Evaluation of Farmers' Perceptions of and Adaptation to the Effects of Climate Change in GamoGofa Zone, SNNPR of Ethiopia

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Abstract: ***The primary objective of this study was to identify factors influencing the perceptions of and choice of adaptation measures to climate change and quantify the extent to which these identified factors influence perceptions of and adaptation to climate change in GamoGofa Zone of SNNP Regional State in Ethiopia. The primary data was collected from 482 farmers from thirteen locations (kebeles) sampled out through a multistage purposive and simple random sampling procedure.In addition to descriptive statistics, Heckman two stage sample selection model was employed to examine farmer's perceptions and adaptations of climate change.The descriptive analysis revealed that 93.78 % of farmers in GamoGofa Zone were perceived the change in climate and as a result, 84.51% of these farmers had responded by adapting. With regard to the Heckman two stage sample selection model result, gender, education level, climate information, off farm income, household size, market distance, agro-ecology, and number of relativeswere significantly affecting the likelihood of climate change perception of farmers. Similarly, age, gender, education level, climate information, farm size, and off farm income were significantly affecting the likelihood of farmers' adaptation to climate changes.***

Keywords: Climate change, perceptions, adaptation, Heckman model, GamoGofa Zone

1. Introduction

Recent reports of IPCC (2001; 2007; 2012; and 2014) on climate change shows that global warming is already altering the world's climate. In recent decades, climate change exert wide spread impacts on natural and human systems on all continents and across the oceans (IPCC, 2014). Compared to other sectors of the economy, since agriculture relies directly on natural resources, global climate change poses serious threats and challenges on agriculture sector (Backlund et al., 2008; Keane et al., 2009; Rosegrant, 2008).

Agriculture is the backbone of Ethiopia's economy, accounted for 42.9 percent of GDP in 2012/13 in contrast to 46.5 percent in 2009/10 (Ministry of Finance and Economic Development: MoFED, 2014). The sector generates over 70 percent export values and employs 85 percent of the labour force (UNDP, 2014).

Despite its high contribution to the overall economy, this already weak sector is challenged by many factors of which climate related disasters like drought and floods are the major ones; which could lead to crop failure, food insecurity, famine, loos of property and life, mass migration and negative economic growth (Devereux, 2000; Mintewab et al, 2014). This is considered as the major demanding situation to the implementation of the country's GTP (MoFED, 2010).
Recently, Ethiopia is suffering from its worst drought since the mid-1980s due to El Nińo-Southern Oscillation (ENSO) episodes which led to a famine which claimed the lives of 400,000 people and spawned the famous Live Aid charity concerts. According to the April 2016 UNICEF Fast Facts Report, the main rainy season (kiremt rains) that is vital for producing over 80 per cent of Ethiopia's agricultural yield failed in 2015 and 2016 due to El Nińo, and a powerful El Niño weather event continues to wreak havoc on children's lives and their families' livelihoods. Moreover, the report showed that during the 2011 Horn of Africa crisis 4.5 million people in Ethiopia were in need of food aid compared to 10.2 million this year (i.e. 2016).

In addition to these, more recently Lal Niña leads Ethiopia to experience one of the worst floods in decades. Due to this, according to the April 2016 UNICEF Fast Facts Report, it is expected that 210,600 people will be affected by flooding, of which 105,300 are expected to be displaced. Displacement, due to flooding, drought or conflict, will lead to critical needs for food, shelter and non-food items. Erratic rain fall also the other dominant climate hazard in Ethiopia which caused heavy crop losses and increased flood frequency (ATPS, 2013).

All the above hazards of climate change results in a wide spread poverty in many parts of the country nowadays, and calls for the appropriate responses to climate change, otherwise the climate change is likely to constrain economic development and poverty reduction efforts and exacerbate already pressing issues. Therefore, there is a need to carry out climate change research and studies to better understand the impacts and identify best adaptation options especially in our case study area.

To date, a few researches have been done on climate related issues in Ethiopia; such as, Temesgen et al (2008), Temesgen et al (2011), Yesuf et al (2008), Aschalew (2014), and Elisabeth (2004). All the above studies suggested for the appropriate adaptation practices as the calculated damages are so severe that the survival of the Ethiopian agriculture sector itself will be at stake. However, existing studies are lacking in at least the following three respective.

First, most of the studies that have been done in Ethiopia mainly focus on farmers in Nile Basin as a case study (ATPS, 2013; Di Falco et al, 2011; Temesgen et al, 2008; Yesuf et al, 2008; Temesgen et al, 2011). Their findings are important only 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, adaptation is conceptualized as a site-specific phenomenon since the projected impacts from climate change can differ greatly even over small geographic areas. Thus, planning officials (for GamoGofa Zone) need to understand these local impacts in detail before they decide on the best responses.

Second, Temesgen& Hassan (2009), and Elisabeth (2004) analyzed the impact of climate change but failed to explicitly explain what adaptation methods they employ and what factors determine the choice of farmers' adaptation strategies. They also failed to make a deeper investigation of the socioeconomic, cultural and environmental conditions experienced by the affected peoples. Moreover, due to the descriptiveness of the analysis, the importance of the research is ambiguous for policy formulation.

Finally,Aschalew (2014), applied a Random utility model to analyze the farmers' choice for different adaptation strategies. However, his study misses the two-step nature of adaptation measure; as a result he made a sample selection bias problem during the decision making processes and furthermore the outcome of the model will be biased. All the above issues/research gaps will be addressed in this paper.

Hence the objective of this study is to identify factors influencing the choice of adaptation measures to climate change and quantify the extent to which these identified factors influence perceptions and adaptation to climate change in GamoGofa Zone.

2. Review of Empirical Literatures

According to Nhemachena and Hassan (2007) study in South Africa, Zambia and Zimbabwe, lack of credit and information concerning climate change forecasting; rationing of inputs and lack of seed resources as important constraints; and access to credit and extension and awareness of climate change are some of the important determinants of farm-level adaptation.
A studies on agricultural technology adoption by Gbetibouo (2009) highlighted that household size, farming experience, wealth, access to credit, access to water, tenure rights, off-farm activities, and access to extension are the main factors that enhance adaptive capacity.

Temesgen et al (2008) investigated the determinants of farmers' choice of adaptation methods and perceptions of climate change in the Nile river basin of Ethiopia, the study revealed 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.

Bryan et al (2010) studied the adaptation strategies of farmers in Ethiopia and South Africa, and analyzed the factors influencing farmers' decision on adaptation. The study identified factors influencing farmers' decision to adapt include wealth, and access to extension, credit, and climate information in Ethiopia; and wealth, government farm support, and access to fertile land and credit in South Africa.

Additionally, Urgessa and Amsalu (2014) examine the farmer's perceptions and adaptation to climate change through conservation agriculture. The result revealed that Farmers level of education, household nonfarm income, livestock ownership, extension on crop and livestock, households' credit accessibility, perception of increase in temperature and perception of decrease in precipitation significantly affect the adaptation to climate change. Similarly, farmers' perception of climate change was affected significantly by information on climate, farmer to farmer extension, local agro -ecology, number of relatives in development group and perception of change in duration of season.

The study conducted by Gebre et al (2015) on farmers' climate change adaptation options and their determinants in Tigray region revealed that Educational level, age, and sex of the household head; farm income, access to extension service, access to credit, access to climate information and agro-ecological settings were the most important determinants factors that affect significantly the choices of farmers to climate change adaptations.

Most recently, by the same fashion, Solomon et al (2016) assess perception and adaptation models of climate change by the rural people of Lake Tana Sub-Basin. Their results revealed that age, educational level, wealth status, agricultural extension services, and distance to the nearest health center are found to be significant for determining climate change adaptation. The farmers 'perceptions to climate change found statistically affected by those factors such as: marital status, farm size, climate change information access and the level of income generations. The majority of the respondents argued that the strategies and programs of climate change adaptations need further enforcement to implement it fully up to the level of expectations.

In general, climate change adaptation has gained much attention today. Farmers nationally and internationally perceived the change in the climate and started taking different adaption measures to it even if it is location specific. Adaption to climate change includes all the adjustments in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.

3. Research Methodology

3.1. Sampling Procedure

The study employed the multiple-stage purposive and random sampling techniques to select a sample of 482 respondents from the Woredas (districts). First, Mirab-Abaya and Bonkeweredas are purposefully selected-due to the reason that they are frequently affected by drought, flood and other climate change resulted problems. According to the Food Security Program office; the intensity, frequency and the effects of drought and other climate change hazards in these woredas, and the number of farmers in need of food aid have increased alarmingly for the past decades. Reports indicate that global climate change to be the cause of such dramatic increase in the intensity and frequency of drought and other problems.

Then, 6 kebeles (the smallest administrative unit) form Mirab-Abaya and 7 kebeles from BonkeWoreda were purposefully selected to represent the three most dominant farming agro-ecology zones in the area (i.e. Kola (lowland), Dega (highland) and W/dega (midland) according to the traditional climatic zone classification system). This helped us to see how adaptive strategies depend on local context and circumstances. Finally, a total of 482 farm households are sampled randomly using probability proportional to the sizes of the households of each kebele from which sample households to be drawn. The study adopted these sampling techniques because they ensure a high degree of sample representativeness by providing respondents with equal chances of being chosen as part of the study sample.

Following Cochran (1977), the formula used to calculate sample size is given as:

$$n_0 = \frac{Z^2 Pq}{e^2}$$

$$n = \frac{n_0}{1 + \frac{(n_0 - 1)}{N}}$$

where $\boldsymbol{n_0}$ is the sample size, $\boldsymbol{n}$ is adjusted sample size in the study area,$\boldsymbol{N}$ is the total number of rural households in Gamo Gofa Zone ($\boldsymbol{N = 277698}$) , $\boldsymbol{Z^2}$ is the abscissa of the normal curve that cuts off an area α at the tails (1 − α equals the desired confidence level, which is 95%) ($Z = 1.96$) , $\boldsymbol{e}$ is the desired level of precision ($e = 5\%$), $\boldsymbol{p}$ is the estimated proportion of an attribute that is present in the population ($\boldsymbol{p = 0.5}$), and $\boldsymbol{q}$ is $\boldsymbol{1 - p}$ ($\boldsymbol{q = 0.5}$).

Based on the above formula, 385 sample households are the minimum sample size required for the study. However, the study randomly sampled 482 farm households in order to increase the representativeness of the samples from the two woreda's kebeles.

3.2. The Analytical Framework: The Heckman's Two-StageSample Selection Model

Comparing the survey results and meteorological station's data is the most common approach in developing countries to assess the farmers' perceptions to climate change (for instance, Gbetibouo, 2009; Maponya&Mpandeli, 2013; Gebre et al, 2015). However, the results of this approach do not indicate whether the results are sensitive to other factors.

In agricultural studies, where the decisions to adopt a new technology involves a process requiring more than one step, models with two-step regressions are employed to correct for the selection bias generated during the decision making processes. For instance, Stan & Willian (2003) analyze the relationship between precision farming information sources and precision farming adaptation of technologies using the Heckman's two-step procedure. In their study, the first stage is the analysis of factors affecting the awareness of new agricultural technologies and the second stage is the adaptation of the new agricultural technologies.

The same methodology is employed for adaptation studies. Adaptation to climate change involves a two-stage process: first, perceiving change and, second, deciding whether or not to adapt by taking a particular measure. This leads to a sample selectivity problem, since only those who perceive climate change will adapt, this implies the need of Heckman's sample selectivity model to correct the bias.

For instance, Maddison (2006), Gbetibouo (2009) and Apata (2011) used Heckman's two-step procedure to analyze farmers' adaptation to climate change. They argues that the adaptation to climate change is a two-step process which involves perceiving that climate is changing in the first step and then responding to changes through adaptation in the second step.

In Ethiopia, Chilot (2007) and Kaliba et al (2000) analyze the two step process of agricultural technology adaptation and the intensity of agricultural input use using Heckman's selection model. Similarly, Temesgen et al. (2008) used the Heckman's two-step procedure to analyze farmers' perceptions of climate change in the first step and then farmers' adaptations to climate change in the second step. Thus, this study adopts the Heckman's two step procedure (Heckman 1976) to analyze the perception of and adaptation to climate change by farmers in GamoGofa Zone, Southern Ethiopia.

The Heckman's sample selection probit model for sample selection assumes that an underlying relationship exists, which consists of the latent equation given by:

$$y_j^* = x_j\beta + u_{1j} \quad (1)$$

Where y_j^* is the latent variable (the propensity to adapt to climate change), x is a k-vector of explanatory variables which include different factors hypothesized to affect adaptation, β is the parameter estimate and u_{1j} is an error term.

Therefore, only the binary outcome given by the probit model is observed as

$$y_j^{probit} = (y_j^* > 0) \quad (2)$$

The dependent variable is observed only if j is observed in the selection equation

$$y_j^{select} = (z_j\delta + u_{2j} > 0)$$
$$u_1 \sim N(0,1) \quad (3)$$
$$u_2 \sim N(0,1)$$
$$corr(u_1, u_2) = \rho$$

Where y_j^{select} is whether a farmer has perceived climate change or not, $z$is an$m$vector of explanatory variables which include different factors hypothesized to affect perception, u_2 is an error term.

The first stage of the Heckman's sample selection model is the perceptions of changes in climate and this is the selection model (equation (3)). The second stage, which is the outcome model (equation (1)), is whether the farmer adapts to climate change, depending on the first stage that she/he perceives a change in climate.

Literature revealed that, when$\rho \neq 0$, the use of standard probit/logit model techniques on equation (1) may produce biased results. To address this biased results Heckman two-stage sample selection model are mostly used. Thus, the Heckman two-stage sample selection model provides consistent, asymptotically efficient estimates for all parameters in such models (Van de Ven and Van Praag, 1981). Hence, Heckman two-stage sample selection model used to analyze the perception and adaptation to climate change by farming households in GamoGofa Zone, Southern part of Ethiopia.

3.3. Empirical Models for the Study

In this study, two models are estimated. Those are, Heckman's selection model and the Heckman's outcome model.

The first stage of the Heckman model considers whether the farmer perceived a climate change; this is the ***selection model***. In the Heckman's selection model, the regressand is a binary variable concerned with whether or not a farmer perceived climate change. The explanatory variables for the selection equation include different socio-demographic and environmental factors based on a literature review of factors affecting the awareness of farmers to climate change or risk perceptions. Age, gender and education of the head of the household, information on climate, access to extension services, household size, non-farm incomes, wealth, distance to input/output market, number of relatives in the village and agro-ecological settings are variables influencing the awareness of farmers to climate change. The algebraic representation of the Heckman's selection model was gives as:

$$P_i = (\vartheta X_i) + \varepsilon \quad (4)$$

Where: P_i= the perception by the ith farmer that climate is changing. X_i= the vector of explanatory variables of probability of perceiving climate change by the ith farmer. And, ϑ = the vector of the parameter estimates of the regressors hypothesized to influence the probability of farmer perceiving the climate change.

Consequently, the linear specification of the Heckman's selection model was given as:

$$P_i = \vartheta_0 + \vartheta_1 age + \vartheta_2 gender + \vartheta_3 education + \vartheta_4 Climinform + \vartheta_5 farmincome + \vartheta_6 offarmincome + \vartheta_7 hhsize + \vartheta_8 extenservice + \vartheta_9 agroecology + \vartheta_{10} Wealth + \vartheta_{11} mktdistance + \vartheta_{12} numberelatives + \varepsilon$$

The second stage of the Heckman model considers the regress also a binary variable - whether a farmer has adapted to climate change or not; and it is conditional on the first stage, that is, a perceived change in climate. This second stage is the o***utcome model***. The dependent variable for the outcome equation is whether a farmer has adapted or not to climate change. The key concern of this issue is to discuss the factors influencing the choice of adaptation measures if the farmers have adapted. This means that the dependent variables are the adaptations measures adopted by farmers such as intercropping, mulching, zero tillage, ridges, etc. The independent variables are those natural, socio-economic, institutional and physical factors influencing the choice of these measures. The explanatory variables are chosen based on previous studies, climate change adaptation literatures and data availability. These variables include: age of the head of the household, household size, gender of the head of the household, non-farm income, access to climate information, education of the head of the household, livestock ownership, access to extension services, access to credit, farm size, distance to input and output markets. The algebraic specification of the Heckman's outcome model was given as:

$$A_i = (\vartheta X_i) + \varepsilon \quad (5)$$

Where: A_i= the adaptation by the ith farmer that climate is changing. X_i= the vector of explanatory variables of probability of adapting to climate change by the ith farmer. And ϑ = the vector of the parameter estimates of the regressors hypothesized to influence the probability of farmer is adaptation to climate change.

Thus, the linear specification of the Heckman's outcome model is given as

$$A_i = \vartheta_0 + \vartheta_1 age + \vartheta_2 gender + \vartheta_3 education + \vartheta_4 Climinform + \vartheta_5 farmsize + \vartheta_6 hhsize + \vartheta_7 offarmincome + \vartheta_8 extenservice + \vartheta_9 Credit + \vartheta_{10} Livestkownership + \vartheta_{11} mktdistance + \varepsilon$$

4. Empirical Results and Discussions

4.1. Descriptive Analysis

4.1.1. Summary Statistics & Mean Difference Test in Perception Equation

In order to understand farmers' perception towards climate change in GamoGofa Zone, 482 sampled farmers were asked to indicate what they had noted regarding long term changes in climate conditions through different perception indicators. Consequently, from the total 482 sampled respondents, 452 farmers in the study area perceived the change in climate while the remaining 30 did not perceived the change in climate (Appendix A). This implies that majority of farmers in the study area are well aware of climate change. Regarding gender distribution, the number of male farmers who perceived climate change are higher than females which were 386. Moreover, perception to climate change was indeed influenced by the agro-ecological zone; from the total number of farmers who did not perceive the climate change 13 of them found in low land part of the zone, and from all farmer respondents who perceived climate change 257 of them found in low land part of the zone (Appendix B).

On average farmers who perceived climate change have more than 6 members of family under one roof while it was around 6 for those who did not perceive the climate change. The t-test values indicated that the mean difference in household size between those who did not perceive the change in climate and those who perceived the climate change was statistically significant at 10 percent probability level (Table 1).The maximum number of relatives of respondent household heads who did not perceive climate change was 50 while it was 100 for those who perceived the change (Appendix C). However, the t-test values showed that there was no significant mean difference between those who did not perceive the change in climate and those who perceived the climate change in number of relatives (Table 1).

The maximum amount of wealth of farm households who did not perceive climate change was 69,050 Birr while it was 280,000Birr for those who perceived the change (Appendix C). Nevertheless, the t-test values showed that there was no significant mean difference between this two groups of farmers (Table 1).The mean of off-farm income during last production period (2018/19) for farmers who did not perceive the climate change and who perceived the change was 675.667 Birr and 3,602.699 Birr respectively. The t-test values indicated that the mean difference in off-farm income of farm households between those who did not perceive the change in climate and those who perceived the change was significant at 1 percent probability level (Table1).

The study further established that on average most farmers who perceived climate change have a good level of education than farmers who didn't perceive the climate change. As shown in table 1 below, the average years of education for farmers who perceived climate change was around 4 years while it was less than 1 year for those who did not perceive the climate change. Indeed, education is expected to increase one's ability to receive, decode, and understand information relevant to make innovative decisions. The t-test values showed that the mean difference in years of education of farm households between those who did not perceive the change in climate and those who perceived the climate change was significant at 1 percent probability level (Table 1).

On the relationship between farmers' perception to climate change and the distance to the nearest input/output market, the study established that the mean distance from the nearest market for those who did not perceive the change in climate was 142.33 minutes while it was around 83 minutes for those households who perceived the change in climate. This showed that majority of farmers who perceived the climate change lived close to the nearest input/output market, compared to those farmers didn't perceive the change. The t-test values showed that the mean difference in distance from the nearest market between those who did not perceive the climate change and those who perceived the climate change was significant at 1 percent probability level. The standard deviation of the respondent households distance from the market was 33.31 for those who did not perceive the climate change and 49.88 for those who perceived the climate change. This shows that the market distance of respondents who did perceive the change in climate deviates larger from its mean than those who didn't perceive the climate change (Table 1).

Table 1: Summary statistics of continuous variables and their mean difference test used in perception equation for the Heckman two stage selection model (n=482)

List of Variables	Farmers who did not perceive climate change		Farmers who perceived the climate change		t-value
	Mean	St. dev	Mean	St. dev	
Age	36.13333	7.142555	42.3031	10.63061	-3.1307***
Education	0.5333333	0.7760792	3.608407	3.15304	-5.3262***
Wealth	16913.33	17648.31	19269.75	19735.72	-0.6372
Off farm income	675.6667	1741.592	3602.699	5925.101	-2.6957***
Household size	5.7	1.985291	6.338496	2.021618	-1.6770*
Market distance	142.3333	33.31494	83.00442	49.88568	6.4164***
Number of relatives	25.4	10.12542	24.35841	13.62468	0.4111

***, ** and * significant at 1%, 5% and 10% respectively
Source: Own Survey, 2019

With regard to the age of the household heads, a cross tabulation between the age of the household head and the farmers' perceptions of climate change revealed that majority of farmers who perceived changes in climate were in the age group between 30 and 60 years (85.8%), compared to farmers below the age of 30 years (6.9%) or above the age of 60 years (7.3%). Moreover, as shown in table 1 below, the study found out that the average years of age for farmers who perceived climate change was around 42.30 years while it was 36.13 years for those who did not perceive the climate change. The t-test values showed that the mean difference between those who did not perceive the climate change and those who perceived the climate change was significant at 1 percent probability level in household heads years of age.

It is believed that gender difference of the farm household heads made farmers to have different probability of perception to climate changes in the surrounding. The $\chi 2$ statistic (25.2139) and its small significance level ($p < 0.001$) indicates existence of relationship between a household's perception of climate change and the gender of the household heads (Table 2).

One way through which farmers perceive the change in climate is having information on climate change. Variability in accessibility of information on climate change between those who did not perceived the change in climate and those who did wasn't the same. The χ2 statistic (36.9357) and its small significance level ($p< 0.001$) indicates existence of relationship between a household's perception of climate change and their access of information on climate change (Table 2).

Agriculture extension service enables farmers to share experience and information between them in perceiving climate change problems occurring in their area. The χ2 test (29.6825) shows significant difference between households who received extension services to those who did not get the extension services (Table 2).

Table 2: Summary statistics of dummy and categorical variables used in perception equation for the Heckman two stage selection model (n=482)

List of Variables	Category	Farmers who did not perceive climate change	Farmers who perceived the climate change	Pearson X^2 - Value
Gender	Female	15	66	25.2139***
	Male	15	386	
Climate Information	Have access	9	357	36.9357***
	Didn't have access	21	95	
Extension Service	Have access	25	446	29.6825***
	Didn't have access	5	6	
Agroecology	Low Land	13	257	2.0900
	High Land	9	104	
	Mid Land	8	91	

***, ** and * significant at 1%, 5% and 10% respectively
Source: Own Survey, 2019

4.1.2. Summary Statistics & Mean Difference Test in Adaptation Equation

Adaptation to climate change is a twostep process which requires that farmers perceive climate change in the first step and respond to changes in the second step through adaptation strategies. This implied that perceiving climate change is prerequisite for adaptation of climate change. It was revealed in the study that out of total of 452 farm household respondents who perceived the change in climate, 382 respondents were adapted the climate change through taking adaptation measures while 70 of them did not adapt the change (Appendix D). However, from the total farm household respondents who adapted climate change 45 were females; likewise 21 were females from the total number of farm household respondents who did not adapt the climate change (Appendix E).

Analysis of the farmers' characteristics in the study revealed that most (85.86%) farmers who adapted to changes in climate were in the age group between 30 and 60 years. Only a handful, 5.50% and 8.64%, were in the age group below 30 years and above 60 years, respectively. In addition, the maximum years of age for household head those who adapted the change in climate was 80 and the minimum years of age was 22; likewise the maximum years of age for household head those who did not adapt the climate change was 56 and the minimum years of age was 25 (Appendix F). The average years of age for those who did not adapt to climate change was around 39 and the age of the household head those who did not adapt the change deviates from its mean by 7.981 years. However, the average years of age for those who adapted climate change was around 43 and the age of the household head those who adapted the change deviates from its mean by 10.92 years. Moreover, the t-test values indicated that the difference in family size of households between those who did not adapt the change in climate and those who adapted the climate change was significant at 1 percent probability level (Table 3).

It was revealed in the study that the maximum off-farm income for household head those who did not adapt and who adapted the climate change was 18,020 Birr and 50,000 Birr, respectively (Appendix F). The average off farm income of those who did not adapt to climate change was around 1809.99 Birr and the off-farm income of the household head those who did not adapt the change deviates from its mean by 3692.5 Birr. However, the mean of off-farm income for farmers who adapted the change in climate was 3931.207 Birr, and the standard deviation of off-farm income of those farmers who adapt to climate change was 6195.883 Birr. This shows that the off-farm income of respondents who did adapt the climate change deviates larger from its mean than those who did not adapted the change in climate. The t-test values indicated that the difference in off-farm income of households between those who did not adapt the change in climate and those who adapted the climate change was significant at 1 percent probability level (Table 3).

With regard to distance that a farmer resides from the nearest market center, the study established that the maximum distance from the market for household head those who adapted climate change was 180 minutes and the minimum distance from the market was 1 minutes; likewise the maximum distance from the market for household head those who did not adapt the climate change was 180 minutes and the minimum distance from the market was 15 minutes (Appendix F). The mean distance from the market for those who did not adapt the climate change was 105 minutes while it was 78.97 minutes for those households who adapted the climate change. The standard deviation of the respondent households distance from market for farmers who did not adapt the climate change was 37.15 minutes and 50.898 minutes for farmers who adapted the climate change. The t-test values showed that the mean difference in distance from the nearest market between those who did not adapt the climate change and those who adapted the climate change was significant at 1 percent probability level (Table 3).

Table 3: Summary statistics of continuous variables and their mean difference test used in adaptation equation for the Heckman two stage selection model (n=482)

List of Variables	Farmers who did not adapt climate change		Farmers who adapted the climate change		t-value
	Mean	St. dev	Mean	St. dev	
Age	38.54286	7.981293	42.99215	10.91617	-3.2532***
Education	3.042857	3.290019	3.712042	3.120639	-1.6354
Farm Size	1.3055	0.8580172	1.252709	0.8411969	0.4812
Off farm income	1809.986	3692.499	3931.207	6195.883	-2.7740***
Household size	6.185714	1.835976	6.366492	2.05482	-0.6874
Market distance	105	37.1542	78.97382	50.89817	4.0819***

***, ** and * significant at 1%, 5% and 10% respectively
Source: Own Survey, 2019

Access to climate change information and agricultural extension services enhances the efficiency of making adoption decisions. Agriculture extension service on crop and livestock is one of the major ways farmers sharing their experiences and information to each other in adapting environmental problems. Out of 382 household heads those adapted to climate change 379 of them were those who get agriculture extension service on crop and livestock. From the total of 70 farmers who did not adapt climate change 67 were those who received agriculture extension service on crop and livestock and 3 of them were those who did not receive the extension service. The $\chi2$ test (5.5340) and its significance level (P=0.019) shows the existence of significant difference between households who received agriculture extension to those who did not get the extension in adaptation to climate change (Table 4).

As for access to climate information, the study established that out of 382 household heads those adapted to the climate change 325 of them were those who get climate change information through radio, television, agriculture cooperatives, and etc. The $\chi2$ statistic (55.2220) and its small significance level (p< 0.001) indicates existence of relationship between a household's adaptation to climate change and their access of information on climate change (Table 4).

In relation to gender, the study found out that farmers those who adapted the change in climate were 382 out of which 45 were female households while those who did not adapt were 70 out of which 21 were female headed households; the rest were male. The $\chi2$ statistic (15.7493) and its small significance level (p < 0.001) indicates existence of relationship between a household's adaption to climate change and the gender of the household heads. Moreover, it shows there is significant difference between female headed households to those who were male headed households in adaptation to climate change (Table 4).

Table 4: Summary statistics of dummy and categorical variables used in adaptation equation for the Heckman two stage selection model (n=482)

List of Variables	Category	Farmers who did not adapt climate change	Farmers who adapted the climate change	Pearson X^2 -Value
Gender	Female	21	45	15.7493***
	Male	49	337	
Climate Information	Have access	32	325	55.2220***
	Didn't have access	38	57	
Extension Service	Have access	67	379	5.5340**
	Didn't have access	3	3	
Credit	Have access	41	259	2.2579
	Didn't have access	29	123	
Livestock Ownership	Owner	63	351	0.2729
	Not owner	7	31	

***, ** and * significant at 1%, 5% and 10% respectively
Source: Own Survey, 2019

4.2. Results of Heckman Two - Stage Sample Selection Model

In order to increase farmer's agriculture production and productivity, farmers should be able to adapt different strategies to reduce the negative impact of climate change. However, decisions to adopt a new technology involves a process requiring more than one step, in the first step farmers should perceive climate change and respond to changes in the second step through adaptation. This leads to a sample selection problem, since only those who perceive climate change will adapt. Therefore, in this study to correct the selection bias problem generated during the decision making processes Heckman two stage sample selection model is employed. Moreover, in this study, two models of Heckman two stage selection model were estimated. The first stage of the Heckman model considers whether the farmer perceived a climate change; this is the selection model. In the second stage, the Heckman's model deals with whether the farmer adapted to a climate change; this is the outcome model.

Different socio-economic and environmental factors affect farmers' abilities to perceive and adapt to climate change. Therefore, in this study, the Heckman two stage selection model analyzed what determines the likelihood of perceiving any change in the climate as well as the likelihood of farmers' adapting to these changes.

As shown in table 5 below, among the explanatory variables used in the selection model, 8 variables were significantly affecting the likelihood of climate change perception of farmers: gender, education level, climate information, off farm income, household size, market distance, agro-ecology, and number of relatives. While the results from the outcome model indicated that age, gender, education level, climate information, farm size, and off farm income were significantly affecting the likelihood of farmers' adaptation to climate changes. The variables having a significant effect on farmers' perception and adaptation to climate change in the study area are discussed below.

As expected, the study established that in GamoGofa Zone the likelihood of a male headed household to perceive climate change was higher than that of a female headed household. The likelihood of perceiving climate change increases by 3.56 % as the household becomes male headed as compared to the female headed households. This result is consistent with the result of Asfaw and Admassie (2004), Tenge and Hella (2004), and Ndambiri et.al (2014) who noted that male headed households were more likely to perceive changes in the surrounding than female headed households. The possible reason is that male headed households have a higher probability of acquiring information than female headed households.

In this study, higher level of education is hypothesized to increase the probability of perceiving climate change. Indeed, one year increase in level of education of the household head raises the probability of perceiving climate change by 3.94 percent. It implies that as the educational level of the household head increases, the level of perception about climate change increases. A similar finding is found in Norris and Batie (1987) who assert that the probability of more educated farmers to perceive climate change was higher than that of less educated farmers. This is because higher education was likely to expose farmers to more information on climate change.

Noticeably, the study established that access to information on climate change from either extension agents, radio & television or any other organizations-like meteorology agencies - is likely to create awareness of climate change. Access to information on climate change increases the probability of perceiving the occurrence of change in climate by 10.93 percent. This implied that access to climate change information is enhanced the efficiency of farmers to perceive climate changes. This finding is similar to those unveiled by Adesina and Forson (1995), Maddison (2006), Nhemachena and Hassan (2007), Gbetibouo (2009), and Urgessa et.al (2014) who noted that farmers with access to information were more likely to perceive climate change than farmers without access to information.

As expected, the study established that off farm income was crucial factor in influencing the likelihood of farmers to perceive climate change. One birr increase in household nonfarm income leads to the increment of the probability of perception to climate change by 0.001 percent. Thus, higher income positively and significantly affects farmers' perception to climate change. Semenza et al. (2008) also agrees with these results who showed that individuals with higher incomes are more likely to know that climate is changing than individuals with lower incomes.

With regard to household size, the study showed an inverse relationship between farmers' perception to climate change and their family size. One member increase in the household size leads to the falls in the probability of perceiving climate change by 0.63 percent. Ndambiri et.al (2014) made a similar observation that larger households had less chances of perceiving climate change than smaller households Therefore, larger households are likely to have a lower probability to perceive climate changes since households with many family members are likely to divert labor force to off-farm activities in an attempt to earn more income to ease the consumption pressure imposed by a large family size.

With regard to the distance to the nearest input/output market, as expected, the results indicate that farmers residing further away from the nearest input/output market were less likely to perceive climate change than farmers residing closer to the market. One minute increase in the distance of the farmers from the nearest market leads to the fall in the probability of perceiving climate change by 0.16 percent; this is because the market serves as a means of exchanging information with other farmers about various issues including climate change and its adaptation options. These results are in line with an observation made by Madison (2006) and Ndambiri et.al (2014) who noted that as the farmer is nearer (closer) to a market, the higher will be the chance to perceive the climate change.

The agro-ecological setting of farmers influences the perception of farmers to climate change. As expected, different farmers living in different agro-ecological settings perceive the occurrence of climate change differently. It was revealed that farmers living in Highland (Dega) and Midland (Woyinadeag) agro-ecological zones were more likely to perceive changes in climate than farmers living lowland (Kola) agro-ecological zones, and their probability of perceiving the occurrence of climate change increases by 3.77 percent and 2.83 percent respectively. Maddison (2006), Nhemachena and Hassan (2007), and Ndambiri et.al (2014) made the same observation that local agro-ecological conditions had a higher likelihood of influencing a farmer to perceive climate change and hence his decision to adapt or not.

Social capital is represented by the number of relatives of a household in the local area, which plays a significant role in information exchange and increases the awareness of farmers on climate change. As expected, households' number of relatives in development group was positively related with perception of climate change. One increase in number of relative of household head raises the probability of perceiving climate change by 0.039 percent. Temesgen et al. (2011), and Isham, (2002) who have separately noted that higher social capital is associated with higher probability of perceiving the climate change.

Table 5: Result of Heckman Two Stage Sample Selection Model

List of Variables	Farmers' Perception to Climate Change (Selection Equation)		Farmers' Adaptation to Climate Change (Outcome Equation)	
	Marginal Effect		Marginal Effect	
	dy/dx	P-Value	dy/dx	P-Value
Age	0.0001894	0.650	0.0053348	0.001***
Gender	0.0356305	0.002***	0.109846	0.014**
Education	0.0393646	0.000***	0.0092524	0.085*
Climate Information	0.1092613	0.000***	0.2745786	0.000***
Farm size			-0.0336673	0.088*
Off farm income	0.0000118	0.000***	0.0131125	0.049**
Household Size	-0.0062885	0.008***	0.004052	0.627
Extension Service	0.0594964	0.126	0.0855239	0.518
Credit			0.0343132	0.299
Livestock ownership			-0.0170791	0.694
Market distance	-0.0009036	0.000***	-0.0003382	0.311
Wealth	0.0021247	0.512		
Agroecology				
Highland	0.0283394	0.000***		
Midland	0.0376742	0.000***		
Number of relatives	0.0003903	0.001***		

***, ** and * significant at 1%, 5% and 10% respectively
Source: Own Survey, 2019

The results from the outcome model indicated that the probability to adapt was found to be higher for the older farmers compared to the younger farmers. One year increase in households' age leads to the increment of the probability of adaptation to climate change by 0.53 percent; this may be because older farmers have more experience in farming and are better able to assess the attributes of modern technology than younger farmers. And therefore, better able to assess the features of a new farming technology than the younger farmers. Okeye (1998), Maddison (2006), Bayard et al. (2007), Gbetibouo (2009), and Ndambiri et.al (2014) attest to these findings when, in their respective studies, they observed a positive relationship between age of the household head and the adoption of improved agricultural technologies.

As for the gender of the household head, the study found out that the probability to adapt of the male headed households was higher than that of the female headed households. The likelihood of taking adaptation practice increases by 10.98 % as the household becomes male headed as compared to the female headed households. The possible reason is that women have lesser access to critical resources (land, cash, and labor), which often undermines their ability to carry out labor-intensive agricultural innovations (De Groote and Coulibaly, 1998). A similar finding is found in Temesgen et al. (2008) and Solomon et al (2016) who assert that male-headed households adapt more readily to climate change.

Higher level of education increases the probability of adopting new technologies (Daberkow and McBride 2003; Adesina and Forson 1995). Indeed, the study established that more educated farmers were more likely to adapt to climate change than farmers with not as much education. A unit increase in number of years of schooling would result in a 0.93 percent increase in the probability of adaptation to climate change; this is because higher education was likely to expose farmers to more information on climate change, and to enhance information access to the farmer for improved technology up take. This result is in line with Wozniak (1984), Temesgen et al. (2008) and Ndambiri et.al (2014) who reported that education increases one's ability to receive, decode, and understand information relevant to making innovative decisions.

Access to climate change information is an important precondition for farmers to take up adaptation measures (Madison, 2006). The study noted that farmers' access to information on climate change through extension agents or other sources is likely to enhance their probability of adaptation to climate change by 27.45 percent, and adaptation of new technologies and take-up adaptation techniques. This observation is similar to that by Solomon et al (2016), Ndambiri et.al (2014), Gbetibouo (2009), and Maddison (2006) who noted that farmers' access to information on climate change has a significant and positive impact on the likelihood of climate change adaptation.

In addition, the study revealed that large farm size reduce farmers' likelihood of taking adaptation practice. One hectare increase in size of farm land results in a 3.37 percent decrease in the probability of adaptation to climate change. The possible reason could be due to the fact that adaptation is plot specific. This means that it is not the size of the farm, but the specific characteristics of the farm that dictate the need for a specific method of adapting to climate change. Even Nyangena (2007), Temesgen et al (2008), and Okonya et.al (2013) made a similar observation, large size of land owned negatively and significantly affected adaptation to climate change.

As to the off farm income, the study found out that farmers with high off farm incomes were more likely to adapt climate change compared to farmers with lower off farm incomes. One birr increase in household off farm income leads to the increment of the probability of adaptation to climate change by 1.31 percent; this because adaptation requires sufficient financial wellbeing to be undertaken. Temesgen et al. (2008), and Okonya, et al. (2013), Urgessa et.al (2014) and Ndambiri et.al (2014) made the same observation that off farm income increase the adaptive capacity of the rural farmers.

5. Conclusions and Policy Implications

The very objective of this study was to evaluate farmers' perceptions of and adaptation to climate change in Ethiopia with special reference to GamoGofa Zone. Hence, the Heckman two stage selection model was applied to identify the major factors influencing the perceptions of and choice of adaptation measures to climate change. Selection model result revealed that the gender of the household head, education level, access to information on climate change, off farm income, household size, distance to the nearest market, local agro-ecology setting, and number of relatives in the village were crucial factors in influencing the likelihood of farmers to perceive climate change. Similarly, the outcome model of Heckman selection model established that factors such as the age of the household head, gender of the household head, education level, access to information on climate change, farm size, and off farm income were also found statistically significant determinants of farmers' adaptation to climate change in GamoGofa Zone. Any policy aimed at enhancing the perception & adaptive capacity of the farmers in the study area should thus consider making use the factors mentioned above.

Even though the current government efforts gradually increase rural adaptive capacity, more needs to be done in terms of effective adaptation to climate change to protect the already weak agricultural sector. Therefore, based on the results of this research work, future policies in study area should focus on:

- Designing and implementing a well-organized mechanism of awareness creation on climate change though different sources, such as mass media and extension services; since access to climate change information is an important precondition for farmers to take up adaptation measures (Madison, 2006).
- It was also discovered in the study that farming in the study area is mostly carried out by men as women are carrying out housing activities. This has important policy implication in that women would therefore need to be empowered through women groups and associations since this can have significant positive impacts for increasing the uptake of adaptation measures by the farmers. The policy framework can also consider promoting women in terms of access to education, assets, and other critical services such as credit, farming technology and inputs supply.
- Since farmers in the study are over dependent on rain-fed agriculture and the rain has becoming more erratic and with delayed onsets of rainfall., research based and farmer friendly technology intervention in irrigation, water harvesting, and moisture management practices for drought mitigation are very crucial policy interventions.
- Encouraging informal social networks and importing adaptive technologies from other part of the country or from other countries with similar socioeconomic and environmental settings enhance the adaptive capacity of farmers in the study area.
- Some of the above factors identified as a determinant of farmers' perception of and adaptation to climate change in the GamoGofa Zone of Ethiopia are directly related to the development of institutions and infrastructure. This is the focus of the current Ethiopian government policy of poverty reduction and accelerated development through investment on social and physical infrastructures both in urban and rural areas (MoFED, 2007). Therefore, in order to enhance the adaptive capacity of farmers in the study area the federal/regional/zonal government should continue and expand the investment on education to enhance human capacity, infrastructure such as roads and telecommunications, and institutions such as credit facilities in the study area.

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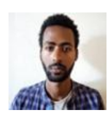

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Appendix A

Farmers' perception to climate change	Freq.	Percent	Cum.
Farmer who did not perceive climate cha	30	6.22	6.22
Farmer who perceived climate change	452	93.78	100.00
Total	482	100.00	

Appendix B

Farmers' perception to climate change and gender of the household head	agro-ecological setting Low Land	Highland	Mid land
Farmer who did not perceive climate chan			
female	4	6	5
male	9	3	3
Farmer who perceived climate change			
female	37	15	14
male	220	89	77

Appendix C

-> perception = Farmer who did not perceive climate change

Variable	Obs	Mean	Std. Dev.	Min	Max
age	30	36.13333	7.142555	24	52
education	30	.5333333	.7760792	0	2
wealth	30	16913.33	17648.31	0	69050
offarmincome	30	675.6667	1741.592	0	8000
hhsize	30	5.7	1.985291	3	10
mktdistance	30	142.3333	33.31494	60	225
numberelat~s	30	25.4	10.12542	10	50

-> perception = Farmer who perceived climate change

Variable	Obs	Mean	Std. Dev.	Min	Max
age	452	42.3031	10.63061	22	80
education	452	3.608407	3.15304	0	15
wealth	452	19269.75	19735.72	0	280000
offarmincome	452	3602.699	5925.101	0	50000
hhsize	452	6.338496	2.021618	1	11
mktdistance	452	83.00442	49.88568	1	180
numberelat~s	452	24.35841	13.62468	4	100

Appendix D

Farmers' adaptation to climate change	Freq.	Percent	Cum.
Farmer who did not adapt climate change	70	15.49	15.49
Farmer who adapted climate change	382	84.51	100.00
Total	452	100.00	

Appendix E

Farmers' adaptation to climate change and gender of the household head	access to credit doesn't have acess t	 have access to credi
Farmer who did not adapt climate change		
female	11	10
male	18	31
Farmer who adapted climate change		
female	17	28
male	106	231

Appendix F

-> adaptation = Farmer who did not adapt climate change

Variable	Obs	Mean	Std. Dev.	Min	Max
age	70	38.54286	7.981293	25	56
education	70	3.042857	3.290019	0	15
farmsize	70	1.3055	.8580172	.06	4
offarmincome	70	1809.986	3692.499	0	18020
hhsize	70	6.185714	1.835976	1	10
mktdistance	70	105	37.1542	15	180

-> adaptation = Farmer who adapted climate change

Variable	Obs	Mean	Std. Dev.	Min	Max
age	382	42.99215	10.91617	22	80
education	382	3.712042	3.120639	0	13
farmsize	382	1.252709	.8411969	.1	5
offarmincome	382	3931.207	6195.883	0	50000
hhsize	382	6.366492	2.05482	2	11
mktdistance	382	78.97382	50.89817	1	180