Determinants of Smallholder Farmers' Adoption of Climate Change and Variability Adaptation Strategies: Evidence from Geze Gofa District, Gamo Gofa Zone, Southern Ethiopia

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Abstract
The increasing trend of climate change has led to growing concern on its impact on different sectors of the economy particularly on agriculture. Coping with the vulnerability and negative effects of climate change on agriculture requires mitigation at the policy level and adaptation at the farm level. Adaptation does not occur without influence from other factors such as socio-economic, cultural, political, geographical, ecological and institutional that shapes the human-environment interactions.However, the ability of farmers to adopt the various adaptation strategies constrained by a number of factors. Therefore, this study identified the micro-level climate adaptation strategies adopted by farmers in Geze Gofa woreda and subsequently examined the determinants of farmers' adoption of adaptation strategies to climate change and variability. The primary data used in this study were collected through semi-structured questionnaires administered to 222 randomly selected farmers. Both descriptive and inferential statistics were used in analyzing the data. Results show that about 62.25 % of the farmers adopted different strategies. To respond to these changes, farmers have adopted crop diversification, planting different crop varieties, changing planting and harvesting dates to correspond to the changing pattern of precipitation, irrigation, planting tree crops, water and soil conservation techniques, and switching to non-farm income activities. The major factors identified to be driving farmers' investment in adaptation practices were age, level of formal education and level of awareness of climate change issues. The major factors constraining them from adapting to climate change were poverty; farmland scarcity and inadequate access to more efficient inputs, lack of information and poor skills, land tenure and labour constraint. Logit regression was used to identify factors that influence the strategies employed by famers for adaptation to climate change. The result of the logit model showed that annual farm income, farming experience, knowledge of climate information, education and extension access variables are significant determinants of climate change adaptation strategies. The study recommends the promulgation of policies to ensure that farmers have access to physical, human and social capital will enhance farmers' ability to respond effectively to changing climate conditions. The findings underscore the need for farmers' education, awareness creation, poverty alleviation and increased access to more efficient inputs as potent tools for climate change adaptation in the area.
Keywords: Climate Change and variability, Adaptation strategies, Smallholder Farmers Determinants, Geze Gofa

1. INTRODUCTION

1.1. Background

Climate change is probably the most complex and challenging environmental problem facing the world today. As the planet warms, rainfall patterns shift, and extreme events such as droughts, floods, and forest fires become more frequent (Zoellick 2009), which results in poor and unpredictable yields, thereby making farmers more vulnerable, particularly in Africa (UNFCCC, 2007). Africa is one of the most vulnerable continents to climate change and climate variability where the situation is aggravated by the interaction of multiple stresses, occurring at various levels, and low adaptive capacity (Boko et al., 2007). Developing countries are especially vulnerable to climate change because of several predisposing factors such as poverty, geographic exposure, heavy dependence on rain fed agriculture and issues of poor governance and social infrastructure (IPCC, 2001; Stern, 2006). In Sub-Saharan Africa agriculture employs 60% to 90% of the total labor force (Thornton et al.., 2006). Climate change has direct impact on agricultural production, because of the climate-dependent nature of agricultural systems. This impact is particularly significant in developing countries where agriculture constitute employment and income sources for the majority of the population. Farmers (who constitute the bulk of the poor in Africa), face prospects of tragic crop failures, reduced agricultural productivity, increased hunger, malnutrition and diseases (Zoellick 2009). For instance, the recurrent droughts in many African countries have demonstrated the effects of climate variability on food resources (Stanturf et al., 2011).

Smallholder farmers are disproportionately affected, with over 1.5 billion people worldwide living in smallholder households in rural areas where their livelihoods depend on agricultural activities (World Bank, 2008). Agriculture is the main source of livelihood for 1.3 billion smallholder farmers worldwide (World Bank, 2008) and is highly vulnerable to climate change, particularly in the Tropics (Salinger et al., 2005).While there is no universally-accepted definition of 'smallholder farmers' (Morton, 2007), most cultivate small areas of land (usually less than 10 ha, often less than 2 ha), use family labor, and depend on their farms as their main source of both food security and income generation (Cornish, 1998; Nagayets, 2005). It is estimated that smallholder farmers represent 85% of the world's farms and provide more than 80% of the food consumed in the developing world (IFAD, 2013). They also occupy a significant portion of the world's farmland ranging from 62% in Africa to 85% in Asia (FAO, 2014). What happens to smallholder farmers in the future – as the climate changes – will therefore have significant social, economic and environmental consequences globally.

Across the world, smallholder farmers are considered to be disproportionately vulnerable to climate change because changes in temperature, rainfall and the frequency or intensity of extreme weather events directly affect their crop and animal productivity as well as their household's food security, income and well-being. While in some cases, climate change may increase the productivity of certain crops (e.g., Rosenzweig et al., 2002; Tubiello and Fischer, 2007; Fuhrer and Gregory, 2014; Schultz and Jones, 2010), a growing number of studies show that the productivity of many crops (e.g., maize, rice, sorghum, cassava) and livestock that smallholder farmers in developing countries raise are expected to be significantly reduced in the coming decades due to increased climate variability and climate change, among other factors . There is therefore an urgent need to identify approaches that strengthen the adaptive capacity of smallholders and enhance their ability to respond to climate change.

Most smallholder farmers, especially in developing countries, have limited capacity to adapt to climate change, given their low education levels, low income, limited land areas, and poor access to technical assistance, market and credits, and often chronic dependence on external support (Morton, 2007; Harvey et al., 2014). In addition, in many regions, smallholder farmers farm on marginal lands (e.g., steep hillside slopes, poor soils or areas prone to flooding or water scarcity) and are therefore highly vulnerable to the impacts of extreme weather events that can cause landslides, flooding, droughts or other problems. Moreover, many smallholders in developing countries live in highly remote areas with low-quality infrastructure that further hampers their access to markets, financial assistance, disaster relief, technical assistance or government support (Harvey et al., 2014). As a result, although many smallholder farmers have been facing adverse climatic events and, in most cases taking corresponding action, most are ill-prepared for the challenge of adapting to the increased frequency and/or intensity of extreme climate events that are expected with climate change.

Climate change is a major development challenge to Ethiopia. Climate change is expected to have serious environmental, economic, and social impacts on Ethiopia, particularly on rural farmers whose livelihoods depend largely on the environmental resources and rainfall. The importance of the agriculture sector in Ethiopia cannot be overemphasized. Agriculture, primarily small-scale, is the backbone of Ethiopia's economy, contributing 42% of the GDP and supporting 85% of employment (FDRE 2011). Agricultural production in Ethiopia is dominated by small-scale subsistence farmers, and is mainly rain-fed, thus highly exposed to climate variability and extremes. According to the World Bank (2006), current rainfall variability already costs the Ethiopian economy 38% of its growth potential. Climate change is likely to worsen this already distressing situation. The major predicted impacts of climate change on Ethiopia's agriculture include frequent droughts and dry spells, shortened growing season, and increased incidence of pests and diseases (NMA 2007). Climate variability and climate change likely are significant contributing factors in the food security challenges Ethiopia currently experiences and will experience going forward. Its geographical location and topography, plus a low adaptive capacity, make the country highly vulnerable to the adverse impacts of climate change. Ethiopia has experienced at least five major national droughts since 1980, along with a large number of localized droughts (World Bank, 2008). These cycles of drought create poverty traps for many households, constantly consuming their efforts to build up assets and increase income. About half of all rural households in the country experienced at least one major drought from 1999 to 2004 (Dercon, 2009).

The country has a complex climate system, in addition to socioeconomic challenges, such as endemic poverty, limited access to capital and global markets, ecosystem degradation, complex disasters, and conflicts. Accordingly, the effect of climate change on Ethiopia's economy will likely be a function of both the macro-economy and sector-specific vulnerability. The present government of Ethiopia has given top priority to this sector and has taken steps to increase its productivity. Analysis of historical climate data show an increase in mean annual temperature by 1.3°C between 1960 and 2006, translating into an average rate of 0.28°C per decade. The annual minimum temperature increased by about 0.37°C every decade between 1951 and 2006 (McSweeney et al. 2008). In contrast, precipitation remained fairly stable when averaged over the country (Schneider et al. 2008). Similarly, no statistically significant trend in mean annual rainfall was observed in any season from 1960-2006 (NMA 2006,). However, the spatial and temporal variability of precipitation is high, thus large-scale trends do not necessarily reflect local conditions. Projecting into the future, most global climate models indicate some increase in rainfall in both dry and wet seasons in Ethiopia (NMA 2006).

Studies with more detailed regional climate models (RCM), however, indicate that the sign of expected rainfall change is uncertain over Ethiopia and East African highlands, and the general consensus is that rainfall variability is likely to increase. With regard to temperature, IPCC's mid-range emission scenario results show that compared to the 1961-1990 average mean annual temperature across Ethiopia will increase by between 0.9 and 1.1°C by the year 2030, and from 1.7 to 2.1°C by the year 2050. The temperature across the country could rise by between 0.5 and 3.6°C by 2080 (NMA 2006). The increasing temperature combined with rainfall variability will have serious consequences on ecosystems, economic sectors and communities of Ethiopia. Ethiopia's National Meteorological Agency (NMA) identifies drought and flood as the major hazards in the future as well, with potential negative impacts on agriculture and food security (FDRE 2011). A study based on the Ricardian method predicts that a unit increase in temperature could result in reduction of the net revenue per hectare by US$177.62 in summer and US$464.71 in winter seasons (Deressa, 2007).

The likely impacts of climate change on the vulnerability of agricultural systems need to be better understood, so that the resilience to current climate variability as well as the risk associated with longer-term climate change can be gauged and appropriate actions taken to increase or restore resilience where it is threatened or lost (Thornton et al., 2008. Understanding the nature of climate change impacts, key vulnerabilities and indigenous adaptive responses at local levels, and the national institutional responses are important for developing appropriate adaptation strategies at community and farm levels. Nevertheless, there is limited research evidence as to whether or not climate change is perceived as a major problem or even a reality by the Ethiopian communities, particularly by the poor and most vulnerable farmers in the rural areas. Similarly, local adaptive responses to climate variability and change are not well documented. Droughts and floods are common phenomena in Ethiopia, occurring every 3 to 5 years (World Bank 2006).

The country has experienced at least five major national droughts since the 1980s, along with dozens of local droughts (World Bank 2009). In particular, there is increased incidence of meteorological drought episodes, famines and climate-sensitive human and crop diseases in the northern highland and southern lowland regions of Ethiopia (Oxfam International 2010, UN-ISDR 2010). In many areas of Ethiopia, the frequency of droughts and floods has increased over the years, resulting in loss of lives and livelihoods (NMA 2007, Oxfam International 2010). Climate change is expected to exacerbate the problem of rainfall variability, and associated drought and flood disasters (NMA 2006). To cushion themselves against the potential livelihood losses, smallholder farmers need to recognize the changes already taking place in their climate and undertake appropriate investments towards adaptation. Adaptation to the adverse consequences of climate change could be viewed from two distinct perspectives; i) the awareness of the risks of climate change and their capacity to adapt to climate change and ii) how adaptation can be carefully planned and implemented to avoid the possibility of mal-adaptation (FAO, 2007).

1.2. Statement of the Problem and Rationale of the Study

Adaptation is widely recognized as a vital component of any policy response to climate change. Studies show that without adaptation, climate change is generally detrimental to the agriculture sector; but with adaptation, vulnerability can largely be reduced (Easterling et al. 1993; Smith 1996; Mendelsohn 1998; Reilly and Schimmelpfennig 1999; Smit and Skinner, 2002). It often involves a combination of various individual responses at the farm-level and assumes that farmers have access to alternative practices and technologies available in the region. Adaptations can either be planned or autonomous with the latter being done without awareness of climate change predictions but based on experience and prevailing conditions (Smithers & Smit, 2009).Adaptation does not occur without influence from other factors such as socio-economic, cultural, political, geographical, ecological and institutional that shape the human-environment interactions (Eriksen et al., 2011). The extent of sustainable adaptation depends on the adaptive capacity, knowledge, skills, robustness of livelihoods and alternatives, resources and institutions accessible to enable undertaking effective adaptation (IPCC, 2007). The adaptive capacity is influenced by factors such as knowledge about climate change, assets, access to appropriate technology, institutions, policies and perceptions inter alia (Adger et al., 2003; IFAD, 2008). Smithers and Smit (2009) contend that environmental perceptions are among key elements influencing adoption of adaptation strategies. Actions that follow perceptions of climate change are informed by different processes such as perception of risk associated with climate change, resource endowments, cultural values, institutional and political environment and there is no guarantee that having perceptions that climate change has or is occurring would prompt effective adaptation responses (Weber, 2010).

Increasing temperature volume and heat intensity and variations in rainfall patterns over time, coupled with frequent mid seasonal droughts and cyclones are clear evidence that the climate has changed in GezeGofa *Woreda*. Smallholder farming is the chief source of livelihood in the area but the rain fed agriculture is highly vulnerable to the vagaries of climate change. Since the 1990s, the area experienced a strong negative trend in the maize production, which accounts for the greater proportion of food production. Physical presence of relief agencies almost yearly to provide food handouts is now a common phenomenon which provides evidence that agricultural production has drastically fallen as farmers cannot produce enough to meet their subsistence food requirements. Negative impacts of climate change can be reduced through adaptation, which requires involvement of the local community. Response to climate change through adaptation however, appears to be weak. It seems that there is a gap between the rate at which climate is changing and the response to reduce its impact through employment of adaptation strategies that ensure sustainable food security by Geze Gofa farmers

Despite Geze Gofa *Woreda* highly experiencing climate change and variability such as late onset and early termination, less amount of precipitation and erratic pattern of precipitation, high intensity of heat for prolonged period of time, and extreme climatic shocks like droughts and floods), micro-level studies at the farm-level on how rural smallholder farmers perceive these changes and how they are responding to the effects of a changing climate are limited. As to the best knowledge of the researcher, no earlier study was conducted on the climate change adaptation strategies of smallholder farmers in this study area. Hence, considering this knowledge gap, the researcher would study on the farm-level determinants of adoption of climate change and variability adaptation strategies in Geze Gofa *Woreda*. This study seeks to investigate the factors that influence farmers' decision to adapt to climate change in order to inform policy formulation that enhances farmers' capacity to adapt to climate change. Unless these factors are known, government support on adaptation to climate change may be ineffective. Hence, the general objective of the study was to examine the determinants of smallholder farmers' adoption of climate change and variability adaptation strategies. The specific objective of the study is to: (i) assess rural farmers' adaptation strategies to climate change, (ii) explore farm-level factors constraining adoption of adaptation strategies, and (iii) analyze the factors that influence rural farmers' adoption of climate change and variability adaptation strategies. The paper is structured as follows. In Section 2, presents Methodology of the study and in Section 3 Major findings of the study are discussed. Section 3 presents the Conclusion and policy implications of the study.

2. METHODOLOGY

2.1. Description of the study Area

The study was conducted in the Geze Gofa *Woreda*, which is one of the 15 districts located in Gamo Gofa Zone, Southern Ethiopia. The administrative center of Geze Gofa district, Bulki town, is located at a distance of 251 kilometers from the Zonal capital, Arba Minchi town, and 517 kilometers south west of Addis Ababa the capital city of Ethiopia. Part of the Gamo Gofa Zone, Geze Gofa is bordered on the south by Oyda woreda , on the west by Basketo special woreda, on the northwest by Melokoza woreda , and on the east by Demba Gofa woreda . It is located approximately between coordinate 10033'06'' to 10050'24'' North latitude and 37042'36'' to 37058'24'' East longitude. Topographically, the area lies in the altitudes range of 690m to 3196m.a.s.l. As a result, the area is characterized by three distinct agro-ecological zones-Highland (*Dega*), Midland (*Woina Dega),* and Lowland (*Kola*), according to the traditional classification system, which mainly relies on altitude and temperature for classification, Ethiopia has five climatic zones.The most commonly used classification systems are the traditional and the agro-climatic zones .According to the traditional classification system, which mainly relies on altitude and temperature for classification, Ethiopia has five climatic zones (Table 1)

Table 1: Traditional climatic zones and their physical characteristics

Zone	Altitude(meters)	Rainfall(mm/ year)	Average temperature(Co)
Wurch(upper high-land)	3200 plus	900- 2,200	>11.5
Dega(highlands)	2,300- 3,200	900- 1,200	17.1/16.0- 11.5
Weynadega(midlands)	1,500- 2,300	800- 1, 200	20.0- 17.5/16.0
Kola(lowlands)	500- 1,500	200- 800	27.5- 20.0
Berha(desert)	Under 500	Under 200	>27.5

Source: Ministry of Agriculture (MOA, 2000)

The area is highly food insecure due to a combination of factors: high population density, small landholdings; low soil fertility and land degradation and rainfall irregularities. The main food crops are maize, enset, sweet potatoes, taro, teff, and yams. Enset and root crops are an important hedge against losses of the less drought-resistant maize; but need forces the poorer majority of households to cut their enset before it matures, forfeiting 2/3 of potential food from the plant. Although all wealth groups sell some crops, none makes as much as half of annual earnings from this. Better-off and middle groups earn most of their cash from livestock and butter sales, whilst casual work is main source of cash for the poor. There are two (bimodal-belg and meher) distinct rainy seasons: the smaller one is the *belg*, from March to May. The main rains are in the *meher* season from July to September. The maize cycle straddles both seasons, whilst teff is a shorter cycle crop depending only on the *meher*, and therefore offers an important 'second chance' for those who can grow it when the *belg* season fails. Sweet potatoes are a particularly important crop, because two harvests per year practiced, with the principal one in the dry season of November-January; but the second, smaller harvest breaks the annual 'hunger' period in May-June. The staple foods are in order of amount consumed: maize, enset, sweet potatoes, taro, teff and yams.

The dual dependency on cereals and perennial/root crops offers some insurance against at least moderate rain failure, since maize is more susceptible than either root crops or enset to long breaks between showers and/or overall moisture deficit. Lack of grazing lands and fodder affect oxen production, so that only the better off and middle wealth group households who own all the plow-oxen are able to till the land efficiently, whilst others have to wait their turn to borrow teams of oxen. Even for middle and better off households, the high prices of inputs, especially chemical fertilizers and improved seed, coupled with a lack of agricultural credit facilities, limit agricultural productivity. In the last five years, food aid for poorer people has been a regular feature. Enset as perennial offers a store of food, but it is a store which takes 4 or more years to fill: when trees are cut one part of the store is evidently lost for as many years as it takes for a replacement to grow. In an area of such frequent food stress, there is a high tendency for people to go beyond the long-term sustainability of the stand of enset stems

2.2. Sampling Design

The study was conducted July to September 2015.This study is based on a cross-sectional household survey data from mixed crops and livestock farmers. To examine the farm-level perceptions of climate change and associated adaptation strategies in Geze Gofa *Woreda*, the selection of study area took into account three distinct different Agroecological Zones (AEZs). This study employed multistage sampling procedure. Geze Gofa *Woreda was purposively selected* at first. The *Woreda* was purposely selected because of the magnitude of climate change related problem observed and personal acquaintance with the study area. Also the Zonal weather related reports shows that almost all *Woredas* in the zone experiencing climate variability and changes. Secondly Study *Kebeles* were identified and stratified into three based on their agroecology, accordingly one *kebele* from highland agro-ecology(Dega), one kebeles from midland(Woina Dega) and one kebele from lowland agro-ecology(Kola) and total of three *Kebeles* (namely *Gorpha, Fane and Tsila*) were purposely selected to represent Highland (Dega), Midland(Woina Dega), and Lowlsnd (Kolla) agro-ecological zones respectively. List of total households of the four selected Kebeles were obtained from district agricultural office and sampling frame of all *Kebeles* were organized. Finally, 222 sample respondents were randomly drawn from sampling frame using simple random sampling based on probability proportional to size. The purpose of analysis in relation to agro-ecological differentiation is to investigate how farmers living in different agro-ecologies perceive, and adapt climate change and how different agro-ecologies are affected by climate change and variability.

2.3. Data Type, Sources and Methods of Collection

The study used both quantitative and qualitative types of data as well as primary and secondary data sources. Primary data collection tools employed discussed below

2.3.1.Semi-structured Questionnaire: Data were collected by means of a semi-structured household questionnaire survey which was pre-tested with 10 farm households in *Gorpha* kebele while the main survey was carried out between June to August 2015 A semi- structured questionnaire was used to gather information on socioeconomic characteristics, crop and domestic livestock management, land tenure, detail of farm inputs and outputs, access to various institutional services, current and past trends of climate change, current adaptation measures undertaken and limitations to adaptation. Prior to the study, a pretesting of the questionnaire was performed to avoid missing any important information. Fifteen enumerators, who have experience in data collection, know the area and communities languages were recruited and trained for one day by researcher. The enumerators received field training about the study objectives and farm household survey. On information on respondents' knowledge, questions sought causes of climate change, perceived changes on onset and offset of seasons, duration of seasons, coldness, hotness, frequency of droughts and floods.

2.3.2. Focus Group Discussion (FGDs): Four Focus Group Discussions (FGDs) were conducted to double check the survey data. Focus group discussion was also conducted to get some qualitative data which used to back the quantitative data.

2.3.3. Key Informant Interview: Key informants drew from *Woreda* Agricultural and Rural Development office, Aged community members and village religious leaders.

2.3.4. Secondary Data: review of secondary data was also conducted Secondary data were collected using secondary data collection checklist from district agricultural office, district information desk, district health office, journals, Books, CSA, NMA records published and unpublished documents and other reports.

2.4. Method of Data Analysis

Descriptive statistics and logistic regression analysis were the main analytical techniques used in this study.

Qualitative analysis of information from focus group discussions and key informant interviews is a continuous process starting during data collection with identification of major themes and ending with an in-depth description of the results. In accordance to Newing (2011) data from focus groups and key informants was summarized according to key themes and illustrated by direct quotes, recounting particularly relevant experiences and views of smallholder farmers, essential for authenticity of findings.

In determining the econometric form to employ for this analysis, three options traditionally utilized to evaluate qualitative dependent variables, such as the dichotomous outcome of “Adapted” and “Not Adapted”, were considered: Linear Probability Models (LPM), probit models, and logit models. Use of LPM is unnecessarily simple in its functional form, and presents the drawbacks of (1) a disturbance term which has a non-normal distribution leading to problems with making valid statistical inferences, (2) assumed heteroskedasticity of the error term which violates the principles of OLS and resulting estimators inefficient, (3) significant lack of meaningful models due to a lack of Goodness of Fit, and (4) without restrictions placed on beta-coefficients, LPM results can imply probabilities beyond the realm of the Bernouli distribution (that is that results lie beyond and between 0 and 1) due to the underlying assumption of linearity, and thus constancy(Gujarati, 2009; Studenmund,2006). Thus, LPMs are essentially ruled out for appropriate application in the case of this research, if more appropriate techniques are available.

Probit and logit models are extraordinarily similar in both their formulation and their results, relying on a “link” function using cumulative distribution functions (CDFs) which are normally and logistically distributed, respectively. As is well-known, these CDFs present a sigmoid (S-shaped) distribution, which more closely resembles the observed distribution of dichotomous data.These models do not use Ordinary Least Squares methodology, but instead rely upon Maximum Likelihood Estimation. The features of probit and logit models make interpretation of resulting coefficients unique from those obtained under an LPM. Of the two, probit models are often seen as better suited for experimental data (Rahm, 1984) and do not enable precision robustness as they fail to allow the modeler to adjust for covariates. Logit models guarantee the estimated probability increases and never cross the range of 0 to 1, and are the most commonly and widely applied. Therefore, Linear Probability Model (LPM) and probit models were rejected in favor of a logit model formulation. This logit model was used to identify the socio-economic factors affecting the farmers’ adoption of adaptive strategies, using the functional form of logit model expressed by Gujrati (Deressa et al, 2009) as:

The Logit model is estimated with maximum likelihood estimation (MLE) technique. The Logit model is specified as:

$$\frac{P_i}{(1-P_i)} = \frac{1+\exp(Z_i)}{1+\exp(-Z_i)} \qquad (1)$$

Where *i*

P_i is the dependent variable which in this study is the probability of adoption of at least one climate adaptation strategy. P_i ranges between 1 and 0 and is nonlinearly related to Z_i and is a linear function of the explanatory or independent variables, X_i , with values ranging from +¥ to -¥ . Because equation (1) is nonlinear, one can linearize the model by taking the natural log. This gives the following linear Logit model:

$$Li = \ln\left[\frac{P_i}{(1-P_i)}\right] = Zi = \beta_0 + \beta_1 X_1 + \ldots + \beta_n X_n + e \qquad (2)$$

Where $\frac{P_i}{(1-P_i)}$

= is the ratio of the probability that a farmer will use any of the listed climate change adaptation strategies

Hence, the dependent variable is binary and its value is 1 for a farmer who used at least one of the listed strategies and 0 for a farmer who used none. b_0 to b_n are parameters to be estimated and *e* is the error term. X_1 to X_n are the independent variables. The description of all the variables (dependent and independent) used for analysis is presented in Table 2.

2.4.1. Definition and justification of model variables

Farmers of course can decide to adapt to climate change for profit motive but this study will assume that if they make the decision to do so, it will be to counter the negative effects of climate change.

Dependent variable (Adoption of adaptation strategies)

The study uses a binary dependent variable taking the value 1 if the farmer adapted to climate change and 0 otherwise. This is done to distinguish between farmers who adapted and those who did not in the study area. A farmer is considered to have adapted to climate change if he/she has employed at least one of the adaptation strategies such as early and late planting, use of drought resistant crops, conservation farming and irrigation farming.

Independent variables

The choice of independent variables to be used in the study is influenced by literature reviewed on factors that influence farmers' decisions to adapt to climate change, previous research findings and the knowledge about adaptation to climate change in Geze Gofa Woreda. Household characteristics, farm characteristics, institutional factors were hypothesized to explain the dependent variable. This current research considers the following as potential factors affecting farmers' decisions to adapt to climate change; education of the household head, farm household size, age of the household head, non farm income, exposure to information on climate change, access to credit, farming experience , farm size and soil fertility. Table 2 provides the variables hypothesized to determine adaptation behavior, a brief description of each variable, its value, and expected sign in relation to adoption of new technologies

Table 2. Variables hypothesized to affect adaptation decisions by farmers in the Geze Gofa Woreda

Variable	**Description Household characteristics**	**Value**	**Expected sign**
Gender	Gender of the head of the farm household	1= male, 0= female	Positive
Household size	Number of family members of a household	Number	Cannot be signed a priori (+ or -)
Farming experience	Number of years of farming experience for the household head	Years	Positive
Education	Number of years of formal schooling attained by the head of the household	Years	Positive
Age	Age of the head of the farm household	Years	Positive
Farm size	Determine if the farm is large-scale or small-scale	1= large scale 0= small scale	Positive
Soil fertility	Land condition. Three dummies: infertile, fertile, and highly fertile	0 or 1	Positive
Extension contact	If household has access to extension services	1=yes, 0= no	Positive
Climate information	If household gets information about weather, climate from any source (extension officers, TV, radio, etc.)	1=yes, 0= no	Positive
Credit	If household has access to credit from any sources	1=yes, 0= no	Positive
Off-farm employment	Income from off-farm activities during the survey year		Positive
Land Tenure condition	If land use is owned or rented/sharecropped, etc.	1= owned 0= otherwise	Positive
Annual farm Income	Annual income from farming in naira in Dollar	Number	Positive
Distance from market	Distance from house to the nearest market in km	Kilo meter	Positive
Agroecology	High land		Positive
	Midland		Positive
	Lowland	0 or 1	Positive

<u>RESULTS AND DISCUSSION</u>

3. Socioeconomic and Demographic Characteristics of Respondents

The result in Table 3 shows that majority 56.76 %(126) of the farmers were males while 43.24 %(96) were females.

Table 3 reveals that majority of the respondents (75 %) are between the ages of 31 – 63 years while only 13.96 % of the respondents are aged greater 63 years. This implies that most farmers are still in their productive age. Majority of the farmers have been farming for the past 33 to 43 years. Again this indicates most farmers are relatively young. According to, older farmers are more risk – averse and less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting adaptation strategies. However, older farmers may also understand the complexities of farming more than younger farmers since they having been into the business longer and experiences may serve as a proxy for age.

Table 3 reports the educational status of the sampled farmers. The result shows that 45.95 % of the farmers had no formal education, 35.14 % had primary education, 14.42 % had secondary education, 4.5 % had certificate and above education. This shows that the farmers have extremely low level of education

Majority (48.65) of the respondents have farm sizes of less than half a hectares with a mean farm size of 0.457 hectares. This is an indication that these farmers are mainly small scale producers. Despite the smallness of the farms, majority (81.53 %) of the farmers own the farms which they cultivate as against 18.47% who rented theirs. Tenancy would motivate farmers to invest more in practices and technologies that would improve their farm outputs including climate adaptation strategies

Table 3. Frequency distribution of respondents by socioeconomic characteristics

VARIABLE		FREQUENCY	PERCENTAGE
SEX	Male	126	56.76
	Female	96	43.24
Age	20-30	21	9.45
	31-41	34	15.31
	42-52	77	34.68
	53-63	63	28.38
	64-74	17	7.66
	>74	14	6.3
Education	No formal	102	45.95
	Primary	78	35.14
	Secondary	32	14.42
	Certificate & above	10	4.5
Household Size	2-5	98	44.15
	6-9	104	46.85
	10-13	20	9
Farming experience (Years):	1-10	31	13.97
	11-21	36	16.22
	22-32	62	27.93
	33-43	67	30.18
	44-54	26	11.72
Farm size	<0.5	108	48.65
	0.5-1	87	39.2
	>1	27	12.16
Market distance (km):	<5	67	30.18
	5-10	100	45.04
	>10	55	24.78
Extension Service	Access	89	40.1
	No access	133	59.9
Credit service	Access	62	27.93
	No access	160	72.07
Climate Information	Access	28	12.61
	No access	194	87.39
Land tenure	Owned	181	81.53
	Rented	41	18.47
Agro-ecology	High land	57	25.68
	Midland	66	29.73
	Lowland	99	44.6
Annual farm income (Dollar)	<100	76	34.23
	100-199	81	36.49
	200-299	45	20.27
	>300	20	9.01
Livestock ownership (TLU)	<5	98	44.15
	5-10	107	48.2
	>10	17	7.65

3.2. Smallholder Farmers' Perception and Knowledge of Climate Change and Variability

Households were asked about their perceptions of temperature volume, heat intensity and rainfall amount, distribution and patterns and extreme events changes trend in the last two to three decades. 197 farmers (88.73 % of the 222 farmers that were interviewed) perceived an "increase" in temperature volume, 2.75 %(6) of respondents perceived a "decrease" in temperature volume, 5.74 %(13) of respondents perceived "no change" in temperature volume, 2.78 %(6) respondents reported they don't know about change volume. On the other hand, 87.64 %(195) of the respondents felt an increase in heat intensity; 1.75 %(4) of the respondents perceived a decrease in heat intensity; 8.76(19) % of the respondents claimed no change in heat intensity; 1.85 %(4) of the respondents reported they don't know about temperature change (Table3).

Most of the interviewed farmers perceived precipitation changes, amount of rainfall and/or distribution, in the study area over the last 30 years. Substantial percentage of respondents (85.6 %) perceived the change in the amount of rainfall. Out of 85.6 % respondent who perceived the change in rainfall amount, 83.64 % of the respondents felt a decrease in the amount of rainfall, and the remaining 6.34 % respondents oppositely felt an increase in the amount of rainfall; on the contrary, 3.02 % of the respondents noticed no change in the amount of rainfall; 3% of the respondents did not give enough attention about the trend of the rainfall volume. The result also indicated that the majority of the respondents (89.6 %) noticed a change in the timing of rains, specifically, 90.68 % observed shorter rainy seasons, and 5.65% observed extended rainy seasons; 3.67% of the respondents observed no change in the rainy season.

Table 4. Households' Perceptions of Changes in Rainfall and Temperature over the Last 20-30 Years

Households' Perception (Counts of households (%) that....	Precipitation	Temperature	
	Rainfall Amount	Temperature Volume	Heat Intensity
Perceived an increase	1.25	88.73	87.64
Perceived a decrease	85.6	2.75	1.75
Perceived no change	5.2	5.74	8.76
Did not know	7.95	2.78	1.85
Total(n)	222	222	222

Temperature and rainfall are the two climatic variables that influence farming the most in the study area. In farming, the amount of rainfall is important and is an indicator of long term changes in the climate system. However, of more importance to farmers is the pattern of the rainfall. If the rain falls in the right amount and then it ceases for a long period before the next rain, the long dry spell can be devastating to farmers. If however the rain falls in small amount but at the expected time and spread over the period of planting, it is a good season for farmer

3.3. Micro-level Farmers' Implemented Adaptation Strategies

The farmers were presented with a number of climate adaptation strategies and then asked to indicate whether they have used any of the listed. This section focuses on the various adjustments that farmers in the survey made in their farming activities if they perceived changes in the climate. In a rural community where agricultural activity is the dominant means of living, adaptive capacity brings the ability of a farming system to adjust to climate change (including climate variability and extremes), to moderate potential damages, to take advantage of opportunities, or to cope with the consequences. In community's life the ultimate goal of an adaptation measure is to increase the capacity of a farming system to survive external shocks or change. The assessment of farm-level adaptation strategies is important to provide information that can be used to formulate policies that enhance adaptation as a tool for managing a variety of risks associated with climate change in agriculture. The farmers were presented with a number of climate adaptation strategies and then asked to indicate whether they have used any of the listed. The results are presented in Table 3. An overwhelming majority (62.25%) of respondent farmers indicated that they had employed at least one of the identified adaptive strategies, with only 37.75 % indicating no adoption of any of the adaptive strategies included in this study. This stands as evidence supporting a conclusion that farmers of this area were taking actionable steps and changing practices to tackle various, known and unforeseen climatic and environmental changes (Table5).

Table5. Micro-level Adaptation strategies Adopted in response to climate change and variability (%)

	Adaptation Strategies	Percentage of Farmers
1	Crop Diversification	62
2	Plant Short-seasoned/early maturing crop varieties	58.25
3	Changing planting dates	61.75
4	Engage in off-farm and non-farm jobs	8
5	Use irrigation, ground water and Water Harvesting	10.6
6	Started Planting Trees as Hedge	17
7	Reduced Livestock Animals	25.7
8	Improved Food Storage Facility	18.5
9	Shift from cereal crops to root crops	62.25
10	Planting trees around and within crops	54.5
11	Using drought and Disease tolerant varieties	42.56
12	Dietary change	22.75
13	Change cropping locations (altitude)	33.33
14	use of drainage system	13
15	Use of conservation farming	26.55
16	changed the amount of land under cultivation or grazed	23.75
17	Practice Prayer or ritual offerings	58.56
18	Increased involvement in soil and water conservation	27.65
19	Moving to different location/resettlement	15.66
20	Not adopted any adaptation measure adopted	37.75
	Total	

Note: A multi response frame was used. Hence, total count is more than the number of respondents

The figures presented in table 8 clearly suggest that crop diversification is the strategy opted by the highest percentage of respondents. Involving in off-farm activities, on the contrary, had been opted by the least number of farmers. Even though a large number of farmers interviewed noticed changes in climate as mentioned above, the results show that almost 37.75% did not undertake any remedial actions. The majority of farmers use shift from cereal crops to root crops (62.25 %); prayer or ritual offerings (62.33%), crop diversification practices such as mixed cropping and crop rotation (62%). About 60.89% of the respondents use early maturing varieties, while 58.25% adopted change of planting dates.

3.3. Constraints to Adopting Adaptation Strategies Faced by Farmers

The most commonly identified barrier was Lack of microfinance and/or insurance services and abject poverty. According to that study, the major factor restraining farmers' adaptation to climate change is inadequate access to credit and agricultural insurance services. Households also reported unavailability of credit facilities to purchase farm inputs such as fertilizers, farm implements and pay labourers. This has serious implications for climate adaptation and agricultural development more broadly in the study area. . The risks presented by climate change to the livelihoods of these households are set to increase (IPCC, 2007), yet the mechanisms needed to reduce this risk are not fully supported. Almost 74.55 % of households cited a lack of financial resources as a serious barrier (Table 6). About 64.75 % also perceived a lack of knowledge concerning appropriate adaptations strategies/options, whilst 63.56 % reported that a lack of irrigation schemes and access to water served as barriers.

Table6. Constraints to Adopting Adaptation Strategies Faced by Farmers in response to climate change and variability (%)

	Constrains to Adoption Adaptation Strategies	Percentage of Farmers
1	Lack of information about long-term Climate change	41.25
2	Lack of knowledge concerning Appropriate adaptations strategies/options	64.75
3	Lack of access to timely weather forecast information	53.65
4	Limited access to agricultural extension services	47.64
5	Lack of market access(Poor transportation networks and market information system)	48.2
6	Lack of irrigation schemes and access to water	63.56
7	Lack of credit or insurance services and abject poverty	74.55
8	Insecure property rights and land tenure issues	34.75
9	Unpredictable weather	41.65
10	Shortage of land(functional landlessness)	43.65
11	Shortage and high cost of farm inputs	37.34

Note: A multi response frame was used. Hence, total count is more than the number of respondents

3.4. Determinants of Farmers' Adoption of Adaptation Strategies

Before the data analysis, the contingency coefficient test was applied to diagnose collinearity and omit independent variables that are highly dependent and strongly correlated to each other. presents the correlations between all the variables hypothesized to influence farmers' perception of changes in the climate. Among the variables, the age of the farmer was found to be correlated inversely with education ($\rho = -0.032$), while it was highly positive and significant at $p < 0.01$ level of significance with farming experience ($\rho = 0.823$). Most importantly, the analysis showed that there is multi-collinearity problem between age and farming experience. Thus, the variable age was dropped from the model because most of farmers are old and variable farming experience is more relevant for the study than the latter. The independent variables are gender, education, farming experience, farm size, land tenure, soil fertility, access to extension services, access to climate information, access to credit, farmers', and agro-ecology dummy for highland and midland with lowland being the reference region for comparison

The Logit results of factors that determine farmers' decision on whether to adopt a climate adaptation strategy is presented in Table 4. The log likelihood function is statistically significant at 1% level. This implies that the variables (farmers socioeconomic characteristics, institutional and other policy variables) included in the logit model are jointly significant in determining farmers decision to adopt one or more climate adaptation strategies. All variables have expected sign. However, only five out of the nine variables are individually statistically significant. These are education, annual income, experience, and extension contact, credit service, and climate information.

The results in Table7 show that education, Membership in CBOs, farm household size, Extension contact; gender credit service , farming experience, annual farm income and exposure to information on climate change, Farm size, and agro-ecology, significantly influence farmers' adaptation to climate change.

Table 7. Logit regression of factors determining adoption of climate change adaptation strategies

Variables	Coefficient	Standard Error	Z-statistic	P-Value
Gender	0.564**	0.461	0.563	0.043
Education	2.203***	0.109	1.894	0.005
Farm experience	0.068***	1.286	2.08	0.003
Annual farm income	1.262**	0.890	1.967	0.062
Extension contact	1.40***	0.209	1.840	0.002
Climate information	2.35***	0.865	4.026	0.001
Land tenure condition	0.238	0.764	0.320	0.772
Distance from market	0.580	0.693	0.780	0.128
Soil fertility	-0.560*	0.654	0.462	0.062
Farm size	0.235*	0.560	1.082	0.084
Membership in CBOs	0.346*	0.451	0.560	0.099
Agro-ecology-Highland	0.570	1.06	1.042	0.449
-Midland	0.584	1.20	1.542	0.756
-Lowland	2.36**	1.24	0.820	0.064
Access to credit	2.26**	0.308	0.67	0.062
Log likelihood	-52.34***			0.000
Pseudo R^2 =0.875				
Constant =3.69				
Total observation=222				

The asterisks [, **, and ***] represent statistical significance at 10%, 5% and 1% levels respectively*

The regression model results explain that education is positive and significantly (at 1% level) related to adaptation strategies to climate change effects. This implies that the probability of adaptation to climate change is greater for those who have higher educational attainment compared to less-educated or illiterate farmers. The coefficient is positive implying that education seems to have a strong influence in adapting to climate change. Moving from one level of education to the next increases the probability of the farmer of adapting to climate change by 20.3%. This implies that as farmers in Geze Gofa Woreda acquire more education, their probability of adapting to climate change increases. These results are in support of the findings of Deressa et *al* (2009) who found a positive relationship between education and adaptation to climate change in Ethiopia. In addition De

Jonge (2010) also found that farmers who have university education are more likely to respond to climate change than farmers who have primary education. It is obvious that educated farmers have more knowledge, a greater ability to understand and respond to anticipated changes, are better able to forecast future scenarios and, overall, have greater access to information and opportunities than others, which might encourage adaptation to climate change. Several studies found that education also positively and significantly affects the adoption of technology (Quayum, 2012; Deressa et al,2008,).

The effect of annual farm income on adoption of climate change adaptation strategies is positive and significant at 5% level. This implies that the probability of adoption of climate change adaptation strategies increases with increase in income. This is not surprising as increased income probably enables a farmer to purchase modern varieties and technologies (e.g irrigation facilities) that reduce the effect of climate change. This implies that farmers with high income are more likely to adopt adaptive strategies than farmers with lower incomes. The findings support projects undertaken by Government Organizations (GOs) and Non-Government Organizations (NGOs) designed to create off-farm livelihoods activities so that farmers can diversify and supplement their income and continue their agricultural operations in the face of climatic uncertainty.

Involvement in cooperatives is positive and significantly (at 1% level) related to adoption of adaptation strategies, implying that the probability of adaptive strategy adoption in higher for those farmers who have connections with different cooperatives enterprises compared to farmers not participating in such coordinated actions and groups. This observation as an indication that membership and engagement in a cooperative encourages farmers to engage in a united strategies orientation; farmers involved in cooperatives share knowledge and innovation ideas, discuss problems and challenges with others, and engage in collaborative decision-making.

4. CONCLUSSION AND POLIY IPLICATION

4.1. CONCLUSSION

Although overwhelming majority of smallholder farmers appears to be aware of climate change, few seem to actively undertake adaptation measures to counteract climate change. Indeed, almost 42% did not undertake any remedial actions. The adaptation options observed in the study area are manifold but the main adaptation strategies of farmers identified include crop diversification, Plant Short-seasoned/early maturing crop varieties, Changing planting dates, Engage in off-farm and non-farm jobs ,Shift from cereal crops to root crops, Improved Food Storage Facility, Using drought and Disease tolerant varieties and etc. The most commonly identified barrier was Lack of microfinance and/or insurance services and abject poverty. The study used the Logit model to assess the factors influencing farmers' choices of climate change and variability adaptation methods. In the model, the dependent variables include different adaptation methods and the explanatory variables include household, farm and institutional characteristics and other factors. The results highlighted that education level, farming experience; access extension services, access to credit and access to climate information are the factors that enhance farmers' adaptive capacity to climate change and variability.

4.2. POLICY IMPLICATIONS

Public policy that creates a supportive rural institutional framework and promotes rural education, rural income initiatives and climate change awareness campaigns may promote the ability of rural farmers to adapt. Factors influencing farmers' decisions to implement adaptation to climate change shows signals for the government to strengthen and develop institutional mechanisms that support farmers to ensure sustainability of their agricultural activities and enhanced food security. Agricultural Extension Services, Department of Meteorological Service and Agricultural Finance Institutions need strengthening while rural micro finance institutions need to be developed. Efforts by government to support farmers' adaptation to climate change are in place but more focus should be placed on effective adaptation to leverage the little resources that are currently allocated for communal agriculture.

The government must support farmers' education through various policies. For example, adult literacy can be intensified and offered to communal farmers at affordable charges. More schools and better education facilities should be provided to the farmers in the rural. Specialized education on climate change and the agriculture sector can help increase farmers' knowledge and help them appreciate the benefits of adapting to climate change. Policies that ensure dissemination of information and research and development on climate change forecasting, changes in agriculture production cycles and appropriate adaptation strategies should be promoted. As such, the government should intensify the provision of extension services by ensuring increased interactions between farmers and extension officers possibly through procuring more vehicles that extension officers can use for field visits. Information generated by the Department of Meteorological Service should timely and in local language reach out to farmers through extension officers to facilitate them make informed decisions and reduce uncertainty and allow them to better prepare for severe weather conditions. The government through extension services should encourage farmer to farmer extension services where farmers can exchange information about their farming experiences in order to tap the experiences gained by experienced farmers.

Increase in affordable lines of credit is important in adapting to climate change. The government can prioritize availability of credit through the formal channels as this will enable the farmers to secure farm inputs on time. With more income, they will be able to buy fertilizers and early yielding crop seed. Agricultural Finance Institutions should be allocated more resources to expand its services to reach farmers rural areas by introducing affordable lines of credit. In addition, the government should look into establishing collaboration with development agencies to facilitate lines of credit to rural farmers. Microfinance development in the district should be promoted where farmers' co-operatives can be introduced to lend credits to the farmers since these do not have stringent collateral requirements as compared to the formal financial institutions.

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