

Smallholder Farmers Adaptation Strategies to Climate Change in Ethiopia: Evidence from Adola Rede Woreda, Oromia Region

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Abstract
The share of agriculture in the Gross Domestic Products (GDP) of Ethiopia is very significant. Although agriculture is undeniably a key economic sector in Ethiopia, it is the most vulnerable to the impacts of climate change. An attempt to reduce the impacts of climate related problems requires appropriate policy responses. A number of studies on climate change adaptation recognize the importance of agro-ecologically based studies for designing context-specific policies and programs to climate change adaptation.
Therefore, this study was carried out with objectives of identifying the determinants of farmers' decision to undertake adaptation measures to climate change and the farmers' preferences to different adaptation strategies in Ethiopia using a case study in Adola Rede Woreda. The primary data was collected from 250 sample households using a survey questionnaire and was analyzed using both descriptive statistics and econometric methods. The logit model was used to identify the determinants to climate change adaptation decision. In addition, the Rank-Ordered Logit Model (ROLM) was used to identify the preference as well as the determinants to preferences for climate change adaptation strategies. Results of the logit regression model show that educational level, farm size owned, number of livestock owned, access to credit, and farmers-to-farmers' extension service are among the factors which are positively and significantly affecting the farmers adaptation decision. However, non farm income and fertility level of the farm negatively and significantly affect farmers' adaptation decision to climate change. Besides, the results of ROLM show that improved crop and livestock variety, Agroforestry, Changing of planting date, Soil and Water Conservation, Small Scale Irrigation and Temporary Migration are the adaptation strategy preferred by the farmers in Adola Rede in that order from the most preferred to the least preferred. The ROLM indicate that demographic, socio-economic and institutional factors determine the preferences for adaptation strategies. Therefore, the government should first understand the farmers' preferences for climate change adaptation together with demographic, socio-economic and institutional factors in designing and implementing appropriate policy response to reduce the impacts of climate change and variability in the study area. In addition, addressing the barrier to climate change adaptation is also very important.
Keywords: climate change, adaptation, agroforestry, rank ordered logit model, Adola Rede

Introduction

1.1. Background of the Study

The Ethiopia's economy continues to be led by agriculture sector. This is evidenced by its lion share contribution to gross domestic product (41%), to export earnings (above 60%) and to employment generation which is about 85% MoFED (2010). By recognizing this, the government of Ethiopia considers agriculture as the major source of overall economic growth in its different growth strategies including the current Growth and Transformation Plan (GTP). In GTP, for example, the overall ambitious economic growth objective basis itself on this sector, hence it was believed and continued to carry the overall burden. In this way, the principal development programme of GTP is to maintain rapid and broad-based growth path that have been witnessed during the past several years and eventually end poverty, in which agriculture leads the overall movement MoFED (2010).
In line with this, the issue of climate change stands at the side of this transformation agenda. The reason is clear and straightforward. Currently the issue of climate change is one of the key global agenda. This is because climate is a major environmental variable that affects nearly all human activities MoFED (2010). For instance, unpredictable weather condition experienced from climate change with its potential negative impacts on socio-economic activity of Ethiopia –particularly on agriculture, is considered as one of the major challenges to implementation of the country's growth and transformation plan (ibid).
In this regard, recorded empirical literatures stressed that the impact of climate change on agricultural production is not a single period phenomenon. For example, Gurung and Bhandari, (2008) stressed that agriculture has already suffered from the negative economic and ecological consequences of climate change. And accordingly, this effect is expected to continue and rural communities are increasingly vulnerable to climate induced hazards, especially in developing countries. Moreover, IPCC (2007) also projected that yields of crops in some countries could be reduced by as much as 50% by 2020, with smallholders being the most affected.
This prediction and expectation coupled with the current situation worries all citizens especially in developing

countries. For example, if we take Ethiopia, the agricultural sector which is the backbone of the country's economy is entirely dominated by smallholder farmers who are very vulnerable and sensitive to climate change related problems. Thus, owing to this fact, the effort should focus on finding mechanisms in which smallholder farmers can reduce these problems and save their lives.

1.2. Statements of the Problem

Agriculture is an essential driver of economic growth, particularly in rural areas and least developed countries. Boosting agricultural production at the national level is, therefore, stimulates overall economic growth and development, particularly in those countries with a high economic dependence on agriculture. However, currently climate change has become a serious threat to sustainable economic growth and development worldwide in general and across developing countries in particular Gebreegziabher et al. (2012).

More specifically, in countries like Ethiopia due to overdependence of its economy on rain-fed agriculture, the impact of climate change and variability on economic, social and environmental condition is immediate and direct. Deressa (2007) showed that Ethiopian agriculture sector is challenged by multiples of factors of which climate related disasters like drought and flood are the major ones. It is this factor that results in a widespread poverty in many parts of the country nowadays. Without appropriate responses climate change is likely to constrain economic development and poverty reduction efforts and exacerbate already pressing issues.

On the other hand, many authors emphasized that vulnerability to climate change and variability varies with time, geographic location and economic, social, and environmental conditions. For instance, climate change impacts on pastoralist and sedentary agriculture are highly region, livestock and crop-specific. Therefore, adaptation is also often conceptualized as a site-specific phenomenon. Hence many authors call for more local-level analyses to gain a better understanding of the fundamental processes underlying adaptation and for better targeting of adaptation policies by national and local governments, NGOs and bi-lateral donors (Boko et al., 2007; Mano and Nhemachena, 2007). Moreover, according to Admassie et al, (2008) in-depth studies on vulnerability and adaptation should continue.

Although lots of researches were done so far on climate related issues in Ethiopia, most of them focused on the farmers in Nile Basin as a case study (Deressa et al, 2008; Yesuf et al, 2008; Deressa et al, 2010; Di Falco et al, 2011). Their findings were very important to make policy intervention at micro level mainly for farmers who share the same socioeconomic, climatic, institutional and environmental condition with farmers of the Nile Basin of Ethiopia. This is due to the fact that, by its very nature adaptation is a local effort since the projected impacts from climate change can differ greatly even over small geographic areas. Thus, planning officials need to understand these local impacts in detail before they decide on the best responses. In short, it is apparent that policy measure intended to reduce the impacts of climate change should be backed up by research with a detail analysis at micro levels.

However, to the best of my knowledge, no research was done so far on the determinants of farmer's decision to take climate change adaptation measures and their preferences for different adaptation strategies in Adola Rede Woreda. Hence this study will fill the literature gap by identifying the specific local level climate change adaptation strategies and the factors affecting the choice of coping mechanisms. In addition, this research could also have a contribution to already existing literature on climate change adaptation strategies by suggesting its finding at the point where there is contradiction on the findings of different case studies.

1.2.1. Research Questions

- What are the determinants of farmers' decision to take adaptation measures to climate change in Adola Rede Woreda?
- What are the most and the least preferred adaptation mechanisms of the farmers in Adola Rede Woreda to reduce the impact of climate change?
- What factors influence the farmers' choice of various adaptation strategies to climatic and variability in Adola Rede Woreda?

1.3. General objective of the study:

The general objective of this study is to identify the determinants of farmer's decision to undertake adaptation measures to climate change and the farmer's preferences as well as the determinants of their preferences to different adaptation strategies in Ethiopia using a case study in Adola Rede Woreda.

1.3.1. Specific objective of the study:

- ✓ To analyse the determinants of climate change adaptation decision of smallholder farmers in Adola Rede Woreda.
- ✓ To identify the most and the least preferred adaptation strategies of smallholder farmers to climate change in Adola Rede Woreda.
- ✓ To identify the determinants of preferences for climate change adaptation strategies

1.4. Significance of the study

As it was recommended by Flyvbjerg (2006), the case study approach is appropriate to make study in-depth. Hence the climate change study needs a detail analysis. This is due to the fact that climate change adaptation differs from region to region and hence it needs detail study to indentify the adaptation methods that fits with specific place. According to Admassie et al, (2008) in-depth studies on vulnerability and adaptation should continue. To this end a representative single-case study approach is appropriate. It could allow addressing a gap in the literature by examining one district level initiative aimed at integrating adaptation strategies to climate change. Thus, this study could have significant contribution for the local and national government, NGOs or other bilateral donors in an effort to minimize the impact of climate change at local level through providing the necessary policy input.

2. Literature Review

2.1. General Overview: Why is Climate Change a Concern in Agriculture?

Climate[1] change affects many sectors, including water resources, agriculture and food security, infrastructures, ecosystems and biodiversity, human health and coastal zones. Moreover, climate change can affect agriculture in a variety of ways. However, this review is focused mainly on the climate change impacts on agriculture due to high dependence of agriculture on climate.

A number factors shape and drive the agricultural sector. Market fluctuations, changes in domestic and international agricultural policies (such as the form and extent of subsidies, incentives, tariffs, credit facilities, and insurance), management practices, terms of trade, the type and availability of technology and extension, land-use regulations and biophysical characteristics (availability of water resources, soil quality, carrying capacity, and pests and diseases) are among the set of primary influences. Given its inherent link to natural resources, agricultural production is also at the mercy of uncertainties driven by climate variation, including extreme events such as flooding and drought Kurukulasuriya P. and Rosenthal S. (2003).

This is due to the fact that climate change exerts multiple stresses on the biophysical as well as the social and institutional environments that impacts agricultural production. Some of the induced changes are expected to be immediate, while others involve gradual shifts in temperature, vegetation cover and species distributions. Climate change is expected to, and in parts of Africa has already begun to, alter the dynamics of drought, rainfall and heat waves, and trigger secondary stresses such as the spread of pests, increased competition for resources, and biodiversity losses Christensen et al (2007).

There is growing evidence that climate change has had negative effects on agriculture. Moreover, there is a widespread agreement that agriculture, mainly in developing countries, is the sector which is most negatively affected by climate change IPCC (2007). Besides, Africa's agriculture is hard hit with impacts of climate change due to its low level of economic development and adaptive capacity.

2.2. Climate Change and Agriculture Sector in Ethiopia

Climate is the main determinant of Ethiopian economic growth. This due to the fact that agriculture sector is continued to be the engine of the country's economic growth. The country's national economy relies mainly on this sector. Agriculture includes crop production, livestock husbandry, forestry, fishery and others. Crop production is estimated to contribute to agriculture sector on average about 60%, livestock sub-sector accounts around 27% and forestry and other sub-sectors around 13% of the total agricultural value in the country NMSA (2001).

Climate related hazards in Ethiopia include drought, floods, heavy rains, strong winds, frost, heat waves (high temperatures), and etc. Climate variability is already imposing a significant challenge to Ethiopia by affecting food security, water and energy supply, poverty reduction and sustainable development efforts, as well as by causing natural resource degradation and natural disasters.

The heavy dependent of Ethiopia's economy on rain fed agriculture exacerbated its vulnerability to climate change impact. In addition its geographical location and topography in combination with low adaptive capacity entail a high vulnerability to the impacts of climate change. Historically the country has been prone to extreme weather variability. Rainfall is highly erratic, most rain falls with high intensity, and there is a high degree of variability in both time and space. Since the early 1980s, the country has suffered seven major droughts five of which have led to famines in addition to dozens of local droughts.

These challenges are likely to be exacerbated by climate change. According to NMA (2007), there has been a warming trend in the annual minimum temperature over the past 55 years. It has been increasing by about 0.37^0C every ten years. The country has also experienced both dry and wet years over the same period. The trend analysis of annual rainfall shows that rainfall remained more or less constant when averaged over the whole country NMA, (2007).

According to PANE (2009), in Ethiopia, agricultural output is highly affected even by changes in a single climate variable, i.e. rainfall. The same is true for the country's GDP as it heavily relies on agriculture (World Bank, 2006; PANE, 2009). This is true in most of African countries, as there is a strong association between

[1] Climate is often described by the statistical interpretation of precipitation and temperature data recorded over a long period of time for a given region or location.

GDP growth and climate variables like rainfall. This resulted due to lack of economic diversification and strong dependence on the agricultural sector (ibid). In addition, in case of Ethiopia, this sector is dominated by small scale farmer who have been characterised by rain fed mixed farming with traditional technologies NMSA (2001). Studies indicated that under future climates many regions of Ethiopia will face decreases in agricultural production. This suggests that agricultural production as an engine of growth is vulnerable to climate change and climate variability. While the more pronounced effects on crops and livestock are likely to materialize in later decades, efforts to enhance the resilience to climate shocks of crop yields and livestock production should be stepped up as soon as possible, particularly on account of the efforts required to strengthen research systems and to transfer and adopt findings from the lab to the field. In this case, the Growth and Transformation Plan supports a number of actions that, by boosting growth, will contribute to the enhancement of Ethiopia's resilience to climatic shocks.

2.3. Adaptation to climate change

Adaptation and mitigation are two separate policy responses to climate change. Both are however intrinsically linked. Mitigation is needed to reduce the impacts and allow for adaptation to takes place, for ecosystems these boundaries are generally narrower than for human systems. Because mitigation measures will not be able to immediately avoid global warming Parry et al., (2007), adaptive measurements will be needed to avert the negative consequences of climate change at the short term. On the longer term mitigation measures will be able to avoid further warming or even reduce the effect.

Numerous studies have emphasized the need to pursue adaptation in addition to mitigation strategies. The IPCC noted that adaptation through changes in processes, practices or structures is a crucial element in reducing potential adverse impacts or enhancing beneficial impacts of climate change IPCC (2001).

Adaptation encompasses actions to reduce vulnerability and build the resilience of ecological and social systems and economic sectors to present and future adverse effects of climate change in order to minimize the threats to life, human health, livelihoods, food security, assets, amenities, ecosystems and sustainable development. Moreover, adaptation to climate change can lessen the yield losses that might result from climate change, or improve yields where climate change is beneficial IPCC (1996). There are many different strategies that farmers can implement to reduce the risk of climate change impacts. Farmers use different adaptation strategies that fit with the types of the climate related problems they faced. This is due to the fact that impact of the climate change is unevenly distributed over different geographic areas and hence the adaptation mechanisms also vary with types and amount of the impact of climate change.

Therefore, we can find a number of adaptation strategies that the farmers used to reduce the impact of climate change in different literature. This includes: changing crop variety, changing planting dates, mix crop and livestock production, decrease livestock, moving animals/temporary migration, change livestock feeds, soil and water management, planting trees, change from livestock to crop production, change animal breeds, seek off-farm employment, planting short season crop, and irrigation/water harvesting are among some of the several strategies available to enhance social resilience in the face of climate change Nhemachena and Hassan (2007).

Despite the wide range of adaptation options, there is no guarantee that a particular farmer will undertake adaptive action. The extent to which adaptation strategies are implemented varies among individual farmers depending on their capacity and willingness to adopt Crimp et al (2010). Hence, there are factors that are restricting adaptive capacity and willingness to adopt as a potential source of limits and barriers to adaptation. The main factors giving rise to limits and barriers to adaptation are biophysical, economic, social, and/or technological in nature.

2.4. Empirical Literature Review

2.4.1. Adaptation strategies and determinants to adaptation:

Hassan R. and Nhemachena C. (2007) analyzed determinants of farm-level climate adaptation measures in Africa using a multinomial choice model to fit data collected from a cross-sectional survey from 11 African countries. The results indicate that specialized crop cultivation (mono cropping) is the agricultural practice most vulnerable to climate change in Africa. According to this study, better access to markets, extension and credit services, technology and farm assets (labour, land and capital) are critical for helping African farmers adapt to climate change.

Seo and Mendelsohn (2006) explore how farmers in Africa have adapted to climate change across 10 African countries including Ethiopia. The study used logit model to estimate whether farmers have adapted livestock management to the range of climates found across Africa. The main findings are that farmers are more likely to choose to have livestock as temperatures increase and as precipitation decrease. Cooler temperatures and wetter conditions on the other hand favour crops. All the climate coefficients except the linear term on winter temperatures are found to be significant. The study reveals that religion determines whether or not a farmer adopts livestock.

A study by Deressa T. (2008) identified the major methods used by farmers to adapt to climate change in the Nile Basin of Ethiopia. The adaptation methods identified include use of different crop varieties, tree planting, soil conservation, early and late planting, and irrigation. Results from the discrete choice model employed indicate that the level of education, gender, age, and wealth of the head of household; access to extension and credit; information on climate, social capital, agro-ecological settings, and temperature all influence farmers' choices. The main barriers include lack of information on adaptation methods and financial constraints. Moreover, the analysis reveals that age of the household head, wealth, information on climate change, social capital, and agro-ecological settings have significant effects on farmers' perceptions of climate change.

In the Nile Basin of Ethiopia, Di Falco et al. (2011) examined the driving forces behind farm households' decisions to adapt to climate change, and the impacts of adaptation on farm households' food productivity. They have estimated a simultaneous equations model with endogenous switching to account for the heterogeneity in the decision to adapt or not, and for unobservable characteristics of farmers and their farm. Finally, they found that access to credit; extension and information are found to be the main drivers behind adaptation. In addition they found that adaptation to climate change increases food productivity.

The findings of Mulatu N. (2011), who analyzed households' preference for five different types of climate change adaptation strategies (i.e. multiple cropping, livestock, soil conservation, irrigation, and changing planting dates) in North Showa Zone using rank-ordered logit model revealed that, multiple cropping is the most preferred and frequently applied adaptation strategy to climate change, while livestock production is the least preferred. In addition, he has also revealed that gender, age, farming experience and education level of the household head, household size, and farm and nonfarm income, farm size and farm distance to homestead, agricultural extension services and access to climate forecast information, farmers' perceptions on temperature and rainfall affect farmers' preference for the climate change adaptation strategies.

Mudzonga E. (2011) examined farmers' adaptation to climate change in Chivi district of Zimbabwe based on a cross sectional data collected through a household survey. This study was conducted with the major aim to examine the factors that influence farmers' decisions to adapt to climate change. A logit model was employed in the study. The findings revealed that education of the household head; farm household size, access to credit; farming experience and exposure to information on climate change all positively and significantly influence farmers' decisions to adapt to climate change in Chivi district.

Deressa *et al* (2009) use a multinomial logit model to study the determinants of farmers' choice of adaptation strategies. The study analyses perception and adaptation by farmers in the Nile Basin of Ethiopia for mixed crop and livestock farmers during the 2004/5 production year. A household survey was conducted. The study reveals that most farmers perceived that temperatures had increased and that precipitation had decreased. Findings reveal that education, age, non farm income, livestock ownership, access to extension services, access to climate information, access to credit, and number of relatives in the community positively influenced the farmer to adapt. Contrary to Deressa et al (2010), household size was found to be insignificant in influencing the farmer's decision to adapt to climate change.

Deressa *et al* (2010) use the Heckman model to the same data where a Multinomial model referred to above was used to assess farmers' adaptation to climate change. This model initially assesses farmers' perceptions that climate is changing followed by examination of the response to this perception in the form of adaption. Thus the Heckman model has two equations; the selection equation and the outcome equation. The study reveals that education of the household head, household size, whether household was male, livestock ownership , use of extension services on crop and livestock production, availability of credit and temperature all positively and significantly affected adaptation to climate change. However, large farm size and high annual average precipitation were negatively related to adaptation.

The study is undertaken by Yohannes L. (2010) in Adama Woreda focused on the factors that influence the farmers' decision to take adaptation strategies. Multinomial Logit model is used to determine the factors affecting the adaptation decision behaviour of the farm households. She showed that, average annual rainfall, average annual temperature, agro-ecological setting, information on climate change have a significant impact on all adaptation options. The distance from the market and the size of the land has a positive and significant influence on soil conservation. In addition the size of the land has a significant influence on planting trees as adaptation. However, farmers' characteristics (such as gender, sex and education), social factors (number of relatives) and institutional factors (extension visits) although these had been found by other studies as a determinants to the adaptation options, in her study they are not significantly different from zero.

3. Methodology

3.1. Description of the Study Area

Adola Rede Woreda is found at 475km from Addis Ababa. The absolute location of the district is between 5^{o}44'10"N- 6^{o}12'38"N and 38^{o}45'10"E - 39^{o}12'37"E. It shares boundary with Girja in North-East direction, Anna Sorra in North-West direction, Oddo Shakiso in Southern direction and Wadara in South-East direction. It has a total area of about 1401km^2. Most part of the topography of this Woreda is characterised by ups and down. Moreover, it has land surface with an elevation ranging from 1500 meters in the Southern portion to over 2000 meters in the North-Western part. Like in many parts of Ethiopia, the farming system in Adola Rede is still traditional with oxen and yolk (animal's power), and labour as the major means of production during land preparation, planting and harvesting as well as post harvest process. Rain-fed agriculture is a common practice for many farm households in this Woreda. However, a semi-nomadic economic activity is also practiced as a means of livelihood by some of its residents.

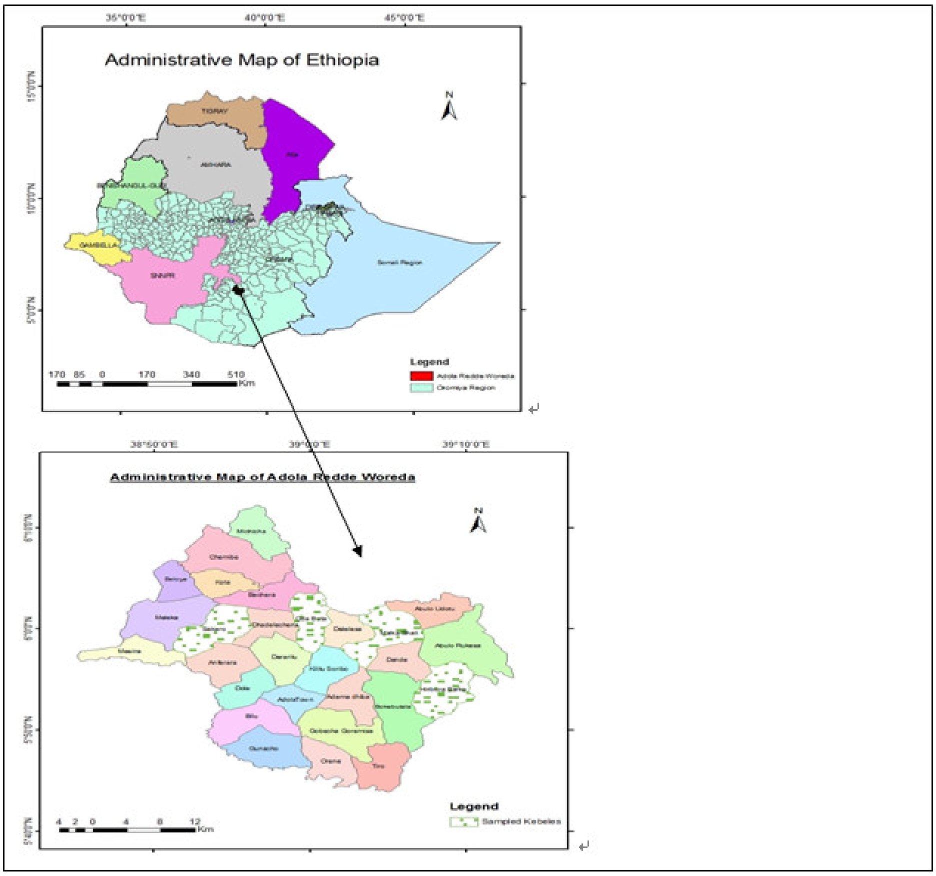


Figure: 3.1. Map of the Study Area

This Woreda has 28 rural kebeles and two urban kebeles. The farmers of this Woreda produce both in meher and belg seasons. They produce cereals such as teff, wheat, barley and maize, pulses such as haricot bean, and others such as fruits and vegetables. Overall, wheat, maize and teff are the major crops cultivated by the farmers in this study area. They also engaged in the production of coffee as means of livelihood. Moreover, this Woreda has a potential for livestock production which is witnessed by farmers ownership large number of livestock.

2.5. Data types and sources

This study was conducted in Adola Rede district to study smallholder farmers' adaptation strategies to climate change. The study was focused on farmers' preferences for different adaptation methods and the factors determining their decision for adaptation to climate change. To undertake this study the primary data was used. The primary data was collected from the farmers of this district. The primary data was collected from the smallholder farmers of the Adola Rede district using a survey questionnaire and interview with key informant groups. The survey questionnaire was prepared in English and translated to local language (Afan Oromo) so as to get accurate information from the households since this language is used by the majority of the resident in this district.

2.6. Sample size and Sampling methods

Adola Rede district has 28 rural kebeles and two urban kebeles. It has three agro-ecological zones namely: dega, woina dega and kola. In this study, a sample of 250 smallholder households was taken from Adola Rede district smallholder farmers. In order to select these respondents a two-stage sampling approach was employed. First, four Kebeles was selected out of 28 rural Kebeles in the district purposively based on agro-ecological zones and the intensity of the impact of the climate change and variability.

Second, using systematic sampling method households were selected from each of the four kebeles proportionally. In this case the lists of the households were collected from the kebele administrator's or development agent officials (DA) of each kebele first. In systematic sampling method by using random numbers to pick up the unit with which to start, an element of randomness is usually introduced. This sampling procedure is useful when sampling frame is available in the form of a list. In such a design the selection process starts by picking some random point in the list and then every n^{th} element is selected until the desired number is secured.

Table: 2.1. Purposively selected kebeles for study, number of households and sample size

No.	Name of kebeles	Agro-climatic zone	Household size	Sample size
1	Melkaa Shaalii	kolla[1]	816	75
2	Odaa butta	kolla	897	82
3	Hirboora barko	woina dega	362	33
4	Saakarroo	dega	655	60
Total sample			2730	250

Source: Adola Rede Woreda Administration, (2011/12)

2.7. Methods of data analysis

For the analysis of the data collected from the sample respondents both descriptive statistics and econometric analysis methods were used. The Logit model was used to identify the factors affecting the farmers' decision to adapt to climate change. Moreover, the Rank-Ordered Logit model was employed to identify the adaptation strategy which was most preferred and least preferred as well as the determinants for their preferences to adaptation strategies.

2.7.1. *Theoretical Framework*

In the study of farm household it is necessary to develop theoretical framework. Accordingly, a random utility model will be employed for this study. Random utility model is a widely applied framework in analysis of farmers' choice for different adaptation strategies Kennedy (1992). In this model, the farmers are assumed to be rational decision makers who maximize expected benefits from adaptation in farming. To do so we assume that, the farmers who face the impact of climate change in farming activities will look for different alternatives of adaptation methods. Let farmer i faces a set of alternatives climate change adaptation methods, j = 1, 2, 3,..., J. The utility farmer i receive from alternative strategy $j \in J$ can be represented by random utility model Kennedy (1992):

$$U_{ij} = V_{ij} + e_{ij} \qquad for \;\; j \epsilon J_i \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (1)$$

Where, $i = 1,..., N$ indexes individual farmer and $j = 1,..., J$ indexes the alternative adaptation methods, V_{ij} is the deterministic component of utility from alternative j and e_{ij} is a random component. The deterministic component V_{ij} may include attributes of the alternatives considered and characteristics of the individual (e.g., age, education, household income, location, farm size, etc). The deterministic component is usually assumed to be linear in parameters:

$$V_{ij} = \beta'_j x_i \quad \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots (2)$$

Where x_i is m-dimensional vector of farmer/farm characteristics of farmer i, β_j is m-dimensional vector of unknown parameters associated with individual farmer i's characteristics that may vary across alternatives.

The farmers can compare the importance of alternative adaptation method j with the importance of alternative adaptation method k in making adaptation decisions such that farmer i will prefer j alternative over alternative k if:

$$U_{ij} \geq U_{ik} \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots 3$$

In estimating models with ranking data, the basic assumption is that the choice behaviour underlying each rank position satisfies Luce's choice axiom, it is well known as the independence from irrelevant alternatives (IIA) Luce (1959). Then, the probability of a ranking can be easily linked to choice probabilities. The model specification following Ben-Akiva *et al.* (1991) is briefly presented here i.e. the joint probability that alternative 1 is preferred to alternative 2 which is in turn preferred to alternative 3, and so on, including all the alternatives, can be represented as follows:

$$Prob\left(U_{i1} \geq U_{i2} \geq U_{i3} \geq \cdots \geq U_{iJ}\right) = \prod_{j*=1}^{J} Prob\left(U_{ij*} \geq U_{ij}\right) for \; j = j*+1 \dots J \dots\dots 4$$

Equation (4) is derived from the Luce - Suppes Ranking Choice Theorem which allows decomposition of the joint probability $Prob\left(U_{i1} \geq U_{i2} \geq U_{i3} \geq \cdots \geq U_{iJ}\right)$ into a series of successive and independent events where U_{ij} represents the utility for the most preferred alternative j* at each stage of decision Chapman and Staelin (1982). The right-hand side of equation (4) is the product of the probability of choosing alternative 1 over the other alternatives, $Prob\left(U_{i1} \geq U_{i2} \geq U_{i3} \geq \cdots \geq U_{iJ}/Ji\right)$, the probability of choosing alternative 2 given that

[1] *Two kebeles are selected from kolla agro-ecological zone because the impact of climate change and variability is higher in kolla than any other agro-ecological zones in this study area. In addition this woreda has 12 kebeles in kola agro-ecological zone out of the total 28 rural kebeles.*

alternative 1 was already selected, $Prob(U_{i2} \geq U_{i3} \geq U_{i4} \geq \cdots \geq Uij/ji - \{1\})$, the probability of choosing alternative 3 given that 1 and 2 are already selected $Prob(U_{i3} \geq U_{i4} \geq U_{i4} \geq \cdots \geq Uij/Ji - \{1,2\})$ and so on.

2.8. Econometric Model

Now, based on the nature of data required to achieve the objectives of the current study we employ the standard Logit and Rank-Ordered Logit models. The Logit model was used to analyse factors affecting farmer's decision to adopt any climate change adaptation strategy (the first objective). However, Rank-Ordered Logit model was used to analyse the farmers' preferences for different adaptation strategies (the second objective). The mathematical specifications of these models are given one by one as follows.

2.8.1. The Logit Model

The Logit model considers the relationship between a binary dependent variable and a set of independent variables which can be a binary or a continuous. For such a dichotomous outcome, the Logit model is appropriate. The Logit model is the easiest and most widely used discrete choice model. Its popularity is due to the fact that the formula for the choice probability takes a closed form and is readily interpretable. To identify key determinants of adaptation decision, a dichotomous variable is computed first which indicate whether the farmer is adopted or not. That is,

$$Y^* = \beta X_i + \epsilon_i \quad \text{...}1$$

Practically, Y* is unobservable. What we can observe is a dummy variable Y_i defined by

$$Y_i = \begin{cases} 1, \text{ if } Y^* > 0 \text{ or (if the farmer adopt)} \\ 0, \text{ otherwise} \end{cases}$$

This show that the farmers will choose to adopt ($Y_i = 1$) if $Y^* > 0$, 0 otherwise. Where Y* show the expected benefits of adapting to climate change relative to not adapting, **X** is a vector of variables that affect the decision to adapt or not to adapt to climate change. We then use a logit regression model including 11 explanatory variables, modelled as follows:

$$P_i = prob(Y_i = 1) = \frac{1}{1+e^{-(\beta_0+\beta_1 x_{1i}+\cdots+\beta_{19} x_{11i})}} = \frac{e^{(\beta_0+\beta_1 x_{1i}+\cdots+\beta_{11} x_{11i})}}{1+e^{(\beta_0+\beta_1 x_{1i}+\cdots+\beta_{11} x_{11i})}} \text{............}2$$

Since the estimated coefficients only show the direction of the effects of the independent variables on the dependent variables and show neither the magnitude nor probabilities. Thus, marginal effect is used instead to interpret the effects which are the relative effect of each independent variable x_i on the probability of the outcome. Marginal effects is calculated by differentiating equation 1 with respect to explanatory variable i.e. x_i.

$$\frac{\partial p_i}{\partial x_i} = \left[\frac{e^{\beta_i' x_i}}{1+e^{\beta_i' x_i}}\right]\beta_i = \quad F(\beta' X)[1 - F(\beta' X)]\beta_i \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots .3$$

2.8.2. The Rank-Ordered Logit Model

The analytical approaches that are commonly used in an adoption decision study involving multiple choices are the multinomial logit (MNL) and multinomial probit (MNP) models. Both the MNL and MNP are important for analyzing farmer adaptation decisions as these are usually made jointly. These approaches are also appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies Hausman and Wise (1978). Both of these models use farmers most preferred choices of adaptation methods from the set alternatives, not the ranked one. However, according to Hassan & Nhemachena (2008) the most preferred climate change adaptation strategies by African farmers are mainly applied in combination with other strategies and not alone.

In this study we have used the Rank-Ordered Logit model (ROLM) to analyze an individual's preferences over a set of alternatives. The advantage of this type of data is that, it provides more information about preferences when compared with data in which individuals are asked to illicit their most preferred choice over a set of alternatives or data in which individuals are asked to rate alternatives without comparison (Beggs, et al., 1981 and Caplan, et al., 2002). In statistical terms, the parameters can then be estimated more efficiently Fok et al (2010).

The adaptation strategies employed so far by most farmers in different parts of the country are reviewed from different literatures. In addition, the adaptation mechanisms to climate change in the study area are also observed and the set of alternatives adaptation mechanisms are determined. In this study farmers were asked to rank six different climate change adaptation strategies in application to their farm. Farmers rank these climate change adaptation strategies from the one they value most to the one they value least. These climate change adaptation methods are:

1. Using improved crop and livestock variety (IV)
2. Change planting dates (CP)
3. Moving animals or temporary migration (TM)
4. Soil and water conservation (SW)
5. Agro-forestry (AF)
6. Small scale irrigation (SI)

One way of understanding the ROLM is to imagine the task of ranking the alternatives as a sequence of choices.

Let $y_r = m$ indicates that alternative m has rank r; that is, alternative m is the r[th] choice. Then we can write the probability of the first choice as $Pr(y_1=m/x)$. The probability of the second choice is conditional on the first choice since if $y_1=m_1$, then $y_2 \neq m_1$. Accordingly the probability of the second choice given as $Pr(y_2=m_2/x, y_1=m_1)$. Extending this logic to climate change adaptation case, we can compute the probability of rank ordering consisting of the six adaptation strategies aforementioned. Here we take the symbol we give for representation for the sake of convenience.

$$Pr(y_1=TM, y_2=AF, y_3=IV, y_4=CP, y_5=SI/X)= Pr(y_1=TM/X)*Pr(y_2=AF/X, y_1=TM)*$$
$$Pr(y_3= IV/X, y_1=TM, y_2= AF)*Pr(y_4=CP/X, y_1=TM, y_2= AF, y_3= IV)*$$
$$Pr(y_5= SI/X, y_1=TM, y_2= AF, y_3= IV, y_4=CP)$$

This equation states that the probability of the specific rank ordering is the product of: (1) the probability of temporary migration is being selected first from the set of choices that include six alternatives; (2) the probability of agro-forestry is being selected first from a choice set that exclude temporary migration; (3) the probability of improved crop and livestock variety is being selected first from a choice set that exclude temporary migration and agro-forestry; (4) the probability of change planting date is being selected first from a choice set that exclude temporary migration, agro-forestry, and improved crop and livestock variety; (5) the probability of small scale irrigation is being selected first from a choice set that exclude temporary migration, agro-forestry, improved crop and livestock variety, and change planting date. We do not consider the last choice since once we know the first five choices, the last choice is determined.

The expression of the above is actually a sequential estimation of Multinomial Logit Models.; a Multinomial Logit Model (MNLM) associated with the most preferred adaptation strategy, a Multinomial Logit for the second most preferred adaptation strategy over the other alternatives excluding the one ranked as the most preferred and so on. Therefore, using the MNLM to model the probability of temporary migration is being selected first yields:

$$Pr(y_1=TM/x)= \frac{\exp(X\beta_{TM/b})}{\sum_{j=1}^{J} \exp(X\beta_{j/b})}$$

Where x contains case specific variables, b is the base category, $\beta_{k,j/b}$ is the effect of x_k on the log odds of choosing alternative j over alternative b and $\beta_{k,b/b}=0$ for all variable k. The probability of agro-forestry is being selected from a choice set that exclude temporary migration requires that we subtract $\exp(X\beta_{TM/b})$, the term corresponds to choice *TM*, from the summation in the denominator:

$$Pr(y_2= AF/X, y_1=SW)= \frac{\exp(X\beta_{AF/b})}{\{\sum_{j=1}^{J} \exp(X\beta_{j/b})\}-\exp(X\beta_{TM/b})}$$

The probability of the remaining adaptation strategy is being selected first could be determined by using the same logic. The ROLM relies on the assumption of Independence of Irrelevant Alternatives (IIA). The IIA property implies that the relative preference between two or more alternatives is independent from all other alternatives being ranked. If the IIA assumption is not satisfied, the ROLM will not be appropriate to model the farmers' preferences for climate change adaptation strategies. Therefore, we assume the Independence of the Irrelevant Alternatives (IIA).

2.9. Interpreting the Rank Ordered Logistic Regression Model

In the study the interpretation was carried out in terms of change in predicted probability for discrete change in the dependent variables. For instance, the discrete changes in the predicted probability of a certain outcome for a change in X_i from baseline say, Xo, to the final value say to, X_f,

$$\frac{\Delta Prob(y = t/X)}{\Delta X_i} = prob(y = t/X, X_i = X_f) - prob(y = t/X, X_i = X_0)$$

Where Prob(y=t|X, Xi) is the probability that y=t given X, by assigning specific value to Xi. The change in the probability is interpreted as indicating that when X_i changes from X_0 to X_f, the predicted probability of outcome t changes by $\frac{\Delta Prob(y=t/X)}{\Delta X_i}$ holding all other variables constant.

2.10. Model variables

This study is based on the assumption that the farmers make the decision to adapt to counter act the negative effects of climate change and not for profit motive following the assumption applied by Deressa (2009) and Mudzonga (2011). **Dependent variable (adapt):** In this study we used a binary dependent variable taking the value 1 if the farmer adopts any of a given strategies and 0 otherwise. In addition, for the ROLM model, the dependent variable is the rankings of farmers for the six adaptation strategies listed in the choice set. **Independent variables:** To determine the independent variables to be used in the study different literatures were reviewed regarding the factors that affect farmers' decisions to adapt to climate change. Thus, this current research considers the following as potential factors affecting farmers' decisions to adapt to climate change.

Table 3.1 The summary statistics for 14 variables included in the final model estimation

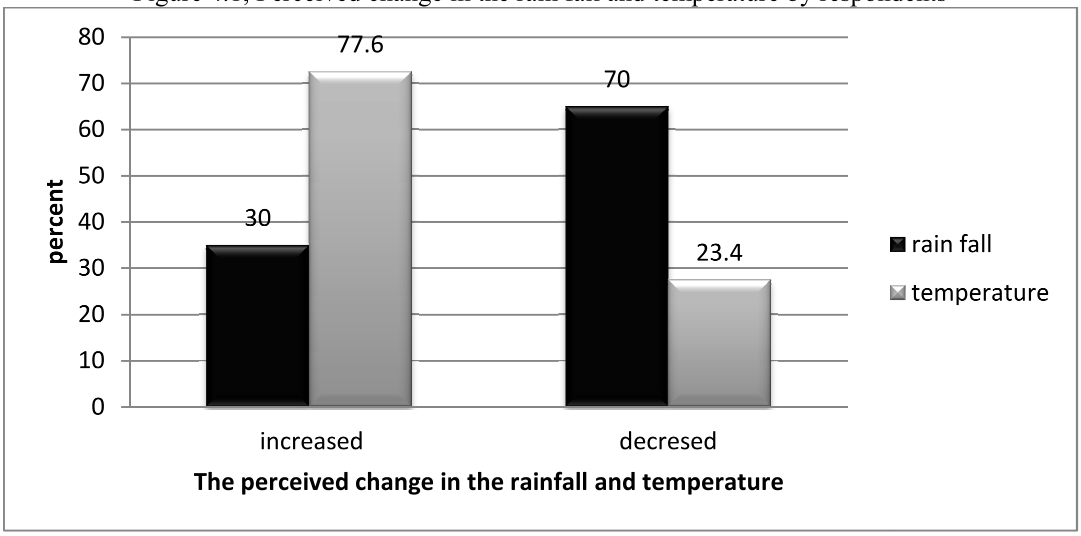
Independent variables	Description	Summary statistics			
		Mean	Std. Dev.	Min	Max
Gender of the household head	Dummy 1 if male, 0 otherwise	.85	.36	0	1
Age of the household head	In number (continuous variable)	41.38	8.57	25	61
Level of education of hh head	In number (continuous variable)	3.58	3.09	0	12
Farm household size	In number(continuous variable)	3.84	2.29	1	16
Farm income	ETB(continuous variable in '000)	17.80	7.25	5	52
Non-farm income	ETB(continuous variable in '000)	.65	2.46	0	15
Access to credit	Dummy 1 if yes, 0 otherwise	.62	.49	0	1
Soil fertility	Dummy 1 if yes, 0 otherwise	.22	.41	0	1
Distance from home-farm	In minutes (continuous variable)	28.50	22.83	2	180
Livestock size	In number(continuous variable)	12.90	5.71	1.43	35.95
Farmers-far extension services	Dummy 1 if yes, 0 otherwise	.88	.32	0	1
Farm size	In hectare(continuous variable)	2.2	1.13	.2	8
Average market distance	In minutes(continuous variable)	56.46	41.73	2	185
Perceived rainfall	Dummy 1 if increase, 0 otherwise	.3	.46	0	1
Perceived temperature	Dummy 1 if increase, 0 otherwise	.78	.42	0	1

3. Data Analysis and Interpretation

3.1. Perception of the Direction of Changes in the Precipitation and Temperature

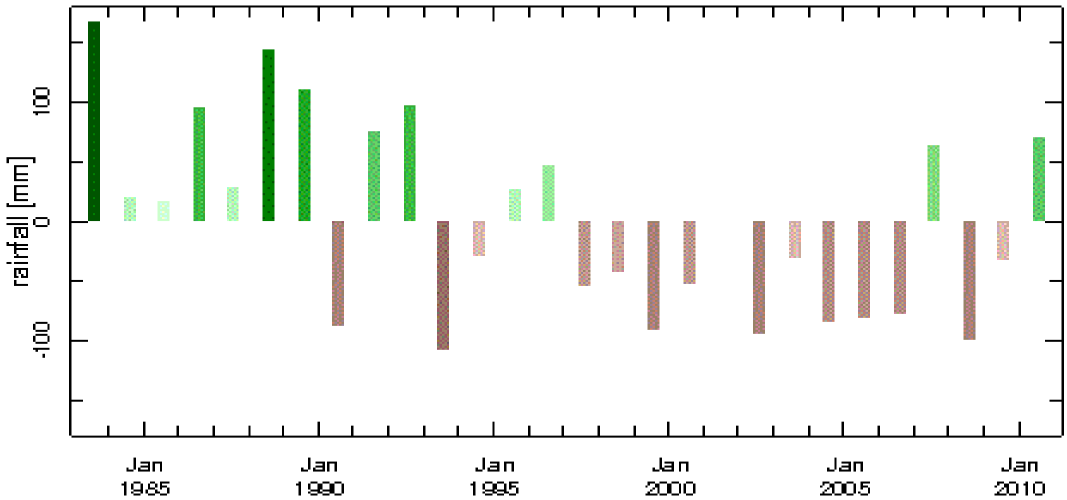
The farmers were asked whether they perceived changes in the rainfall and temperature in their locality. And then those who perceived the change in the in rainfall and temperature were again asked to identify the direction of the change they have perceived. The graph below shows that direction of the perceived changes in rainfall and temperature level by the farmers in the Adola Rede.

Figure 4.1, Perceived change in the rain fall and temperature by respondents



As the above graph clearly show about 30% and 77.4% of the respondents perceived that there is an increment in the level of rainfall and temperature in the Adola Rede respectively. While about 70% and 23.4% of the respondent perceived that there is a decrease in the level of the rainfall and temperature level respectively in this woreda. This variation in the direction of the perceived change in the rainfall and temperature is may be due that fact that that respondents were selected from each agro-ecological zone i.e. kola, woina dega and dega. Hence the degrees of variation of these elements are not the same across agro-ecological zones. In general, the majority of the farmers in the study area had perceived a decrease in precipitation but an increase in the level of temperature. In this regard, the meteorological data is also in support of the farmers' perception. As indicated in the figure 4.2, there is high rainfall variability in the study area.

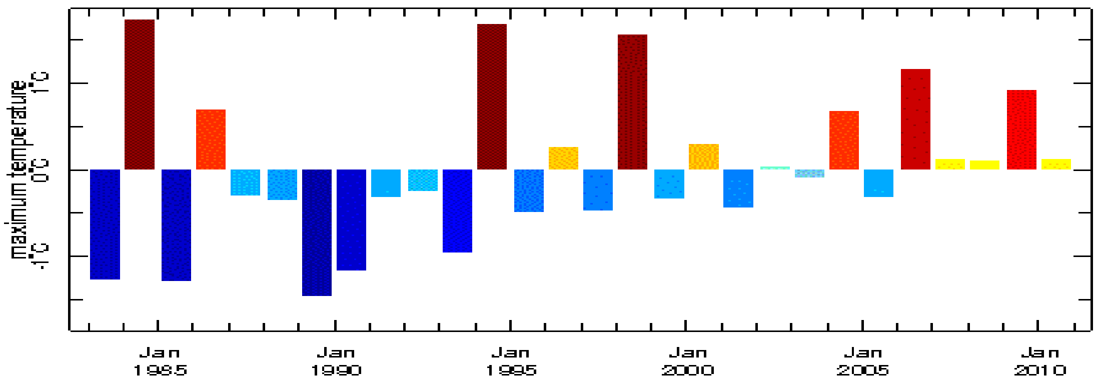
Figure 4.2: Kiremt (June-September) Rainfall Anomalies[1] of Adola Rede Woreda from (1985-2010)



Source: Adopted from National Meteorological Agency Website

Particularly, the rainfall anomalies of the study area indicate that during the last decade (2000-2010) the summer rainfall (kiremt rainfall) is mainly below the long term average which is a clearly indicate a decrement in the level of rainfall in the study area. This was extremely affected the farmers economic activities. Hence, it was highly depend on rain fed agriculture. The metrological data also align the farmers' perceived direction of change in the level of temperature in the study area. As shown in the maximum temperature anomalies in the figure 4.3 and the minimum temperature amoralities in figure 4.4, the level of temperature in the study area shows variability. However, during the last decade (2000-2010) the maximum as well as the minimum temperature level show an increment. Hence, it was above the long term average temperature level for the study area.

Figure 4.3: Yearly Seasonal Maximum Temperature Anomalies of Adola Rede Woreda from (1985-2010)[2]

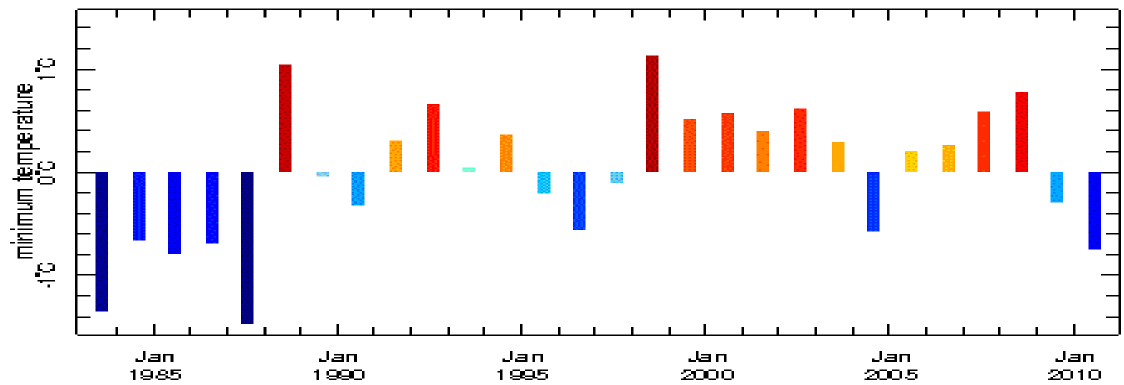


Source: Adopted from National Meteorological Agency Website

[1] Anomaly means a departure from a reference values or long term average.

[2]Adopted from National Metrological Agency Website: http://www.ethiomet.gov.et

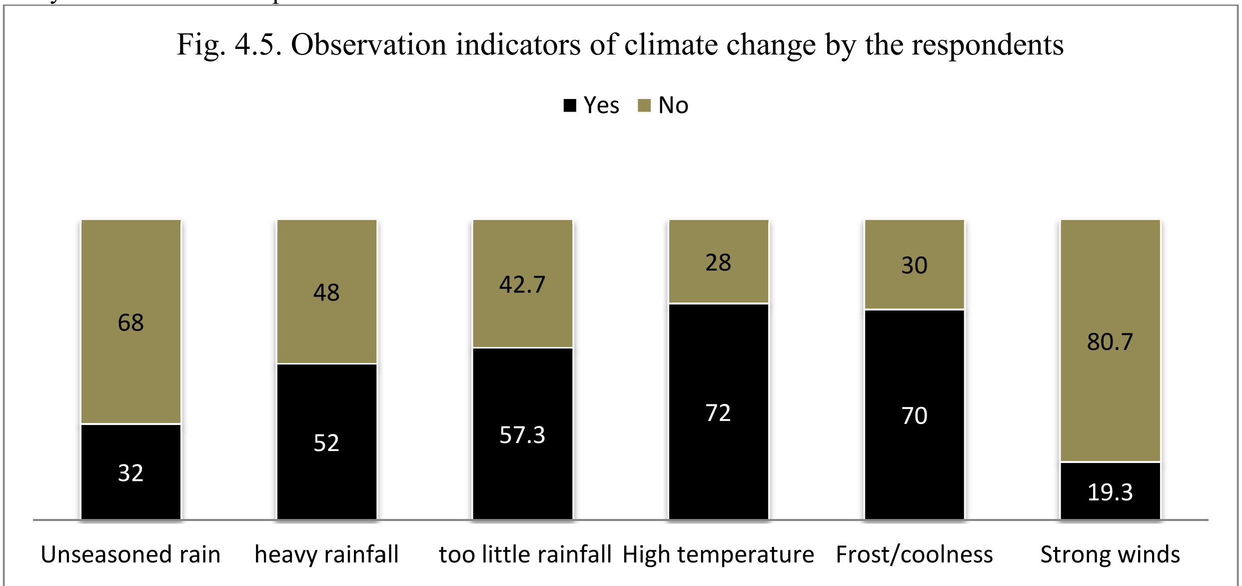
Figure 4.4: Yearly Seasonal Minimum. Temperature Anomalies of Adola Rede Woreda from (1985-2010)



Source: Adopted from National Meteorological Agency Website

3.2. Farmers Observation of Climate Change Indicator in Adola Rede

In the figure below we try to present the farmers' observation of climate change indicators. As it is shown below some of respondents were not observed these climate change indicators. For example, while about 32% of the respondents confirm the presence of unseasoned rainfall the remaining 68% of the respondents revealed that there is no unseasoned rainfall in their locality. On the other hand, about 52% of the respondents perceived that the presence of heavy rainfall but nearly half of the respondents were not sure if there is such climate related problem. However, about 57.3% of the respondents revealed that there is too little rainfall in their locality. This difference in their response shows that presence of erratic rainfall in this woreda. Hence, sometimes there is heavy rain while in other period there is too little rainfall.



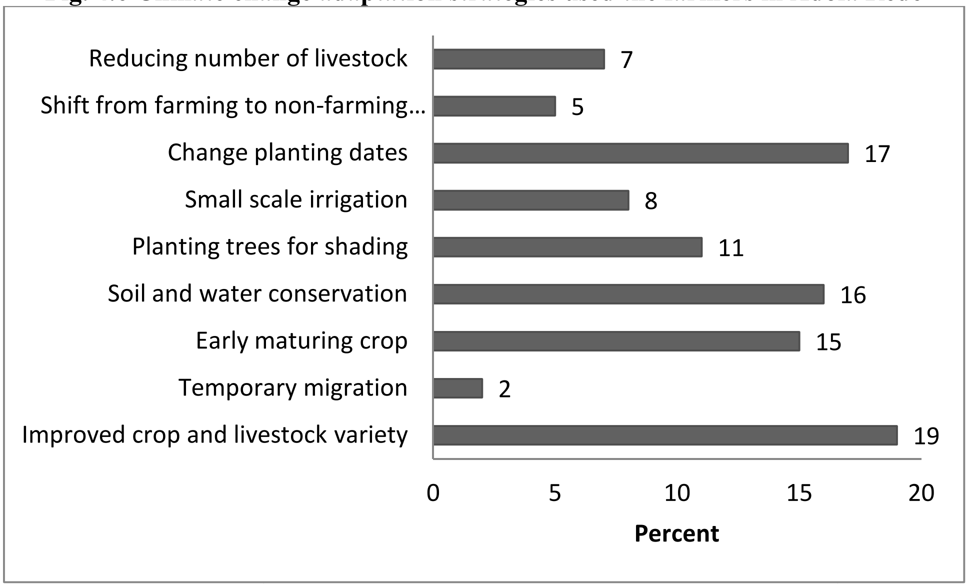
In other words, most the respondent in this study revealed that there is high temperature[1] as well as frost/coolness i.e. about 72% and 70% of the respondents respectively certify the presence of these climate change indicator in this woreda. As the respondent clarify how these contradicting indicator observed here within a woreda, they said, the day time has high hotness while at the night the coolness will take place. In this study area, there is no immense problem of strong winds. The problem of strong wind is observed by 19.3% of the respondents while the remaining 80.7% the respondents said that there is such problem.

3.3. Climate change adaptation strategies used the farmers in Adola Rede

Once the adopter and non adopter is identified, only those who take climate change adaptation measures so far were asked which climate change adaptation measure they have been using so far. Accordingly, using of improved crop and livestock variety is highly implemented climate change adaptation strategy. Changing of planting date and soil and water conservation is the second and the third highly implemented adaptation strategies. However, in the study area temporary migration is the least implemented adaptation strategy.

[1] High temperature in this sense implies observation of high warming.

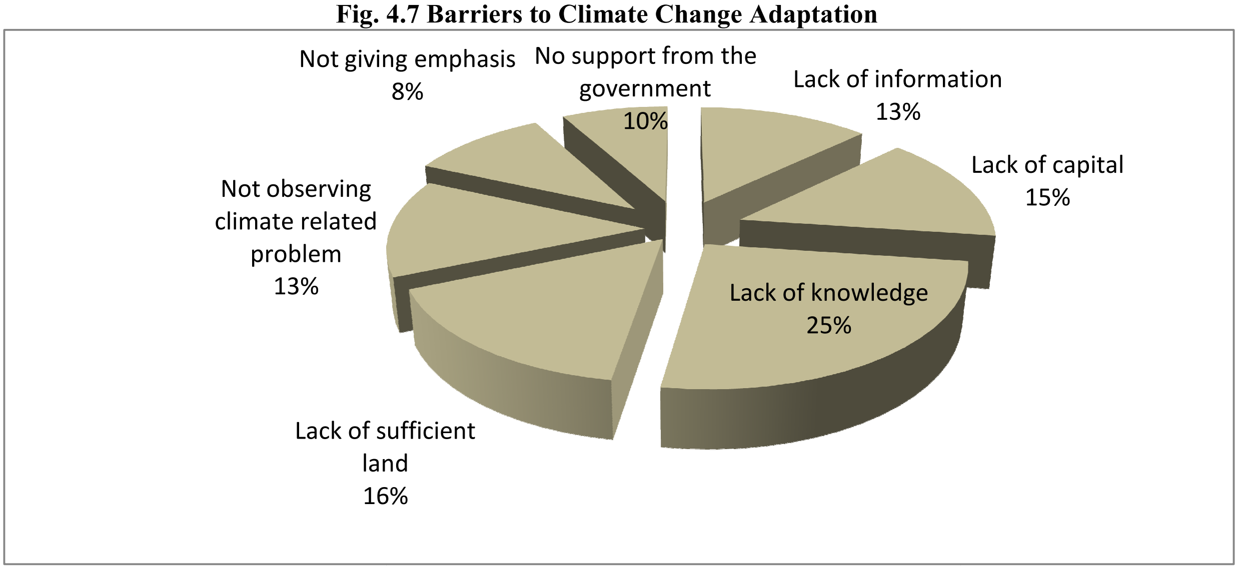
Fig. 4.6 Climate change adaptation strategies used the farmers in Adola Rede



3.4. Barriers to Climate Change Adaptation

The response of the farmers why they don't take any measure which could help the withstand climate change impact is discussed herein with help of the below graph.

Fig. 4.7 Barriers to Climate Change Adaptation



The major barriers to climate change adaptation in Adola Rede are lack of knowledge, lack of sufficient land, lack of capital and lack of information are the major one respectively. However, lack of support from the government as well as not giving emphasis is also among the barriers to climate change adaptation in Adola Rede.

3.5. Econometric Estimation, Results and Discussions

In this section we have included data analysis using econometric method. Before conducting econometric estimation we try to undertake different tests which very necessary for binary logit model as well as rank ordered logit model to achieve different objectives. The model is fitted using STATA version 12. However, prior to running the final regression analysis, the existence of multicollinearity using was checked Variance Inflating Factor (VIF) and the contingency coefficient (CC) methods. From this test we found that there is no severe problem of multicollinearity among the explanatory variables. Hence, value of VIF for each explanatory variable is less than 7 with mean VIF, 4.33. In addition, the from contingency coefficient methods of detecting multicollinearity is also less than 4 for all of the explanatory variables.

3.5.1. The determinants of climate change adaptation decision

From the regression result, we obtained Pseudo R-square value of 0.6670 which shows 66.7 percent of the model was explained by the included regressors. In addition, the estimated probability greater than chi-square value (Prob > chi-square = 0.0000), suggests that all the model parameters are jointly significant in explaining the dependent variable at less than 1 percent significance level. The coefficient from the logit regression indicates only the direction of the effect not the magnitude. Thus, the interpretation is undertaken through the marginal effect.

Table 4.1 Parameter Estimates of the Logit of Climate Change Adaptation Strategies

adapt	Coef.	Std. Err.	z	P>|z|
sex	1.269	1.169	1.08	0.278
age	.052	.043	1.23	0.220
educ	.264**	.132	2.00	0.045
aLF	.232	.155	1.49	0.135
finc	.055	.044	1.27	0.205
fsize	.642*	.376	1.71	0.087
nfinc	-.278***	.073	-3.79	0.000
lsize	.351***	.088	3.99	0.000
sfert	-1.224*	.738	-1.66	0.097
credit	2.475***	.822	3.01	0.003
ffext	1.504**	.707	2.13	0.033
_cons	-8.354***	2.392	-3.49	0.000
Logistic regression		chi2(11) = 53.89		
Number of obs = 250		Prob > chi2 = 0.0000		
Log likelihood = -37.684169		Pseudo R2 = 0.6670		
***Significant at 1% level **Significant at 5% level * Significant at 10% level				

Source: Own survey results, 2013

Table 4.2 The Marginal Effects for the Logit Model

variable	dy/dx	Std. Err.	z	P>z	X-bar
sex*	.0344	.03701	0.93	0.353	.848
age	.0006	.00067	0.88	0.381	41.384
educ	.0036	.00192	1.89	0.059	3.584
aLF	.0029	.00253	1.15	0.249	3.844
finc	.0007	.00083	0.83	0.404	17.797
fsize	.0097	.0067	1.45	0.147	2.198
nfinc	-.0044	.0024	-1.84	0.066	.649
lsize	.0046	.00215	2.14	0.032	12.904
sfert*	-.0185	.02163	-0.86	0.391	.216
credit*	.0552	.02649	2.09	0.037	.616
ffext*	.0379	.03584	1.06	0.289	.884

(*)dy/dx is for discrete change of dummy variable from 0 to 1

Level of education is one the statistically significant explanatory variable at 5% level of significance as shown by a p-value of 0.045 as shown in the table 4.5. The coefficient is positive implying that education has a positive influence in decision of taking adaptation measure to climate change. An increase in the level of education by one year for the mean educational level increases the likelihood for adaptation by 0.36% keeping other things at their respective mean. This result is in support of the findings of Deressa et *al* (2009) who found a positive relationship between education and adaptation to climate change in Ethiopia.

Farm size is also statistically significant explanatory variable in our model. The positive sign of its coefficient indicates the presence of positive relationship between farm size and farmers decision for taking climate change adaptation measure in Adola Rede. For instance, one hectare increases in the farm size from its mean increase the likelihood for adaptation by 0.97% holding other things at their respective mean. The result of this study is in line with the hypothesized direction of effects of this variable. For instance, the bigger the size of the farm, the greater the proportion of land allocated for modern crop varieties the adaptation strategies that the farmer is likely to adopt.

Non-farm income is high significant explanatory variable in this model with p-value of 0.000. Its coefficient has a negative which satisfy the hypothesized direction of effects of the non farm income in adapting to climate change. In this study we found that an increase in the non farm income by 1000 ETB from its mean value decreases the probability of taking adaptation measure by 0.44% holding other things at their respective mean. As the farmers' income from non-farm activities increased they devote less and less time for farming activities hence it could negatively affect the farmers' climate change adaptation decision.

The number of the livestock owned by the farmer is highly significant (at 1% significance level) explanatory variable in this study. Its direction of effect is also positive which show the positive effect of the livestock size in influencing the farmers' decision of taking adaptation measure. A unit increase in the number of livestock owned by the household from its mean value increases the probability of adapting to climate change by 0.46% holding other things at their respective mean. In this case livestock is considered as an asset for the farmers. Therefore, having a large number of livestock can strengthen farmers' adaptive capacity to climate change. On the other hand, livestock rearing is one part of agricultural activities which is also subject to climate change impact. Consequently, as the number of the livestock increased the farmers will look for adaptation measures that safeguard their assets against climate related problems.

Soil fertility is also significantly influence the farmers' decision of adaptation to climate change. It negatively influences the farmers' adaptation decision since its coefficient has negative sign. As compared to the farmer who has not fertile land, the probability of adapting to climate change decreases by 1.85% for the farmer who has a fertile land keeping other things at their respective mean. This is due to the fact that, when the farmers have fertile land its productivity per hectare is higher. In such case, they may not be hard hit by the impacts of climate change which in turn reduce the likelihood for taking adaptation measures.

Access to credit is also highly significant variable with p-value of 0.003. The coefficient of this variable is positive which show the positive influence of this variable in adapting to climate change in Adola Rede. As compared to the farmer who has no access to credit, the likelihood for adapting to climate change increases by 5.53% for the farmer who has credit access holding other things at their respective mean. Climate change adaptation needs money to purchase improved inputs such as fertilizer, improved seeds, improved livestock variety and others like different seedlings. Therefore, access to credit is very important to finance the purchase of necessary inputs for adapting to climate change. That is why here we found positive effect on adaptation decision. This result is similar to the findings of Deressa *et al* (2009) as well as Di Falco *et al* (2011) which were conducted in Nile Basin of Ethiopia.

Farmers-to-farmers extension service is also the significant explanatory variable. This variable positively affect the adaptation decision hence it has a positive coefficient. As compared to the farmers who have no access to farmers to farmer's extension service, the probability of adapting to climate change increases by 3.8% for those who have access to this service keeping other things at their respective mean. Different farmers have different skills, working habits, and experience. Therefore, sharing of experience among farmers is very important to build up the knowledge of the farmers and will help them to take the adaptation measures. Deressa *et al* (2010) also found that access to farmers to farmers' extension services positively affects adaptation to climate extreme.

3.5.2. Results of Rank Ordered Logit Model

After identifying those who take climate change adaptation measure and not, rank ordered logit model is fitted only for those who adapt to climate change. However, the tests were done before running the final regression. The model estimation test is one of the tests we have conducted for the sake of identifying the best model. Here the Bayesian Information Criterion (BIC), chi-square statistics and Prob > LR were used to compared among the model estimated and finally the model with lowest BIC was selected. Then after, presence of multicollinearity problem among explanatory variables is checked using VIF and there is no indicator for sever multicollineairty problem hence we have VIF less than 2 for each variable. Tests for assumption of independence for irrelevant alternative (IIA) were also conducted and end up with accepting the null hypothesis. In addition, the Wald test was also used here to indentify the significance of individual explanatory variable and for this model educational level, market distance and farmers to farmers' extension services were found insignificant.

Table 4.3 Parameter Estimates of the ROLM of Climate Change Adaptation Strategies

Explanatory var.	Climate change impact adaptation strategies									
	Improved crop and livestock		Change planting date		Temporary migration		Agro-forestry		Small-scale irrigation	
	Coeff	Pvalue	Coeff	Pvalue	Coeff	Pvalue	Coeff	Pvalue	Coeff	Pvalue
sex	1.1176	0.094	-.2953	0.023	-.9851	0.039	-.3482	0.440	-.2368	0.001
age	-.0372	0.020	-.0398	0.010	-.0310	0.065	-.0274	0.084	-.0436	0.008
Educ*	-.0285	0.519	.1160	0.046	.0115	0.808	-.0207	0.096	.1432	0.020
Act. LF	.1119	0.093	.1047	0.029	0760	0.026	-.0196	0.755	.2347	0.010
Far inco	.0728	0.012	.0981	0.001	-.0286	0.202	.0073	0.014	.0764	0.013
Farm siz	.0929	0.034	-.0534	0.683	.0056	0.967	.0252	0.043	-.2778	0.024
Dfarm	-.0110	0.093	. 0946	0.004	.0036	0.568	-.0031	0.632	.0959	0.004
Soil fert	.3110	0.421	1.1464	0.013	-.1143	0.780	-.2449	0.519	.4140	0.406
Livestck	-.0204	0.440	-.0165	0.595	-.0108	0.702	-.0375	0.020	-.0575	0.034
Dmkt*	-.0028	0.462	-.0042	0.259	.0046	0.236	.0029	0.430	.0034	0.392
credit	.1244	0.059	.08134	0.074	-.4489	0.028	.3262	0.044	-.4379	0.219
ffext	.817	0.093	-.53084	0.246	-.2225	0.644	-.4715	0.313	-.8443	0.159
Perc. rf	-.1459	0.056	-.2604	0.015	-.5993	0.082	0273	0.008	-.8309	0.013
Perc.te	.3172	0.050	-.3244	0.022	-.1769	0.010	.1225	0.003	-.1249	0.720
Cons.	4.260	0.000	2.493	0.016	2.069	0.065	2.216	0.041	2.641	0.018

Base category:	Soil and Water Conservation	LR chi-square (75):	283.19
Number of observation:	1248	*p*- value:	0.0000
Number of groups:	208	Log-Likelihood:	-1226.888

Table 4.4 Odds of Overall Adaptation Strategies Ranking By Households

Alternatives	Coefficient	e^b
Improved crop and livestock variety	0.67861	1.9711
Change planting dates	0.01597	1.0161
Temporary migration	-0.84606	0.4291
Agro-forestry	0.13168	1.1407
Small-scale irrigation	-0.59459	0.5518
Soil and water conservation	0	1
Log likelihood = -1271.918	LR chi2(5) = 193.13	Prob > chi2 = 0.0000

The above table show that, the odds of improved crop and livestock variety is higher indicating that this climate change adaptation strategy is the most preferred among all options presented for ranking. This is followed by agro-forestry and changing of planting date which has odds of 1.1407 and 1.0161 respectively. Soil and water conservation as an adaptation strategy has odds of 1 which shows it is the fourth most preferred adaptation strategy. Small scale irrigation as climate change impact adaptation has an odds of 0.5518 which show that it is the fifth most preferred adaptation strategies by the farmers in the study area. While temporary migration has odds of 0.42910 indicating that, it is the least preferred strategy. This indicates that using improved crop and livestock variety is the most preferred while temporary migration is the least preferred climate change adaptation strategy by the farmers of Adola Rede woreda

Table 4.5 The Predicted Probability for Ranking Adaptation Strategies First

Alternatives	Probability
Improved crop and livestock variety	.33649462
Change planting dates	.16408281
Temporary migration	.06398268
Agro-forestry	.1870238
Small-scale irrigation	.08528254
Soil and water conservation	.16313355

From this table we can understand that an average farm household in the sample has 0.34 probability of ranking improved crop and livestock variety as climate change adaptation strategies that they most highly favour. In the study area, an average farm household within the sample has 0.19 probability of ranking agro-forestry climate change adaptation strategy that they most preferred. In addition, there is a probability of 0.164 of observing changing of planting date as the most preferred climate change adaptation strategies by the farm households in the sample. In this study area an average farm household in the sample has 0.163 of ranking soil and water conservation as best climate change adaptation strategy. However, small scale irrigation and temporary migration are the fifth and sixth preferred climate change adaptation as they have 0.09 and 0.06 probability of to be ranked first respectively. Overall using improved crop and livestock variety is the most highly preferred climate change adaptation strategies in Adola Rede woreda while temporary migration is the least preferred adaptation strategy.

Table 4.6: The predicted probability change of ROLM for adaptation strategies

The table below present the discrete change in the predicted probability. Here we have used changes from 0 to 1 for dummy variables. However, for continuous variables we estimate two predicted probability. The first value in the table below show the change in the predicted probability for a unit change in the independent variables centered on its mean. Whereas, the second result in the table below show the change in the predicted probability for a standard deviation change in the independent variables centered on its mean.

Explanatory variables	Improved crop and livestock	Change planting date	Temporary migration	Agro-forestry	Small-scale irrigation	Soil and water conservation
sex	-.110	.0315	.0374	.0276	.0206	.0680
age	-.0025	.0016	-.0001	.0005	-.0012	.0049
	-.0215	.0141	-.0007	.0039	-.0102	.0425
Education level	-.0075	.0038	.0011	-.0027	.0042	.0010
	-.0232	.0116	.0035	-.0083	.0132	.0032
Active labour force	.0185	-.0026	.0012	-.0143	.0067	.0094
	.0444	-.0062	.0029	-.0345	.0158	.0225
Farm income	.0026	.0022	-.0017	.0018	.0001	.0004
	.0185	.0149	-.0116	.0125	.0007	.0027
Farm size	.0259	.0113	-.0010	.0010	.0109	.0034
	.0285	.0124	-.0011	.0008	.0120	.0038
Distance from home	-.0024	.0007	.0005	.0002	.0003	.0007
to farm	-.0499	.0149	.0102	.0036	.0076	.0135
Soil fertility	.0723	.0315	-.0133	-.0587	-.0144	-.0174
Market distance	-.0008	-.0006	.0003	.0007	.0003	.0001
	-.0276	-.0214	.0116	.0228	.0116	.0029
Livestock size	.0003	.0032	.0006	-.0034	-.0032	.0032
	.0017	.0169	.0029	-.0179	-.0172	.0169
Access to credit	.0154	.0005	-.0378	.0441	.0092	-.0130
Farmers-farmers ex	.0962	.0047	.0188	.0159	-.0168	.0735
Perceived rain	.0328	-.0031	-.0206	-.0092	-.0425	.0425
Perceived rain	-.0524	-.0267	-.0005	.0497	.0037	.0261

The above table indicate that, male-headed households have a probability of 11% lower than female-headed households in ranking improved crop and livestock variety as the most highly preferred strategy. However, in ranking strategies like changing of planting date, temporary migration, agro-forestry, small scale irrigation and soil and water conservation first; male-headed households have a probability of 3.15%, 3.74%, 2.76%, 2.06% and 6.8% higher than female-headed households respectively.

A one year increase in the age of the household head which is centered on its mean could results for 0.49%, 0.16%, and 0.05% increase in the probability of soil and water conservation, changing of planting date, and agro-forestry first respectively. However, a one year increase in the age of the household head which is centered on its mean could results for 0.25%, 0.12%, and 0.01% decrease in the probability of ranking improved crop and livestock variety, small-scale irrigation, and temporary migration first respectively. Similarly, a standard deviation increase in the age of the household head which is centered on its mean could results for 4.25%, 1.41%, and 0.39% increase in the probability of soil and water conservation, changing of planting date, and agro-forestry first respectively whereas it could results for 2.15%, 1.02%, and 0.07% decrease in the probability of ranking improved crop and livestock variety, small-scale irrigation, and temporary migration first respectively. In general, the remaining explanatory variables could also be interpreted similar to the above interpretation.

5. Conclusions and Policy Implications

5.1. Conclusions

The following conclusion is drawn based the analysis of the study. In Adola Rede Woreda, almost all of the farmers were aware off the change in the level of precipitation and temperature during the last fifteen years. However, their perception in the change of elements of climate is not similar. While 30% and 77.6% of the respondents perceived an increment in precipitation and warming respectively the remaining portion of the farm households in Adola Rede had perceived its counterpart. In spite of this disparity in the perceived direction of change in the elements of climate, more than 80% of the households of Adola Rede have already take climate change adaptation measures for reducing the impacts of climate change.

The level impact of climate change is different from one region to another. The findings of this study also strengthen this fact hence within the same Woreda some had observed climate change indicators and were being affected by its impacts while the others not. Some of the indicators of climate change that have been observed in Adola Rede include: unseasoned rainfall, heavy as well as too little rainfall, warming as well as coolness and strong wind. Despite the presence of these problems, most of the farmers of Adola Rede had perceived an increment in their farming productivity during the last fifteen years.

Despite the perception of the presence of climate change, some of the farmers in this Woreda have not taken adaptation measures to climate change due to different impeding factors. The major barriers to climate change adaptation in Adola Rede are lack of knowledge, lack of sufficient land, lack of capital and lack of information are the major barriers respectively. In addition, lack of support from the government as well as not giving emphasis is also among the barriers to climate change adaptation in Adola Rede.

Moreover, results of the logit regression model show that educational level of the household head, farm size owned by the household, number of livestock owned by the household, access to credit, and access to farmers-to-farmers' extension service are among the factors which are positively affect the farmers climate change adaptation. However, the non farm income and fertility of the farm are the determinant for climate change adaptation. These variables negatively affect adaptation to climate change.

Besides, the farmer preferences for climate change adaptation are also identified using the rank ordered logit regression model. The results of ROLM show that improved crop and livestock variety is the most preferred climate adaptation strategy while temporary migration is the least preferred adaptation strategy. Agro-forestry, changing of planting date, soil and water conservation and small scale irrigation are the adaptation strategy used by the farmers in Adola Rede in their order from the second most preferred to the second least preferred respectively. The ROL model also helps us to identify the determinants of farmers' preferences for climate change adaptation strategies. Hence gender of the household head, age of the household head, number of active labour force in the family, farm income, farm size, access to credit, number of livestock the farm household owned, distance from home to farm, soil fertility, perceived rainfall and perceived temperature are found significant in explaining the model.

For instance, gender of the household being male has a positive influence in ranking all strategies first except for improved crop and livestock variety. An increment in age reduces the likelihood for ranking adaptation strategies such as improved crop and livestock variety, temporary migration and soil and water conservation first. On the other hand, number of active labour force positive affect the probability of ranking improved crop and livestock variety, soil and water conservation, small-scale irrigation and temporary migration first. Similarly, the household income from farm and the farm size are positively affecting the likelihood for ranking all strategy first except for temporary migration. The likelihood of ranking crop and livestock variety as well as changing of planting date first are also positively influenced by the soil fertility level of the farm. In addition, the probability of temporary migration is being ranked first is also negatively affected by access to credit, perceived rainfall and temperature. On the other hand, the probability of agro-forestry and small scale irrigation being ranked first is also negatively affected by livestock size and perceived rainfall.

5.2. Recommendation and Policy Implication

As per the findings of this study, the following recommendations were forwarded for reducing the impacts of climate change on agriculture. Although there is an attempt to conserve soil and water through construction of check dam, it is not sufficient in solving this pressing issue in the study area. Therefore, the government and any concern body should give emphasis to address this issue through paying greater attention for conserving soils and water ahead of the land lost its fertile soils. In the study area, rain water harvesting practice is not well-known. Thus, the government should pay attention to make the farmers understand how to harvest and efficiently use the rain water. In addition, the farmers should also focus on maintaining their soil fertility and farm productivity by investing their time and labour in conserving soil and water.

The government and any concerning body should pay due attention for the conservation of forest by means of participatory forest management and taking strong legal measures against illegal timber producers and traders in order to solve the problem of drought and its possible consequences. This is due to the fact that, the farmers in the study area encountered with the problems such as death of livestock, crop failure and food insecurity as a result of drought which in turn resulted from climate variability.

In addition, the problem of food insecurity is also encountered by the farmers of this Woreda especially when there is crop failure due to off-seasonal rainfall. Therefore, parallel to the provision of food aid, in case the need arise, it is highly valuable to strengthen the farmers' adaptive capacity to climate change through providing early maturing crop to farmers in order to cultivate after clearing the failed crop. Besides, the role of appropriate climate forecast is very crucial for pre-informing the farmers about the future weather condition. Therefore, in this case the role of metrological agency is very worthwhile in communicating information about weather condition to the farmer using different mechanisms.

Besides, addressing the climate related problems calls for the government as well as non-governmental organisation working on this issue to first tackle the barriers to climate change adaptation in the study area. These include provision of the necessary capital inputs at affordable price, initiating the farmers to give emphasis for the issue of climate by creating detailed awareness about the causes and consequences of climate change as well as the adaptation methods together with continuous follow up from agricultural extension officers. For instance, provisions of material as well as technical support for the farmers necessary to implement small scale irrigation are highly valuable. Hence, it can transform the farmers from rain fed agriculture to modern agriculture and strengthen their income generating capacity.

In the study area, although there are necessary services like formal extension service, education and credit, the farmers could not easily benefit from such services. For example, access to credit for the farmers is not an easy task. In addition, most of the farmers in the study area did not have access to farmers-to-farmers' extension services. Thus, the government or any concerned body should also make accessing credit, education and extension service for the farmers its centre of attention. The farmers should also develop social capital by creating conducive environment for better social interaction. This is very necessary for farmers to share experience among them and to contribute labour for one another in time the situation call for.

Besides, the policy program which is intended at reducing the climate related problems should also focus on accessing improved inputs such as improved seeds, improved livestock breeds and fertilizer to farmers with reasonable price. Additionally, provision of crop and livestock insurance has very crucial role in supporting the smallholder farmers to recover from risks against climate related problems. Finally, the government should first understand the farmers' preferences for climate change adaptation together with demographic, socio-economic and institutional factors in designing and implementing appropriate policy response to reduce the impacts of climate change and variability in the study area.

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