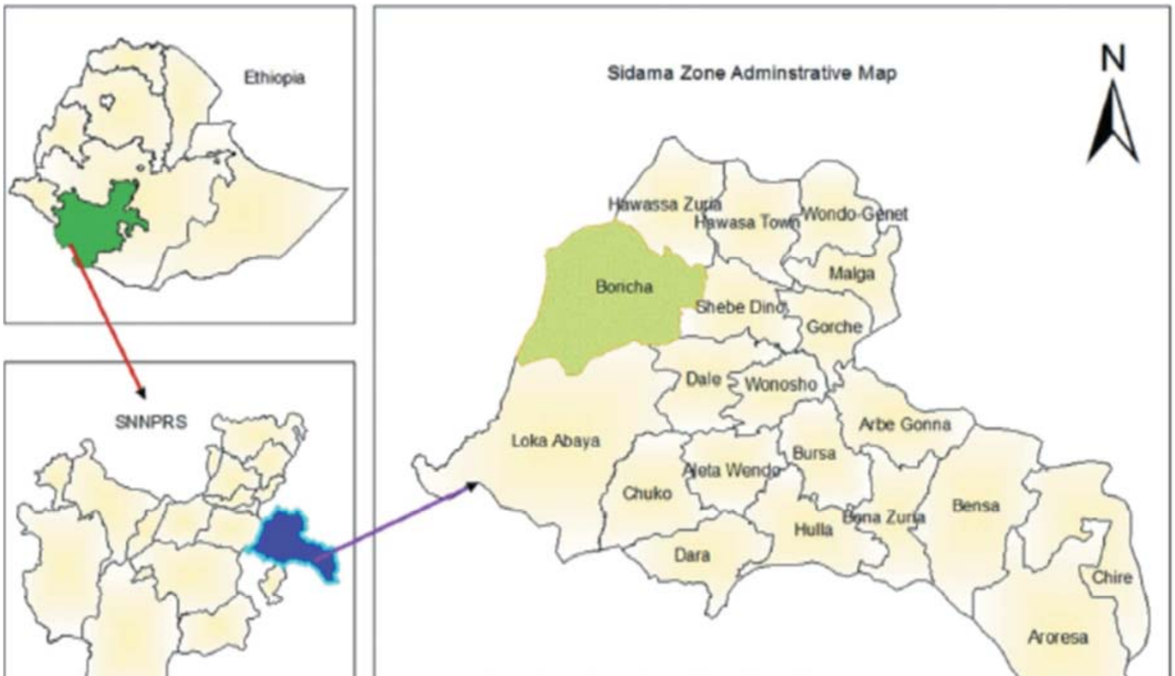

Figure 1. *Administrative location of Boricha woreda.*

2. Materials and Methods

2.1. Description of the Study Area

Boricha woreda is found in Sidama maize belt zone which covers the lowest areas of Sidaama administrative region, including parts of Hawassa, Dale, Aleta Wondo, Dara, Bensa and Aroresa woredas. Although described by many officials as lowland or kola, it technically falls into the borderline area between the kola and woyna dega agro-ecological zones, with altitudes in the range of 1400–1700 m above sea level. Average annual rainfall is in the range of 700-1200 mm per year and falls during two rainy seasons, the Belg and Kiremt rains. The total population of this woreda was 284,576 in 2011 and it is estimated to be 310,533 at present (2018). The landscape varies between undulating hills and plains. Most of the household surveyed community members describe about the area that, as recently as one generation ago, the area was covered by acacia forest, but these days it is increasingly bare. No river crosses this area, making the population largely dependent on man-made ponds and shallow wells for water for both humans and livestock. As a result the area tends to be dry during the period of December to February, making water availability a major problem. Farmers describe themselves as Belg-dependent, since the Belg rains in March to April are key for the production of maize, the main crop, which is planted only once per year. Other food crops such as haricot beans, sweet potatoes and teff can be planted twice per year, during each rainy season. When the Belg rains are poor and maize production fails, farmers try to intensify the area planted with these short-maturing crops during the subsequent Meher season in order to compensate for the lost maize.

2.2. Sample Size and Sampling Techniques

Multistage sampling techniques were used to select sites and draw the size of the sample of households for the study. First four kebeles were selected from the area considering their agro-ecology. During reconnaissance survey, the study area was divided in to two zones based on precipitation and temperature, i.e. relatively dry and semi-humid zones. From each zone two kebeles were selected. Then sample size of interviewees was determined by using the following formula, which is widely used in the literature:

$$n = N/1+Ne^2$$

where "n" is the sample size, "N" is the population size and "e" is the level of precision [21].

Using tabulated values that correspond with the calculated value using the above formula and 7% precision level for 95% of confidence, the sample size of interviewees was determined to be 200 from the total of 4,849 households which is the population of the sampled kebeles.

2.3. Method of Data Collection and Types of Data

A combination of data collecting procedures were employed in order to triangulate information to develop an in-depth analysis of climate change impacts and coping capacity in the households and communities visited within the four kebeles of the study area. Both primary and secondary data sources were used. The primary data were collected by using structured questionnaires and interviews for households. On the other hand, secondary data such as; agricultural yields data were collected from Boricha woreda agriculture and rural development office (ARDO) and meteorological data from National Meteorological Agency Hawassa branch for four stations of the district, namely Darara, Yirba, Balela and Bilate.

Data from Balela station were used as complementary since data were incomplete in all stations and this station has only 10 years data of both temperature and rainfall. Population data of the area were also collected from central statistical agency, Boricha district ARDO, and from other studies.

2.4. Data Analysis and Tools Used

In order to describe and compare rainfall variability mean, standard deviation and percentage were computed. The trend of rainfall variability was calculated by mean, standard deviation (SD) and coefficient of variability (CV) by using the following formula.

$$CV=S.\ D/Mean$$

where C. V.=coefficient of variability of rainfall and S. D=standard deviation.

To determine the functional relationship that may exist between a response variable, "Y" and a set of controlled (input variables denoted by X_1, X_2…. X_k) regression model was employed. In this case the response variable is the crop yield and the independent or input variables are rainfall and temperature. To predict unknown "Y" from known "X" the following formula was used [7]:

$$Y=\beta_0+\beta_1 Xi + \beta_2 X_2 + €,$$

where "Y" is known as the dependent or response variable, in this case crop yield, and "X_1" and "X_2"are known as the independent variables or predictors, in this case rainfall and temperature, "β_0 and β_1 and β_2" are unknown parameters, or the estimate of y-intercept and the estimates of the slopes (slope of regression line), respectively and"€," is the error term. The slope of the line equals the change in "Y" for each unit change in "X". If the slope is positive, "Y" increases as "X" increases. If it is negative, "Y" decreases as "X" increases [13]. Categorical or nominal variables cannot be studied by linear regression models [6]. Accordingly for variable with more than two categories of classification, "Multinomial Logistic regression analysis" (MNL) was applied. This model can be used to analyze crops [4, 8]; and livestock [16] choices as methods to adapt to the negative impacts of climate variability as analysis of decisions across more than two categories.

The questionnaire was designed with some coping responses already included as the author has previous experience in the area and knows some of the farmers coping mechanisms. Other variables considered in this study consist of household characteristics such as age of household head, education level of household head, family size, farm-income, and ownership of livestock

3. Results and Discussion

3.1. Trends in Annual Precipitation

Results in appendix A depict that the annual rainfall has decreased from 1376 mm to 1076 mm for Darara and from 1152 mm to 1022 mm for Yirba, but high variability and controversial trends (both upward and downward) are shown for Bilate station. It is found that relatively high rainfall occurs in Darara followed by records at Yirba station and lower highly variable records are available for the Bilate station. Figures 2, 3, and 4 show the trends of rainfall data recorded for the Darara, Yirba and Bilate stations, respectively. Trends indicate decrease in rainfall in the last 30 years except for Bilate station, where data indicate progressively more rain in the recent few years though it is lowland and the amount of rainfall is low in this station when compared with other stations.

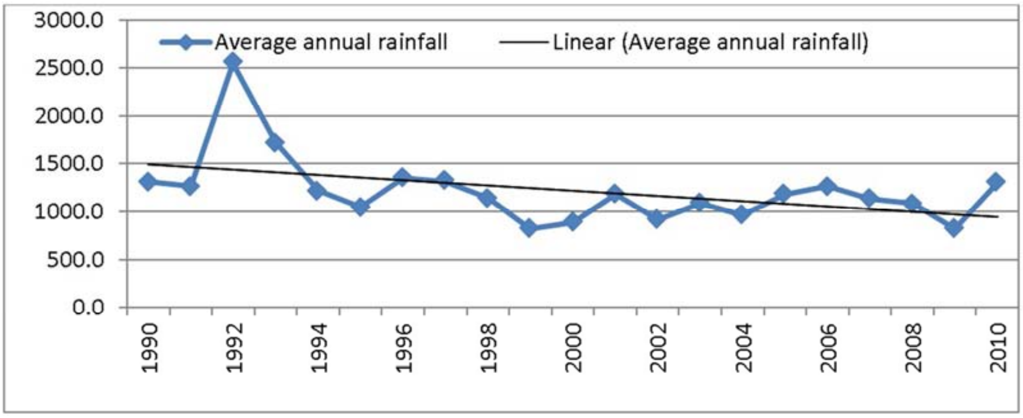

Figure 2. *Rainfall trend at Darara meteorological station.*

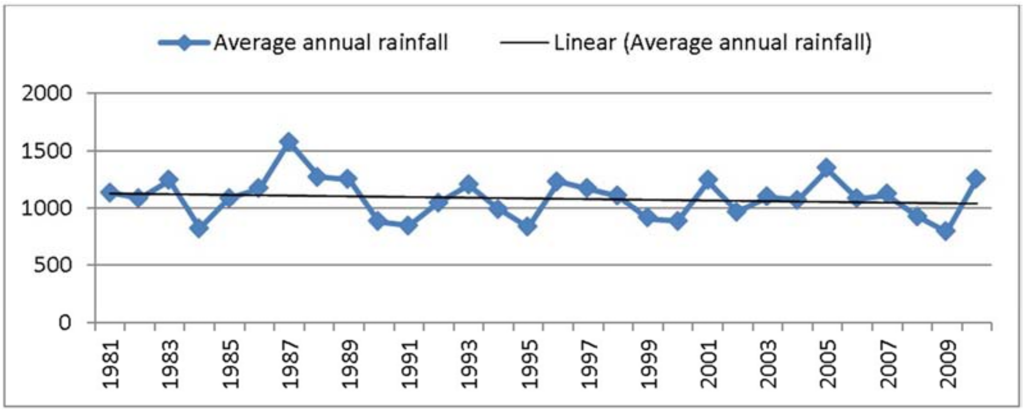

Figure 3. *Rainfall trend at Yirba meteorological station.*

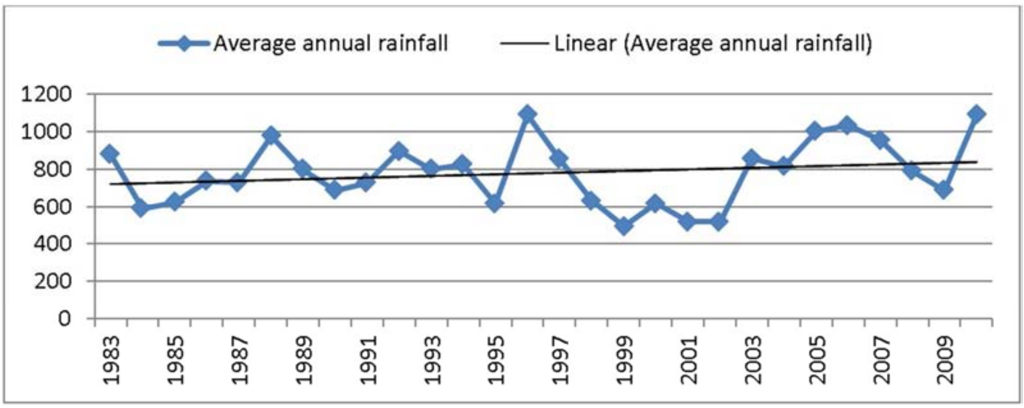

Figure 4. *Rainfall trend of Bilate meteorological station.*

Table 1. *Inter-annual and intra-annual coefficients of rainfall variability by percent.*

Station	Inter-annual	Intra-annual average	Seasonal average	
			Belg	Meher
Derara	30%	70%	46%	49%
Yirba	16%	69%	51	33%
Bilate	22%	71%	58	53%
Average	23%	70%	52%	45%

Annual rainfall uncertainty was measured by using annual coefficient of variation (CV). The inter-annual coefficient of variation is 30% for Darara station, 16% for Yirba station and 22% for Bilate station which is moderate when averaged (Table 1). This means that the annual rainfall variability also has negative impact on agricultural productivity in the Boricha district.

Intra-annual variability of rainfall showed very high values of the coefficient of variation (CV) for all stations. The average intra-annual coefficient of variation for Darara, Yirba and Bilate was 70%, 69% and 71%, respectively (Table 1). The value of CV calculated for two rainy seasons also shows that there was high rainfall variability between years and seasons. Its average value was 52% for Belg (March, April, and May) and 45% for Meher (Jun, July, August and September). This means that rainfall totals are highly variable from year to year, which makes it very difficult to plan and depend on rain-fed agriculture as the main economic activity of most local families.

The monthly coefficient of variation is highest in Bilate station (55%) followed by Darara station (48%) and Yirba station (41%). In all stations March and June are the months with the highest CV (60% and 55%) followed by May, July and April (49%, 47% and 46%, respectively). September and August are also months with high CV values (40% and 39%). National Meteorological Agency of Ethiopia (NMA) classified rainfall variability based on the values of coefficient of variation as < 20 as low variability, from 20 to 30 moderate variability, and >30 high variability [9]. According to Kassahun [5] this result is prevalent in most parts of Ethiopia.

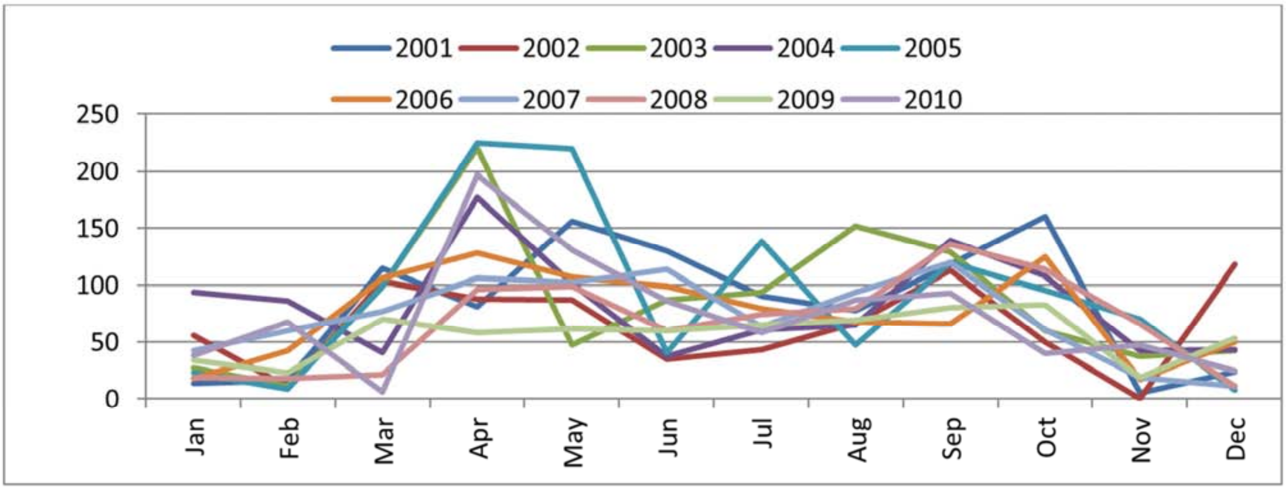

Figure 5. *Seasonal rainfall variability for three stations for the last 10 years.*

Results in Figure 5 confirm that in some years or seasons, rain falls heavily starting early and stopping soon. While in other years, or seasons, rain falls with lower intensity commences late and stops earlier. The consequence of late commencement and early cessation of rainfall is sharp reduction in maize production (major crop in the area).

3.2. Trends in Average Annual Temperature

The year-to-year variation of annual minimum and maximum temperatures, expressed in terms of temperature differences recorded at the Bilate station (the only one having temperature data), is provided in (Appendix A). Results in appendix A show that the area has been experiencing a warming trend in the past 30 years. However, the recent years are the warmest, compared to the early years. Minimum temperature has increased by 2.4°C from 1991 to 2000, and by 0.6°C from 2001 to 2010. Maximum temperature has increased by 0.15°C in the past decade (2001-2010) and it has been more or less constant from 1981 to 2000 with the change of 0.04°C and the average value of 30.27°C (Figure 6).

Data in appendix A clearly reveal that there has been an increasing trend in the annual minimum temperature over the past 30 years. In these years minimum temperature has been showing more variation than maximum temperature. Increases in minimum temperature are higher in the recent decades (1991-2000 and 2001–2010). In theory, this warming trend can increases evapotranspiration in plants which constrains crop production by limiting water availability and growth of many plants as any amount of warming will result in increased water stress due to water loss by evapotranspiration.

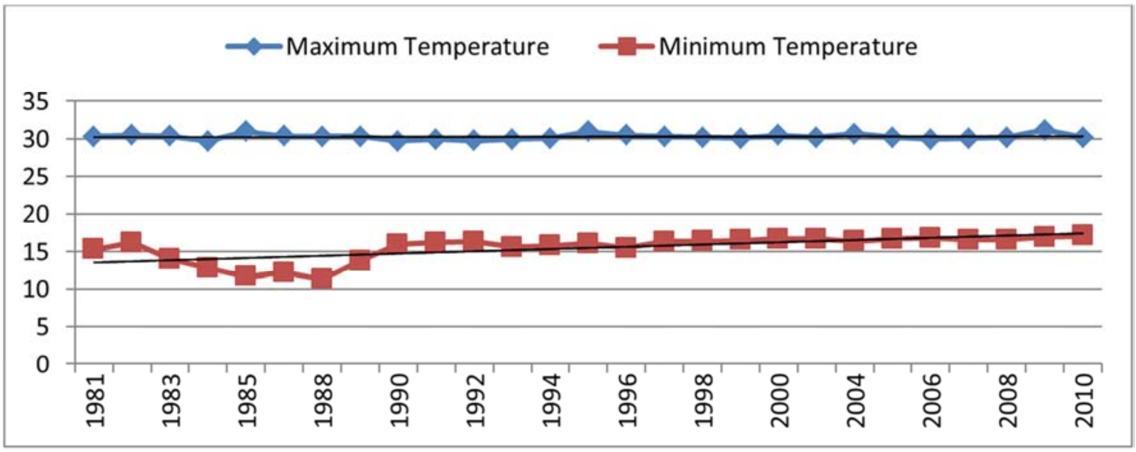

Figure 6. *Trends in temperature at Bilate station.*

3.3. Trends in Agricultural Production and Productivity

The annual agricultural production data collected from Boricha district ARDO for the years 2001-2010 were analyzed in this study using quantitative statistical methods. The results of the analysis reveal that there are appreciable variations in the crop production output from year to year. There is a significant difference in the average annual maize production output, which is the basic food crop in the area. Very low maize yields were recorded in 2004 and 2009, and significantly low yields were recorded in 2006 (Table 2).

Table 2 clearly shows that the yields of other crop types also show significant variation in the above mentioned years. Moreover, among these three years (2004, 2006 and 2009) low yields were recorded in 2004 and 2009 not only in terms of maize production but also in terms of all other crop types.

Table 2. *Crop yield and livestock trends in ('000□) in tons (crops) and in number (livestock).*

Year	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Maize yield	65.7	105.6	326.2	55.5	255	194	210	361.6	152	432.9
Other crops	20.9	37.2	143.3	116.9	153	117	198.3	184.5	67.6	383.8
Livestock	xx	xx	xx	xx	190	194	198	169	203	207

Livestock data of the past 6 years show a slightly increasing trend in the number of livestock except for 2008 in which the number of livestock decreased (Table 2). Conceivable explanations for increasing trend are that there were many households who were beneficiaries of the Productive Safety Net Program (PSNP) in the study area. The PSNP is a public program through which food-insecure people are employed in public works such as road construction for five days a month during dry season, or given direct support for those who cannot participate in community works but need support. It enables food insecure households to smooth consumption so that they will not need to sell their productive assets such as livestock in order to compensate for food shortages [1]. There were about 8% beneficiaries of this program from 22 kebeles out of 46 kebeles in 2005 and about 15% from 42 kebeles out of 46 kebeles in 2006 in the area [18].

Moreover, according to the Boricha woreda ARDO, about 6,917 households were beneficiaries of household asset building program which is the extension of PSNP, and cattle were provided for food insecure households from 2005 to 2010 by investing about 15,247,200 Ethiopian birr funded by the United States Agency for International Development (USAID), Canadian International Development Agency (CIDA), and other European donors.

Another explanation could be that water demand for livestock and for crops is not the same both in the amount of water available and in time. Comparatively a short time shortage of rainfall such as during the flowering period may be more critical for crops than livestock. Moreover, crops failed due to intra-annual rainfall variability, will be fodder for livestock compensating the shortage of pasture.

3.4. Rainfall and Agricultural Productivity

The results of this study reveal that there was variability in climate, particularly rainfall and minimum temperature making agricultural performance difficult in the area. Figure 7 concentrates on 3 years where rainfall was poor and crop yields suffer. The Figure shows that the lowest average annual rainfall was recorded in 2009. Agricultural data also show that there was significant yield reduction in 2009 and 2006 (Table 2). It is also reported by Boricha district ARDO that in 2004, there was a significant crop yield reduction. However, meteorological data reveal that the area received relatively moderate amounts of rainfall in 2004 and 2006. But there was significant intra-annual rainfall variability in these years (Figure 7), meaning that the rain falls at the wrong time of the year.

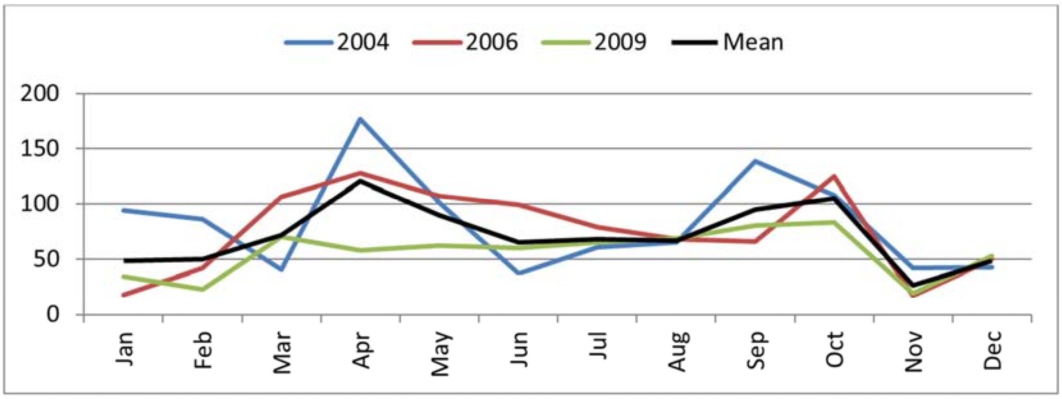

Figure 7. *Seasonal rainfall variability and shortage in 2004, 2006, 2009 and mean.*

Figure 7 shows that in these years intra-seasonal dry spells occurred due to inadequate rainfall in June, July and August, during the growing and flowering period before crop maturity. Moderate amounts of rainfall were recorded in April and May which is the early period of farming and in September and October (late period of farming), which is less important than early and mid-periods of farming for maize production in the area.

Linear regression estimation results calculated to check the effect of rainfall variability on crop yields in the last 10 years also reveal that there is a positive relationship between crop yields and annual rainfall, indicating that if rainfall increases, so does the yield of the crop and vice versa. This yields-rainfall relationship is statistically significant. As indicated in appendix B, with the same temperature, crop productivity is found to be 1.5 units higher for every unit increase in rainfall or with the same temperature; the yield of the crop is found to be 1.5 units lower for every unit decrease in rainfall.

Figure 8 shows this strong linear relationship between the annual rainfall and crop yield indicating that annual rainfall amount (total annual rain) affects agricultural productivity.

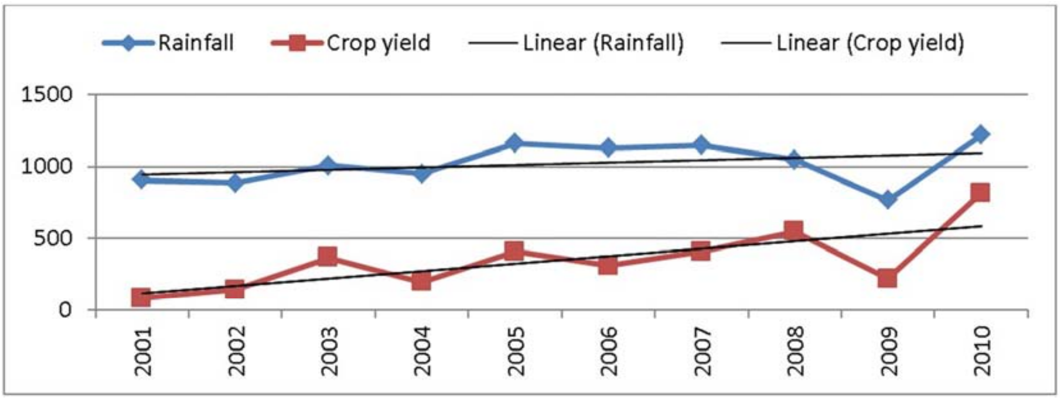

Figure 8. *Mean annual rainfall and crop yield trend relationships.*

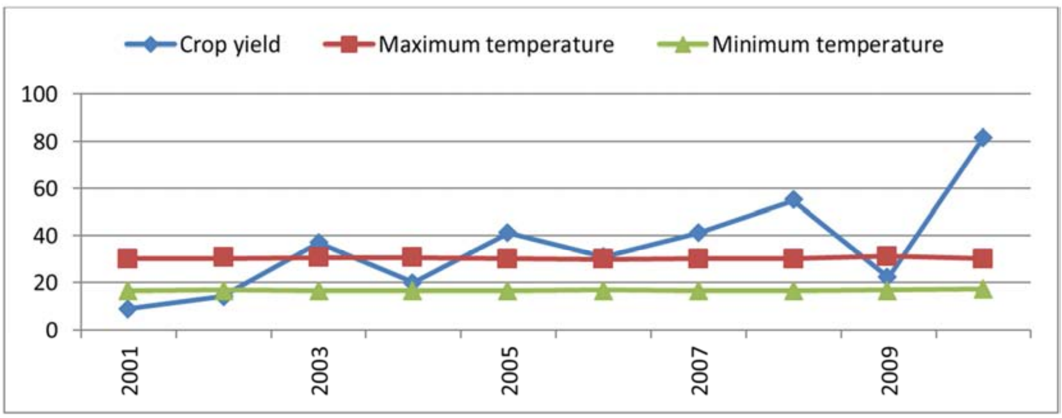

Figure 9. *Temperature and crop yield trends relationships.*

3.5. Temperature and Agricultural Productivity

As indicated in (appendix A) crop yield and minimum temperature are positively correlated. A negative relationship is established between maximum temperature and crop yields indicating that increases in maximum temperature result in decreases in the crop yield. However, the relationship between the crop yields and maximum and minimum temperatures is statistically insignificant, meaning that temperature in this part of Ethiopia does not have a significant influence on crop yields (Figure 9).

3.6. Household Survey Findings

Table 3 presents the background characteristics of respondents. The distribution of household size given in table 3 reveals that the majority of the households (45.5%) have sizes of 4-6 individuals followed by 7-9 (35.5%) and 10+ (12.5%). Only 6.5% of the households have 1-3 individuals. The computed mean household size is 7 individuals which is well above the national Ethiopia mean (4.8 individuals). This large size family unit combined with increasing agricultural land shortage, unemployment, high dependency ratio due to age, and increased climatic unpredictability increases the probability of food shortages in the area.

The percentage distribution of educational status of the respondents indicates that 50% of the respondents were found to be illiterate, while the remaining 50% achieved a certain level of education (46% primary education and 4% secondary education). This indicates that access to education is one of the significant problems in the area. This lack of investment in human capital limits the opportunities of households to diversify their livelihood options, making them more vulnerable to climate induced risks (Table 3).

Table 3. *Percentage distribution of respondents by background characteristics (n=200).*

Characteristics	Frequency	Percentage
Age		
30 – 39	96	48
40 – 49	50	25
50 – 59	34	17
60 and above	20	10
Education Status		
No formal education	100	50
Elementary (1-8)	92	46
Secondary (9-12)	8	4
Household size		
1-3 members	13	6.5
4 -6	91	45.5
7 -9	71	35.5
10 – 12	21	10.5
Above 12	4	2

Table 4. *Percentage distribution of livestock ownership by households.*

No	Type of livestock	Number of livestock	10 years ago	At present
		0	22.5	19
		1-2	25	50
1	Cows and bullock	3-6	25	27.5
		7-10	12.5	3
		11-20	15	0.5
		0	49	64.5
		1 - 2	10.5	22.5
2	Sheep and goats	3 -5	18	7.5
		6 - 8	7.5	2
		9 - 12	15	1.5
		0	77	90
3	Horses, donkeys and mules	1	13.5	9
		2 - 4	9.5	1

As indicated in table 4, respondents who owned no cows and bullock account for 22.5%, no goats and sheep account for 49% and no horses and donkeys 77% 10 years ago. The corresponding values at present are 19%, 64.5% and 90%, respectively. Ten years ago, 15% of respondents were the owners of 11–20 cows and bullocks whereas at present only 0.5% of them have 11–20 cows and bullocks. The percentage of respondents who were the owners of 7–10 cows and bullocks was 12.5% 10 years ago which is reduced to 3% at present.

About 22.5% of respondents reported that they were the owners of 6–12 goats and sheep 10 years ago, while only 3.5% of them have 6–12 goats and sheep at present. It is also seen that 10.5% of the respondents were owners of 1–2 goats and sheep and 18% owned 3–5 goats and sheep 10 years ago. The maximum percentage of respondents reported to be the owners of 2–4 horses and donkeys 10 years ago is 9.5% which is only 1% at the present. This indicates that there is declining trend in this productive and life supporting asset of livestock ownership among the surveyed households. Many households own fewer or no livestock compared to the situation 10 years ago.

3.7. Local Awareness and Perception of Climate Variability and Trends

Farmers were interviewed whether they have experienced variability in temperature and rainfall or not in the last 15 years. Results show that 97% of households reported that they have been experiencing increase in the mean temperature while the corresponding response to significant rainfall variability accounts for 97.5% in the last 15 years. The remaining 2.5% and 3% of respondents reported that there was insignificant variation in rainfall and no change in temperature, respectively (Table 5). As Table 5 shows, almost the entire households (98.5%) reported that there has been severe drought followed by rare drought (1%) and constant drought (0.5%). The majority of the respondents (71.5%) also noted that there has been frequent flood if there is rainfall followed by rare flood (18.5%) and significant flood impact (10%) in the last 15 years. Among these climate change related impacts rainfall variability is reported to be the most (87%) followed by drought (8.5%) and temperature (4.5%).

Table 5. *Households' perceptions on climate variability (n=200).*

Characteristics	Frequency	Percent
Rainfall variability		
Important	195	97.5
Unchanged	-	-
Little	5	2.5
Temperature in the 15 years		
Increased	194	97
Remains the same	6	3
In the last 15 years flood was		
Frequent if there is rainfall	143	71.5
Rare	37	18.5
Important	20	10
In the last 15 years drought was		
Severe	197	98.5
Constant	1	0.5
Rare	2	1
Climate change related factor (s), that may entail important problem in daily life in the area		
Rainfall variability	174	87
Increase in temperature	9	4.5
Drought	17	8.5

3.8. Food Security Status

The study also employed the interview questionnaire to evaluate food security status, basically the four dimensions of food security in the area. Table 6 presents food security status of the surveyed households.

Table 6. *Percentage distribution of households by food security indicators (n=200).*

Indicators	Frequency	Percent
Sources of food for family members in the last 15 years		
A. Crop production and livestock rearing	62	31
B. Purchasing from open market by selling asset	84	42
C. Food aid and petty trading	54	27
The amount of food that the family as a whole had to eat		
Often not enough to eat	1	0.5
Sometimes not enough to eat	189	94.5
Enough but not always the kind of food we want to eat	10	5
Food variety status of the food that the household consumed		
We get variety food during crop harvesting period only	120	60
We do not get variety food at all	80	40
Meanses through which households get food during low rainfall.		
Stored food	34	17
Food aid	66	33
Buy from open market by selling asset	49	24.5
Wage labour	51	25.5
Ability of family to buy sufficient and desired food		
Yes	66	33
No	134	67

Majority of the respondents (60%) reported that they get relatively good variety of food during the harvesting period only. In the remaining part of the year (each year), they eat what they get for survival. The remaining 40% of the respondents reported that they do not get different types of food at all. During low rainfall and where there is food shortage, about 33% of households reported to get food from NGOs (food appeal/aid) followed by those work for some better-off families (25.5%) and those who buy from open markets by selling assets such as livestock (24.5%). Only 17% of the respondents indicated that they get food from what they have saved for bad days. For the simple emotional food security status question (ability to buy adequate and desired food during food shortages), a good proportion of the respondents (67%) reported that they are not able to buy adequate and desired amount of food for their family members due to low income and inflation during food shortages. Similarly, almost all of the respondents (96.5%) reported that the last 15 years were not the average years in terms of the amount of food that their families had to eat.

This shows that the four dimensions of food security are not fulfilled indicating that there is food insecurity in the area.

3.9. Climate Change Coping Mechanisms

Coping is the process by which people or organizations use available resources and abilities to face adverse consequences that could lead to a disaster and involves managing resources, both in normal times as well as during crises or adverse conditions [10]. It is the short-term and immediate oriented towards survival, motivated by crisis (reactive), often degrades the resource base and prompted by a lack of alternatives [19].

During food shortages, which occurred repeatedly over years due to human and climate induced impacts; the people in the study area have been using different coping strategies to reduce their vulnerability. Table 7 presents information on the possible types of climate change coping strategies used by households.

Table 7. *Percentage distribution of respondents by reported coping strategies (n=200).*

Strategies and variables	Frequency	Percent
Use enset and early maturing crops	40	20
Petty trade and wage labor	16	8
Selling asset	24	12
Selling fire wood and depending on food aid	19	9.5
Using inter-croping	26	13
Temporary migration in search of work	17	8.5
Resource exchange with neighborhood	19	9.5
Minimizing food consumption	25	12.5
Nothing to do	14	7

Results in Table 7 above reveal that households use a number of coping strategies ranging from one or more major coping strategies to various complementary strategies such as switching between major and complementary activities during both chronic and transitory food shortages.

Some commonly used major coping strategies in the study area include using “enset” which is a drought resisting crop and cultivating early maturing crops such as sweet potato. Most commonly used complementary coping strategies in the study area are: reducing food consumption, wage labor, petty trading, temporary migration of household members in search of work, food aid/appeal, asset liquidating and selling fire wood.

The outputs of the multinomial logistic regression analysis on these data indicate that there are certain household level variables affecting the probabilities of coping strategies used by households in the study area. These include age of household head, education level of the household head, family size, livestock ownership, the presence of working age young household members and farm income.

There is a positive relationship between the age of the household head and coping strategies used by households, indicating that age which approximates experience matters in coping to climate change. The presence of working age young household members who can generate income for the households is also positively associated with some of the coping strategies used by households such as petty trade, temporary migration and inter-cropping indicating the increased probability of households to use these strategies.

Strong positive relationship is established between the education level of the household head and the coping strategies used by households. Good reasons for this are that the higher level of educational attainment is associated with better access to information and awareness on climate variability, higher productivity, hence, better adaptive capacity.

Moreover, people with better educational status, usually engage in more sustainable adaptation strategies. Furthermore, when the education level increases, there is likelihood that the household shifts its portfolio to more non-agricultural activities. By contrast, the part of population with low level of educational attainment is characterized by low adaptive capacity. A unit increase in the level of education from its mean is found to increase the probability of using different coping strategies by 14.2%, holding all other variables constant at the reference point (Appendix B).

The result of the MNL analysis output also shows positive relationship between livestock ownership and coping strategies indicating that livestock ownership increases the probability of owners to cope with climate extreme events. Livestock owners not only sell livestock to fulfill their food needs, but also use them as the source of fertilizer to produce “enset” and other early maturing crops, since livestock provide manure for farming activities. For every increase in the number of livestock from the mean, the probability of using different coping strategies is seen to increase by 26.5%. The current farm-income status of households is also linked to using different coping strategies. The majority of the respondents reported that their farm-income is decreasing (89%), which forces them to adopt some coping mechanisms.

Generally, for a household the average age of household head is 45, with primary level of education, having a family size of 7 individuals, and 1 livestock, the predicted probability of using different coping strategies is 33% (increases from 0 to 0.33) (Appendix B).

4. Conclusions

Results of analysis indicate that there is considerable variability in climatic elements (rainfall and temperature). Minimum temperature has increased by 2.4°C from 1991 to 2000 and by 0.6°C from 2001 to 2010. Maximum temperature has increased by 0.15°C from 2001 to 2010 and it has been remained more or less constant from 1981 to 2010.

Rainfall has shown moderate inter-annual and high intra-annual variability. The highest coefficient of variation (CV) occurs in the early period of farming (Belg) followed by mid-period (Meher) before crop maturity with CV values of 52% and 45%, respectively.

Results obtained from the analysis of rainfall variation coefficient, regression models, marginal impact, and descriptive statistics show that climate variability impacts on agricultural productivity. Rainfall variability has significant negative impacts on outputs of crops in the study area. The study reveal that what matters most in crop production in the area is not the amount of rainfall per year, but how that amount deviates from the average rainfall (which is supposed to be the optimal level) due to both inter-annual and intra-annual rainfall variation.

When the rainfall varies from the average value or falls late or early in the season, the level of production is significantly diminished for all crop types. Moreover, the study found that there has been significant variation in temperature and a warming trend in the last three decades which exacerbates persistent water scarcity through evaporation. The study has also found out that there is a relatively high level of household food insecurity among the studied population, which is being made worse by climate changes towards less rainfall, high minimum temperatures and seasonal changes in the precipitation pattern, with the Belg (short rainy) season arriving late, merging with the long rainy season or bringing inadequate amounts of rainfall.

It is also found that households in the study areas have been employing a variety of coping strategies which are not sustainable, ranging from minimizing food consumption, migration of household members rather than using sustainable adaption strategies to climate variability. Coping strategies have been playing a mediating and surviving role during food shortages for local households until they get more food access. Results from the multinomial logistic regression model show that different socio-economic and environmental factors affect the coping strategies of different households to adapt or cope with climate extreme events. These factors are age of household head, family size, education level of household head, livestock ownership and farm-income.

A large family size is found to increase the probability of households to diversify livelihood and coping strategies by using available labor with the family. The results of the empirical analysis proved that the age of the household has positive impact in using different coping strategies and being opened to adaptation strategies. On the other hand it is found that the education level of the household heads has less effect than whether the household head has experience when it comes to adapting against the impacts of climate change.

Finally, the leading conclusion from the results of this analysis and the basic message of this study is that climate variability has led to the reduction of crop yields and has exacerbated the risk of food insecurity in Boricha district.

5. Recommendation

Based on the key findings of the study, short term and long term intervention programs are recommended to reduce vulnerability to climate related risks namely, drought and seasonal variations in rainfall seasons. As part of short-term intervention programs, it is important to follow the following recommendations:

1) Chronic food shortages have to be alleviated by expanding safety net programs which have already been initiated in the area, so as to enable the poor households to have relatively adequate entitlement of food, either via alternative crops, access to credit, diversification of economic activities, access to improved/ drought resistant seeds etc.
2) Use of organic fertilizers such as manure should also be promoted since it is easy to have access by almost all farmers, which is affordable, provides improvement in yields, better restoration of soil fertility and moisture.

As part of the long-term strategy, the local and/or national governments may use the following interventions to improve adaptation to climate change impacts in the future.

1) Promoting rainwater harvesting and water management systems to allow farmers to store run-off during the rainy season in ponds which could be lined with impermeable materials for efficient use of water or unlined and made from local materials.
2) Improving rain-fed agriculture and water resource management systems through practices that retain water in farm lands such as terracing, making contour bunds, planting trees as wind blocks, conservation agriculture, such as conservation tillage, crop rotation and crop cover.
3) Expansion of new varieties of crops and diversification from traditional crops to high yield crops which can with stand stress due to drought.
4) Promoting small scale irrigation projects which are of a more practical nature than large projects, to increase agricultural productivity and to reduce vulnerability of small-holder farmers to climate related risks by increasing their entitlement for food.
5) Government policies and investment strategies that support the provision of education to ensure compulsory primary education and strengthening adult education are necessary to enhance the adapting capacity of farmers to climate variability.
6) Policies should encourage income generating capacity of farmers by promoting micro financing at the local level

and keeping/buying more productive assets especially livestock, which enables consumption smoothing and buffers farmers against the effects of crop failure or low yields during harsh climatic conditions.

7) Adequate extension of information services is needed to ensure that farmers receive up-to-date information about rainfall and temperature patterns in the forthcoming season (medium term forecasts) so that they can make well informed decisions about their planting dates.
8) Establishing an institution at local level for climate change adaptation and environmental protection so as to promote sustainable and up-to-date adaptation strategies, and to incorporate local knowledge into policy and actions that may help local, regional and national governments to accommodate the needs of poor families.

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Appendix

Appendix A- Meteorological Data

Table 8. *Rainfall trends of the three meteorological stations of the district.*

Stations	Years	Total annual maximum rainfall	Total annual minimum rainfall	Total mean annual rainfall
Darara	1990-1999	2550 mm	823 mm	1376 mm
	2000-2010	1307 mm	820 mm	1076 mm
Yirba	1981-1990	1575 mm	825 mm	1154 mm
	1991-2000	1231 mm	830 mm	1152 mm
	2001-2010	1338 mm	795 mm	1022 mm
Bilate	1983-1992	977 mm	587 mm	764 mm
	1993-2002	1086 mm	493 mm	696 mm
	2003-2010	1088 mm	688 mm	902 mm

Table 9. *Temperature trend at Bilate station in the last 30 years.*

Year	Maximum temperature	Minimum temperature	Change in temperature	
			Maximum	Minimum
1981-1990	30.29°C	13.7°C		
1991-2000	30.25°C	16.14°C	-0.04°C	2.44°C
2001-2010	30.4°C	16.7°C	0.15°C	0.56°C

Appendix B: Regression Outputs

Table 10. *Linear regression model output.*

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.	95% Confidence Interval for B	
	B	Std. Error	Beta			Lower bound	Upper bound
Constant	-14754.8	6020.2		-2.451	0.050	-29485.7	-23.88
Mean rainfall	1.53	0.414	1.023	3.692	0.010	0.516	2.54
Maximum temperature	260.5	163.1	0.440	1.598	0.161	-138.5	659.53
Minimum temperature	336.7	224.97	0.296	1.597	0.185	-213.8	887.18

Table 11. *Parameter estimates from the multinomial logistic adaptation model.*

Explanatory variables	Coefficients with respective response variables							
	EEC	PTL	AS	FFA	IC	TM	RE	FCM
Age	0.098	0.11**	0.11**	0.12**	0.17***	0.1	0.16*	0.16
Family size	0.13**	0.3**	0.2	0.22	-0.14	-0.3	0.18	0.2**
Education	0.18	1.6**	0.64	1.4**	0.85	0.8	0.95	-0.14
Young	-1.4**	1.3	-1.34**	-1.3	0.63	1.6	-1.24	-2.1**
Livestock	1.4	-3.2*	15.4	-2.3**	0.92	-2.1**	0.4	-0.4
Number of observations=200 Pseudo R^2=0.20, Log likelihood=-345.43 LR chi^2 (48)=147.72, Probability > chi^2=0.0000								

** Significant at 10%, * Significant at 5% and *** Significant at 1%

Note: 1. Base category variable is nothing to do for coping.

2. EEC: Enset and early maturing crops; PTL: Petty trade and wage labor; AS: Asset selling; FFA: Fire wood selling and depending on food aid; IC: Inter-cropping; TM: Temporary migration; RE: Resource exchange with neighborhood; FCM: Food consumption minimizing.

Table 12. *Marginal effects estimation after multinomial logistic regression model output, Y=Prob (Adaptation==1) (predict)=0.3304.*

Variable	d_y/d_x	Std. Err.	z	P>|z|	[95% C. I.]	X
Age*	.0049887	.16928	-0.03	0.046	-.336776.326798	45.105
Educat~n*	.1417617	2.70704	-0.05	0.018	-5.44746 5.16393	0.5
Family Size	.0113231	.64633	-0.02	0.14	-1.25546 1.27811	6.64
Young	-.2060318	4.33682	-0.05	0.063	-8.70604 8.29398	0.295
Livest~k*	.2651382	1.41396	0.19	0.047	-2.50616 3.03644	0.845

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