

# Smallholder Farmers' Perception and Adaptation to Climate Change in Kurmuk District, Ethiopia

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## Abstract

Ethiopia is among the countries experiencing frequent drought and highly vulnerable to climate change associated impacts. Adaptation to climate change impacts are key element for sustainable development of economy. The objective of the study was analysis determinates of smallholder farmer's climate change perception and adaptation options in Kurmuk district. For the study both primary and secondary data sources were employed. The primary data collected from 160 randomly selected sample households. The binary logit and multinomial logit model were employed to identify the factor that determines smallholder farmers' climate change perception and adaptation strategies respectively. Results revealed that sex, extension service, credit access, climate information and distance from market are significantly affects smallholder farmers' perception to climate change in kurmuk district, While, sex, education, cultivated land, access to credit services, climate information, access to market, extension service, distance from farm, off-farm income and on-farm income are found statistically significant affected adaptation options of smallholder farmers. Therefore, strengthening extension services, access credit services, disseminating climate and market information, diversification of farmer's income are among the recommendable mechanisms to advance their perception and adaptation to climate change.

**Keywords:** climate change, perception, adaptation, multinomial logit

## 1. Introduction

Climate change is the current most serious challenging and cross cutting issue over the world which will be able to retard the acceleration of sustainable development goal. The climate variability and extremes is a key driver behind the recent rise in global hunger and one of the leading causes of severe food crises (Molotoks et al., 2018). climate change affecting agriculture and food security and challenge of ending hunger and malnutrition (El Bilali et al., 2020). Low income producers and consumers of food in Africa are more vulnerable to climate change, owing to their comparatively limited ability to invest in more adapted institutions and technologies under increasing climatic risks (Zougmor é et al., 2021).

Ethiopian agriculture system is climate-sensitive and due low adaptive capacity of the subsistence farmers (Asfaw et al. 2021). Climate change impact adaption is key element for sustainable and transformational development of all sectors of economy and in particular agriculture sector. Ethiopia is among the countries experiencing frequent drought and highly vulnerable to climate change associated impacts Gebreegziabher *et al.* (2012). The projection of the mean annual temperature will increase in the range 0.9 -1.1 °c by 2030, 1.7-2.1 °c by 2050 & 2.7 -3.4 °c by 2080 as compared to the normal 1961 -1990. The cause for climate variability and climate change due to the country is dependence on rain-fed agriculture under-development of water resources, low health service coverage, a high population growth rate, low economic development, inadequate road infrastructure in drought prone areas, weak institutional structures, and lack of awareness and relatively low adaptive capacity to deal with these expected changes (Bigger and Webber, 2021).

Benishangul Gumuz region is among the developing regions of Ethiopia which is highly depending on natural resource which contribute for drivers of climate change. According to the regional Food Security Disaster Risk Prevention and Preparedness office annual report (2016), the occurrence of Elino at Kurmuk, Sherkole , Guba and Menge districts. In

the Kurmuk district out of the 16 *kebeles* in district in 12 *kebeles*, were affected and 1,135.25 hectare of land cultivated crops damaged and about 16,130 populations were relief assisted. The recover and cope up strategies of smallholders farmers from climate change impacts is important understand the effort of smallholder farmer’s to reduce these problems and improve effort to strength smallholder farmers’ adaptation to climate change to enhance the resilience of agricultural sectors. Therefore, study aim was to identify smallholder farmers’ adaptation strategies to climate change and variability’s in Kurmuk district.

**2. Empirical Review and Model Specification**

According to the United Nations’ Intergovernmental Panel on Climate Change (IPCC) (1994) responses to climate change can be grouped into two categories: mitigation and adaptation. Mitigation embraces responses that deal with the cause of climate change rather than the impact climate change has on a given area (Carter et al., 1996). Responses classified as adaptations deal with the impact of climate change rather than the cause. One of the main objectives of this study was to identify smallholder farmers’ adaptation strategies to climate change and variability’s. Previous studies in Africa have used various empirical methods to analyze the perception of climate change variability, determinants of adaptations to climate change and choice of adaptation strategies. Depending on the assumed distribution that the random term follows several qualitative choices, models such as linear probability, logit/probit, model could be used. For instance, a probit model (Bryan et al., 2009) Multinomial logit model (Belay et al.2017, Atinkut and Mebrat, 2016, Deressa et al.,2009, Aemro et al.,2012, Zizinga et.al., 2017 and Yenealem et al., 2013 etc ...),multivariate probit(Arun and Yeo, 2019, Tesfaye and Seifu,2016, Sani et.al 2016, Feleke et.al.,2016, Ojo, and Baiyegunhi,2018 etc...), ordered probit (Ndambiri et al., 2012),Heckman model(Tesso et al.,2012, Asayehegn et.al.,2017 Ndambiri et al.(2013).

Some recent empirical studies of technology adoption and climate adaptation decisions assume that farmers consider a set possible practices and choose the practice that maximizes expected utility (Kassie et al., 2009).The theoretical framework draws on adaption options based on the random utility model as specified by (Green, 2003). The selection of whether or not to use any adaptation option could fall under the general framework of its value and production improvement capacity. Assume a rational farmer who pursues to improve agricultural productions over a specific time and must choose among a set of ‘j’ adaptation options. Hence, the farmer ‘i’ decides to use ‘j’ adaptation options if the perceived benefit from option ‘j’ is greater than the utility from other options k stated as:

$$U_{ij} (1) (\beta' jXi + \epsilon_j) > U_{ik} (\beta' kXi + \epsilon_k), k \neq j, \tag{1}$$

Where  $U_{ij}$  and  $U_{ik}$  are the perceived value by farmer i of adaptation options j andk, respectively;  $Xi$  is a vector of explanatory variables that influence the choice of the adaptation option:  $\beta_j$  and  $\beta_k$  are parameters to be estimated and  $\epsilon_j$  and  $\epsilon_k$  are the error terms. Under the revealed preference assumptions that the farmer practices an adaptation option that generates net benefits and doesn’t practice an adaptation option otherwise, we can relate the observable climate change adaption choice of practices to the unobservable continuous net gain variable as  $Yij = 1$  if  $Uij > 0$  and  $Yij = 0$  if  $Uij \leq 0$

$$\begin{aligned} P\left(\frac{Y-1}{X}\right) &= P\left(\frac{U_{ij} > U_{ik}}{X}\right) \\ &= P\left(\beta' jXi + \epsilon_j - \beta' kXi - \epsilon_k > 0/X\right) \\ &= P\left(\beta' j - \beta' k Xi + \epsilon_j - \epsilon_k > 0/X\right) \\ &= P\left(\beta * Xi + \epsilon * > \frac{0}{X}\right) = F(\beta * Xi), \end{aligned} \tag{2}$$

Where  $\epsilon^*$  = a random disturbance term,  $\beta^*$  = a vector of unknown parameters that can be interpreted as the net influence of the vector of explanatory variables influencing adaptation, and  $F(\beta * Xi)$  = the cumulative distribution of  $\epsilon^*$  evaluated at  $\beta * Xi$ . In this study, we assumed that several adaptation choices and the appropriate economic model would be either a multinomial logit/ probit (MNL/p) regression model. Both models estimate the effect of explanatory variables on a dependent variable involving multiple choices with unordered response categories (Omer, 2019). The MNL specification was adapted to model climate change adaptation behavior of farmers involving in Kurmuk district

dependent variables with multiple choices. Thus, the probability that household ‘i’ with characteristics ‘X’ choose adaptation option ‘j’ was specified as:

$$P_{ij} = \text{prob}(Y = 1) = \frac{e^{\beta_j X_i}}{1 + \sum_{j=1}^J e^{\beta_j X_i}} \quad (3)$$

Where  $\beta$  is a vector of parameters that satisfy  $\ln(P_{ij}/P_{ik}) = X_i'(\beta_j - \beta_k)$ . Undesirable and consistent parameter estimates of the MNL model require the assumption of independences of irrelevant alternatives (IIA) to hold. Differentiating the above equation with respect to each explanatory variable provides marginal effects of the explanatory variables given as:

$$\frac{\partial P_{ij}}{\partial X_k} = p_i (B_{ij} - \sum_{j=1}^{j-1} p_i B_{ij}) \quad (4)$$

Where,  $i = 1, 2, \dots, N$  are the individual farmer and  $j = 1, 2, \dots, J$  are the alternative adaptation methods,  $X_{ij}$  vector are factors that influence farmers’ choice and adaptation method to climate change and  $\varepsilon_{ij}$  is the random error term /disturbance term. Farmers perceive climate change in different ways. For example, farmers perceive climate change through drought, floods, off seasonal rainfall (erratic rain fall), too much rainfall, too little rainfall, higher temperature, frost, high winds, frequent animal disease, frequent crop disease and frequent human disease. Farmer’s perception to climate changes a dichotomous form which is “1” if they perceive “0” otherwise. According to Gujarat (1995) the binary logit distribution function can thus be specified as;

$$p_i = \frac{1}{1 + e^{-z_i}} \quad (5)$$

Where  $p_i$  = probability of success

e = Base of natural logarithms

$Z_i$  = explanatory variables

$$Z_i = \beta_0 + \beta_1 x_1 + \beta_2 x_2 \dots \dots + \beta_m x_m \quad (6)$$

The odds ratio of the probability farmers to perceive and the probability not perceiving  $(1 - p_i)$  represented as

$$\frac{p_i}{1-p_i} = \frac{1+e^{z_i}}{1+e^{-z_i}} = e^z \quad (7)$$

Taking the natural logarithms of the odds ratio of equation (4) will result in what is known as the log model as indicated below

$$\ln\left(\frac{p_i}{1-p_i}\right) = \ln(e^{\beta_0 + \sum_{i=0}^m (\beta_i x_i)}) = Z_i \quad (8)$$

$$\text{The final logit model has the form } Z_i = \beta_0 + \sum \beta_i x_i + u_i \quad (9)$$

### 3. Methods

#### 3.1 Study Area

This study was conducted in Kurmuk district, which is one of district in Asossa zone Benshangul Gumuz regional state. The district is characterized by two livelihood zones dry kolla and wet kolla. The District is characterized by a crop-livestock mixed farming. Farmers keep a significant number of cattle, sheep, donkey, and got for various purposes. Crops widely produced in the area include maize and sorghum. Moreover, vegetables and root crops produced in the area include onions, potato, tomato, pepper, cabbage, and sweet potato. The livelihoods of the district are highly vulnerable and affected by climate change variability.

### 3.2 Sampling Techniques and Sample Size Determination

A multistage sampling procedure was used to sample smallholder farmers from Kurmuk district. A total of 60 farmers from three kebeles (Dul-Hode, Agubela and Famatsare) of Kurmuk district were selected and interviewed on smallholder farmers' adaptation strategies to climate change and variability's, socio-demographic and institutional characteristics. The Yamane (1967) formula was used for population known and the district population (smallholder farmers) were almost homogenous as follows:

$$n = \frac{N}{1+N(e)^2} = \frac{862}{1+862(0.07^2)} \sim 165 \quad (10)$$

Where, n = sample size,

N= Population size and

e = level of precision assumed 7%

Table 1. Sampled distribution of smallholder farmers

No	Kebeles	Total numbers household's	sampled household's
1	<b>Dul-Hode</b>	299	56
2	<b>Agubela</b>	387	72
3	<b>Famatsare</b>	176	32
	Total	862	160

Source: Kurmuk Office of Agriculture 2020.

### 3.3 Data Types, Sources and Method of Data Collection

Both primary and secondary data was utilized in this study. The primary data was gathered from sample household heads using structured questionnaire through face-to-face interviews in January 2020. Questionnaire and checklist were prepared and pretested before data collection. Key informants drawn from development agents (DAs) and model farmers were interviewed for in-depth qualitative information and triangulating data from the household survey.

## 4. Result and Discussions

### 4.1 Socio Demographic Characteristics of Households

Out 160 households about 64% of households perceived climate change and have adopted various climate change adaptation strategies'. Out of 160 households interviewed about 84% were male head and 16% were female head. The average age for household was 40 years. The overall mean of family size of household was found to be 7 per household. The average education of household head was 4.5 years. The mean of cultivated land of household head was 2 hectares. The mean of distance from farm and distance from market for household head was 10 and 6 kilometres respectively. About 60% of households access to credit service are perceive the climate change, while about 90% of households who have access to climate change had perceived the climate changes and variability. About 83% of households whose have an access to extension service had perceive climate change. From 160 sampled households about 69% of households were perceived climate change and variability. The result of the study showed about 87% of household perceive climate variability through decrease in rain fall distribution, while, 95% perceive increase in temperature from year to year. The result of the study showed about 22% of believed that the cause of climate change and variability was human action on natural resources, about 8% believed that natural process, about 26% believed both of both human action and natural process. The result showed that respondent households on consequences of climate change. Among these, 65% of the respondents respond that reduced crop yield, 60% weeds and pests, 58% outbreak disease, 56% food shortage, 55% reduced water quality and size, 54% frequent crop disease and 54% respond livestock death observed due to climate change.

### 4.2 Determinants of Smallholder Farmers' Perception to Climate Change

A binary logit model employed for perception analysis using 12 explanatory variables. The model overall goodness of fit parameters predicted and chi-square tests show that the overall goodness of fit model was 160.69 and statistically significant at less than 1%. This shows that jointly independent variables included in the logistic regression model. The pseudo -R2 values show that the independent variables included in the regression explain a significant proportion of the variability in the farmer likelihood to perceive climate change. Thus, pseudo - R2 = 0.81 shows that about 81% of the variation in the dependent variable was for the explanatory variables included in the model.

Table 2. Determinants of smallholder farmers’ perception to climate change

Variables	Coefficient	Standard error	Marginal effect
Constant	4.139	18.098	-
Sex	0.548***	2.638	0.275
Age	0.67	0.264	0.001
Education	0.385	0.376	0.020
Family size	-0.293	-0.121	0.034
Cultivated land	1.141	1.552	0.025
Access of credit service	1.433**	2.801	0.257
Climate information	1.535***	3.055	0.556
Distance from farm	5.022	1.647	-0.013
Extension service	1.320**	2.903	0.057
Income from farming	1.153	-0.672	0.141
Income from off farming	1.583	-0.227	0.886
Distance market	-0.093**	-0.223	-1.12
Log likelihood	-19.02		
LR chi2(10)	160.69		
Prob > chi2	0.000		
Pseudo R2	0.81		
Number of observation	160		
	***, ** and * significant at 1%, 5% and 10% respectively		

Source: Model output, 2020

The study showed that climate information was positively and significant affects household’s perception to climate change and variability. The marginal effect of the variable shows smallholder those have access to climate information are more likely to perceive climate change by 55.6% over those have no access to climate information. This finding is similar to the findings of Ndambiri et al.(2013) and Tesso et al.(2012) that access to climate information have a positive relationship with perception to climate change. Access to credit service had a positive relationship with household perception to climate change. Farmers those who have access credit more likely to perceive climate change by 25.7% over those have no credit access. This finding is supported by of Tesso et al.(2012).Sex of household head had a positively affects household perception to climate change. The marginal effect of the variable showed male headed households is more likely to perceive climate change by 27.5% than female headed. This finding is similar to the finding of Juana et al.(2013).

Distance from market negatively affects farmers’ perception to climate change. The marginal effect result shows that one kilo meter increase in distance from market resulted in a likelihood of smallholder farmers’ perceiving climate change is decrease by 1.2% keeping other factors constant. The finding supported Ndambiri e al.(2013)and Tesso et al.(2012).Access to extension service was positively affects household perception of climate change. The result of study shows those farmers have access to extension service more likely to perceive climate change by 5.7% over those have no access to extension service. This finding is similar to Ndambiri et al.(2013)and Tesso et al.(2012).

#### 4.3 Determinants of Smallholder Farmers’ Adaptation Option to Climate Change

In this section, the multinomial logit (MNL) model for adaptation choices to climate change adaption options in Kurmuk district was estimated by using the statistical software STATA version 14. The analysis was based on cross-sectional data collected from the rural households of Kurmuk district. Before initial runs of the model, the data were checked for the presence of any multicollinearity in the data set. Among the variables hypothesized to influence adaptation in the above section, these correlation coefficients which do not suggest the incidence of strong co-linearity were dropped from the model. The multinomial logit econometric model was preferred because there is no fears of adaptation categories are dependent of each other. Therefore the detail explanation based on the regression result presented as follows. The likelihood function for the multinomial logit model was significant Wald  $\chi^2 = 127.469$ ,  $P < 0.0000$ ), showing a strong explanatory power.

As shown in Table 5 below, the likelihood of taking adaptation practice found to be statistically significant for the factor variable of the sex of the household head at the 1% level of significance. The result of study shows being male head household leads to more crop diversification as an adaptation option than female head household. This finding is supported by Yenealem et al.(2013), Deressa et al.(2009), Aemro et al.(2012). Education level of household head had a positive association to improved crop and livestock production an adaptation option. The education level of household head increase household head motivates to prefer more adaptation options. Size of cultivated land owned household head statically significant to soil and water conservation practices positively. The households whose have more

cultivated land had used soil and conservation practices as options to climate change adaption options. The finding supported Asfaw et al.(2019). Access to credit services significant affects all adaptation options positively.

Table 3. Determinants of smallholder farmers’ adaptation option to climate change

Variables	Crop diversification		Improved crop and livestock production		Soil and water conservation practices		Tree plantation	
	Coefficients	Marginal effect	Coefficients	Marginal effect	Coefficients	Marginal effect	Coefficients	Marginal effect
Constant	-4.139	-	21.739	-	-0.179	-	17.41	-
Male	2.638	0.313*	2.297	0.08	1.478	0.0003	1.754	0.034
Age	0.056	0.010	-0.007	-0.004	0.0002	-0.004	0.049	0.003
Education of household	0.376	0.012	0.462	0.015	0.502	0.023*	0.467	0.018
Family size	-0.121	-0.030	0.234	0.035	-0.124	-0.012	-0.044	-0.001
Cult	1.552	0.104	1.063	-0.027	2.299	0.150**	1.462	0.027
Access to credit	2.801	0.086*	3.710	0.137**	3.885	0.184***	3.063	0.065**
Climate information	3.056	0.350**	1.810	0.001	2.178	0.044	2.557	0.084
Market access	5.023	0.311***	3.941	0.001**	5.92	0.264***	4.475	0.054***
Access to extension	2.903	0.093**	5.526	0.277***	3.73	0.115**	3.935	0.132***
Non- farm income	-0.672	-0.083	-0.956	-0.064	-0.265	0.027	-0.237	0.031
Farm income	-0.227	0.296	-2.701	-0.218	-1.06	-0.007	-2.868	-0.26*
Distance from farm	-0.223	0.007	-0.356	-0.014	-0.272	-0.0048	-0.477	-0.034**
Wald $\chi^2 = -127.469$			Pseudo R2 = 0.4824					
LR chi2(48) = 237.58			Number of obs = 160					
Prob > chi2 = 0.0000			***, ** and * significant at 1%, 5% and 10% respectively					

Source: model output, 2020

Households whose have access to climatic information diversify crop production to cope up the climate change variability. This finding is similar with the findings of Ndambiri et al.(2013), Deressa et al.(2009), Aemro et al.(2012) and Belay et al.(2017).Household whose have market access for input and output significantly affect crop diversification, improved livestock and crop production, soil and water conservation practices and tree plantation adaptation jointly. This finding supported Belay et al.(2017). Households whose have an access to credit service were adopt or more preference to use crop diversification, improved livestock and crop production, soil and water conservation practices and tree plantation jointly. This finding is similar to Deressa et al.(2009) and Aemro et al.(2013) Climate information significantly and positively affects household crop diversification.

Extension service affects adaptation crop diversification, improved livestock and crop production, soil and water conservation practices and tree plantation positively. Households those have access to extension service more probably prefer to use crop diversification, improved livestock and crop production, soil and water conservation practices and tree plantation as an adaptation options jointly. The finding is similar with Deressa et al.(2009), Aemro et al.(2012) and Bedeke et al.(2019).Off-farm income was significantly affects adaptation option of improved crop and livestock production and tree planation negatively. The households those participated in off-farm income less allocation labour, money and time to tree planation, improve crop and livestock production. This finding is similar to Deressa et al.(2009) and Aemro et al.(2012). Distance from farm was negatively affects household choice improved crop and livestock production and tree planation options. Households those have distance from their farm lands have less choose improved crop and livestock production and tree plantation as an adaptation option. The finding supported by Aemro et al.(2012).

## 5. Conclusion

Ethiopia's vulnerability to climate change. Agriculture is the most susceptible sector to climate change related hazards. Adaptation to climate change impacts are key element for sustainable and transformational development of agriculture. This study investigated how smallholder farmers perceive climate change, what adaptation strategies they practice, and factors that influence their adaptation decisions. Both primary and secondary data were used for the study. The primary data collected from by using household survey from 160 randomly selected sample households. The logistic regression and multinomial logit model were employed to identify the factors that shape smallholder farmers' climate change perception and adaptation strategies respectively. Results revealed that sex, extension service, credit access, climate information and distance from market are significantly affects smallholder farmers' perception to climate change in kurmuk district. sex, education, cultivated land, credit access, climate information, market access, extension service, distance from farm, off-farm income and on-farm income are found statistically significant affected adaptation options of smallholder farmers. Furthermore, about 69% of the respondent household perceive climate change and about 64% used adaptation option to climate change impacts. Therefore, strengthening extension services, access credit services, disseminating climate and market information, diversification of farmer's income are among the recommendable mechanisms to advance their perception and adaptation to climate change in the study area and other similar parts of the country.

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