

Analysis of perception and adaptation to climate change in the Nile basin of Ethiopia

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Abstract

This study employed the Hickman probit model to analyse the two- step process of adaptation to climate change, which initially requires farmer’s perception that climate is changing and then responding to changes through adaptation. The analysis of perception of farmers to climate change revealed that age of the household head; wealth, information on climate change, social capital and agro ecological settings have significant impact on the perception of farmers to climate change. Moreover, the analysis of factors affecting adaptation to climate change indicates that education of the head of the household, household size, gender of the head of the household being male, livestock ownership and extension on crop and livestock production, availability of credit and temperature have positive and significant impact on adaptation to climate change. Additionally, the main barriers to adaptation identified include lack of information on adaptation methods and financial constraints to using the methods.

Key words: adaptation, perception, and climate change, Nile Basin of Ethiopia

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1. Introduction

Studies indicate that Africa's agriculture is negatively affected by climate change (Pearce et al. 1996; McCarthy et al. 2001). Adaptation is identified as one of the policy options to reduce the negative impact of climate change (Adger et al., 2003; Kurukulasuriya and Mendelsohn, 2006a). Adaptation to climate change refers to adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC, 2001). Common adaptation methods in agriculture include: use of new crop varieties and livestock species that are more suited to drier conditions, irrigation, crop diversification, mixed crop livestock farming systems and changing planting dates (Bradshaw et al., 2004; Kurukulasuriya and Mendelsohn, 2006; Nhemachena and Hassan, 2007).

Agriculture is the main sector of the Ethiopian economy. It contributes about 52% of the GDP, generates more than 85% of the foreign exchange earnings and employs about 80% of the population (CSA, 2004). Despite its high contribution to the overall economy, this sector is challenged by multitudes of factors of which climate related disasters like drought and flood, which often causes famine, are the major ones (Deressa, 2007). The knowledge of the adaptation methods and factors affecting the perceptions to climate change enhance policy towards tackling the challenges that climate change is imposing on Ethiopian farmers.

Some attempts have been made to study the impact of climate change on Ethiopian agriculture (NMSA, 2001; Deressa, 2007). NMSA (2001) identified potential adaptation measures to cope with adverse impacts of climate change on crop and livestock production but failed to indicate the factors which dictate the choice of any of the adaptation measures implied. Deressa (2007) employed the Ricardian approach to estimate the monetary impact of climate change on Ethiopian agriculture. Even though, the applied Ricardian approach includes adaptation, it does not address factors affecting perceptions to climate change. Adaptation to climate change is a two-step process, which initially requires the perception that climate is changing and then responding to changes through adaptation (Maddison, 2006).

So far, there has been no study undertaken in Ethiopia to analyze factors affecting the perception and adaptations to climate change. Thus, the objective of this study is to identify the factors that influence perception and adaptation to climate change in order to guide policy makers on ways to promote adaptation.

This paper is organised as follows: section two describes a review of literature. Section three discusses the methodology. Section four discusses the results and section five concludes and gives policy recommendations.

2. Review of Literature on Analytical Methods

The fact that much climate change adaptation research in the field of economics has not been done so far limits the ease of comparing methodologies and debating on the appropriateness of any given model. Despite this fact, methodological similarities could be traced between agricultural technology adoption, climate change adaptation methods and other related models involving decisions to whether to adopt or not a given course of action and the steps economic agents take in the process of action.

Agricultural technology adoption models are based on farmers' utility or profit maximizing behaviours (Norris and Batie, 1987; Pryanishnikov and Katarina, 2003). The assumption here is that farmers adopt a new technology only when the perceived utility or profit from using this new technology is significantly greater than the traditional or the old method. While utility is not directly observed, the actions of economic agents are observed through the choices they make.

Probit and logit models are the most commonly used models in the analysis of agricultural technology adoption research. Binary probit or logit models are employed when the number of choices available is two (whether to adopt or not). The extensions of these models, most often referred to as multivariate models, are employed when the number of choices available is more than two. The most commonly cited multivariate choice models in unordered choices are multinomial logit (MNL) and multinomial probit (MNP) models. Multivariate choice models are advantages over their counterparts of binomial logit and probit models in two aspects (Wu and Babcock, 1998). First, they allow exploring both factors conditioning specific choices or combination of choices and second, they take care of self- selection and interactions between alternatives.

These models have also been employed in climate changes studies pertaining to the conceptual similarities in agricultural technology adoption and climate change studies. For example, For instance, Nhemachena and Hassan (2007) employed the multivariate probit model to analyse factors influencing the choice of climate change adaptation options in Southern Africa. Kurukulasuriya and Mendelsohn (2006) and employed the

multinomial logit model to see if crop choice by farmers is climate sensitive. Similarly Seo and Mendelsohn (2006) used the multinomial logit model to analyze how livestock species choice is climate sensitive.

More over, when decision process by farmers to adopt a new technology requires 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 and William (2003) employed the Heckman's two- step procedure to analyze the factors affection the awareness and adoption of new agricultural technologies in the United States of America. In the Stan and William (2003) study, the first stage is the analysis of factors affecting the awareness of new agricultural technologies and the second stage is adoption of the new agricultural technologies. Similarly Yirga (2007) and Kaliba et al (2000) employed the Heckman's selection model to analyze the two-step processes of agricultural technology adoption and the intensity of agricultural input use.

By the same token, Maddison (2006) argued that 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. Thus, this study adopts the Heckman's two-step procedure (Heckman 1976) to analyze the perception and adaptation to climate change in the Nile Basin of Ethiopia.

3 Empirical models

The Heckman's two-step procedure is adopted for this study. Adaptation to climate change involves a two-stage process: first perceiving change and then deciding whether or not to adapt by taking a particular measure. This leads to sample selectivity problem since only those who perceive climate change will adapt, where as we need to infer about the adaptation made by the agricultural population in general, which implies the use of Heckman's sample selectivity probit model (Maddison, 2006).

The probit model for sample selection assumes that there exists an underlying relationship

$$\text{The latent equation given by: } y_j^* = x_j\beta + u_{1j} \quad (1)$$

Such that we observe only the binary outcome given by the probit model as:

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

The dependent variable is observed only if the observation j is observed if the selection equation:

$$y_j^{select} = (z_j\delta + u_{2j} > 0) \quad (3)$$

$$u_1 \sim N(0, 1)$$

$$u_2 \sim N(0, 1)$$

$$corr(u_1, u_2) = \rho$$

Where, x is a k - vector of regressors, z is an m vector of repressors; u_1 and u_2 are error terms.

When $\rho \neq 0$, standard probit techniques applied to equation (1) yield biased results. Thus, the Heckman probit (heckprob) provides consistent, asymptotically efficient estimates for all parameters in such models (StataCorp, 2003). Thus, the Heckman probit selection model is employed to analyse the perception and adaptation to climate change in the Nile Basin of Ethiopia.

Model variables

For this study, the first stage of the heckman probit model is the perceptions to changes in climate change and this is the selection model, while the second stage model is whether the farmer adapted to climate change, conditional on the first stage that he perceived a change in climate. This second stage is the outcome model. The variables hypothesised as affecting perceptions and adaptations to changes in climatic conditions along with their respective dependent variables as indicated below (Table 1).

Dependent variables for the outcome equation

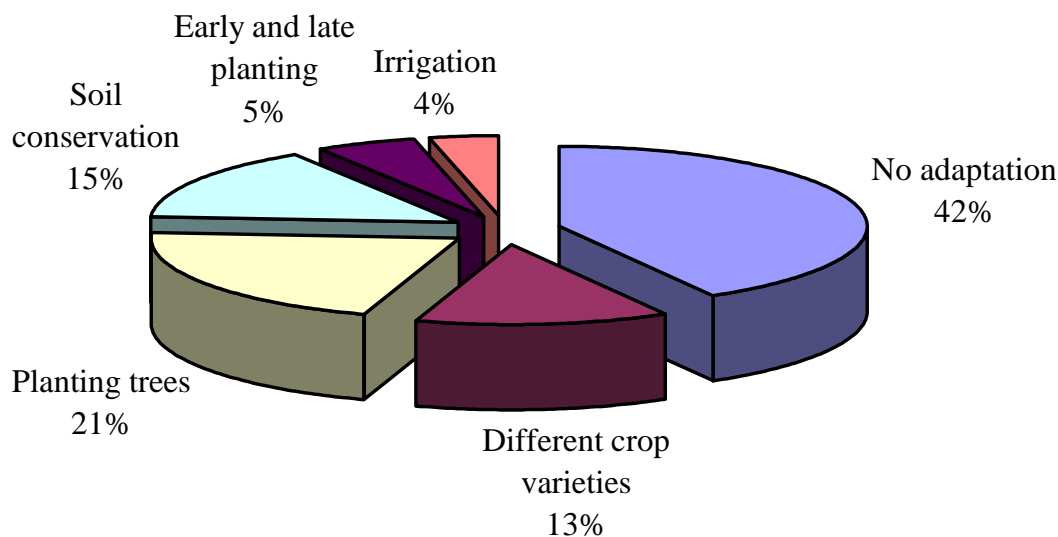
The climate change research community has identified different adaptation methods. The adaptation methods most commonly cited in literature include: use of new crop varieties and livestock species that are more suited to drier conditions, irrigation, crop diversification, mixed crop livestock farming systems, changing planting dates, diversifying from farm to non-farm activity, increased use of water and soil conservation techniques, changed use of capital and labour and shading and sheltering / tree planting (Bradshaw et al., 2004; Kurukulasuriya and Mendelsohn, 2006a; Maddison, 2006; Nhemachena and Hassan, 2007).

The adaptation methods for this study are based on asking farmers about their perceptions on climate change and the actions they take to counteract the negative impact of climate change (Figure 1). The adaptation measures reported by farmers might be profit driven rather than climate change. Despite this missing link, we assume that their actions are driven by climatic factors as reported by farmers themselves as in the studies by Maddison (2006) and Nhemachena and Hassan (2007).

Table 1 Description of model variables for the Heckman probit selection model

Outcome equation			Selection Equation		
Dependent variable			Dependent variable		
Description	Farmers reported to have adapted (%)	Farmers reported not adapted (%)	Description	Farmers perceived change in temperature / rainfall (%)	Farmers not perceived change in temperature / rainfall (%)
Adaptation to climate change	58	42	Perception of climate change	83	17
Independent variables			Independent variables		
Description	Mean	Standard deviation	Description	Mean	Standard deviation
Education	1.7035	2.7777	Education	1.7035	2.7777
Size of household	6.1493	2.2206	Age of HH	44.2915	12.6248
Gender	0.8963	0.3051	Farm income	4374.7610	7018.6360
Non-farm income	218.2594	790.9987	Non-farm income	218.2594	790.9987
Livestock ownership	0.9488	0.2205	Information on climate	0.3731	0.4839
Extension on crop & livestock	0.5455	0.4982	Farmer to farmer extension	0.4833	0.5000
Credit	0.2191	0.4138	Number of relatives	13.3725	19.4420
Farm size in hectares	2.02	1.18	Local Agro ecology “Kolla”	0.25	0.43
Distance to output market	5.70	4.14	Local Agro ecology “Dega”	0.25	0.43
Distance to input market	5.61	4.22			
Temperature	18.61	1.34			
Precipitation	115.64	35.57			

Figure 1 farmers adapting to climate change



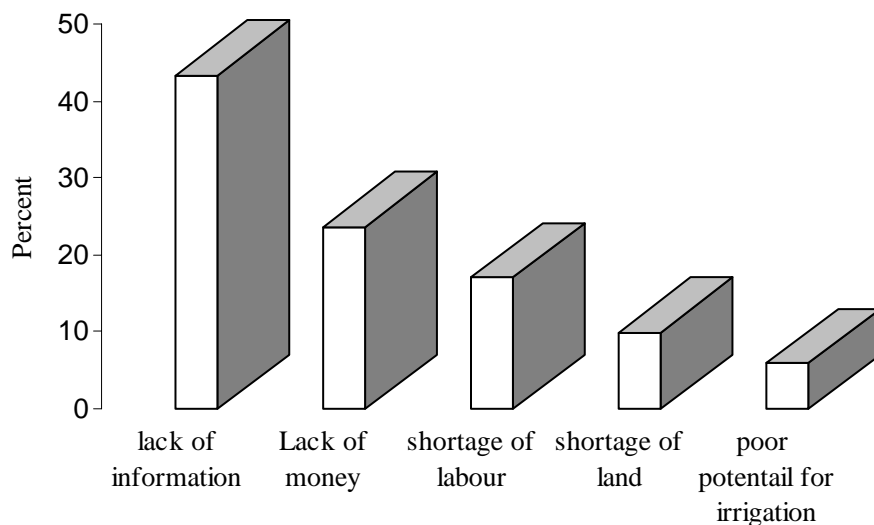
As indicated on figure one above, use of different crop varieties is the most commonly used method where as use of irrigation is the least adaptation practiced among the major adaptation methods identified in the Nile Basin of Ethiopia. More use of different crop varieties as adaptation could be associated with the less expense and ease of access by farmers; and the limited use of irrigation could be attributed to need for more capital and the low potential for irrigation. Moreover, about 42 percent of the surveyed farmers reported not to have taken any adaptation method indicated on the figure above due to many reasons.

Barriers to Adaptation

The analysis of barriers to adaptation to climate change in the Nile basin of Ethiopia indicates that there are five major constraints to adaptation. These are lack of information, lack of money, shortage of labour, shortage of land and poor potential for irrigation (Figure 2). Most of these constraints are associated with poverty. For instance, lack of information to adaptation options could be attributed to the fact that research on climate change and adaptation options have not been strengthened in the country and thus, information is lacking in this area. Lack of money hinders farmers from getting the necessary resources and technologies

which assist to adapt to climate change. Adaptation to climate change is costly (Mendelson, 2004), and this cost could be revealed through the need for intensive labour use. Thus, if farmers do not have sufficient family labour or the financial means to higher labour, they can not adapt. Shortage of land has been associated with high population pressure. High population pressures force farmers to intensively farm over a small plot of land and make them unable to conserve from further damages by practices such as planting trees which competes agricultural land. Given the fact that the Nile Basin in Ethiopia is considered very rich in water resources (FAO, 1997), poor irrigation potential can most probably be associated with the inability of farmers to use the already existing water due to technological incapability. Farmers in Ethiopia in general are very poor and can not afford to invest on irrigation technology not only to adapt to climate change but also to sustain their livelihood during harsh climatic extremes such as drought which often causes famine.

Figure 2 Barriers to adaptation



Explanatory variables for the outcome equation

As indicated in table 1 above, the explanatory variables for this study include: education of the head of the household, household size, gender of the head of the household, non-farm income, livestock ownership, extension on crop and livestock production, access to credit, farm size, distance to input and output markets, temperature and precipitation.

Higher level of education is believed to be associated with access to information on improved technologies and productivity consequences (Norris and Bati, 1987). Evidence from various sources indicates that there is a positive relationship between the education level of the household head and the adoption of improved technologies (Igoden et al., 1990; Lin, 1991) and adaptation to climate change (Maddison, 2006). Therefore, farmers with higher levels of education are more likely to better adapt to climate change.

The influence of household size on use of adaptation methods can be seen from two angles. The first assumption is that households with large family members may be forced to divert part of the labour force to off-farm activities in an attempt to earn income in order to ease the consumption pressure imposed by a large family size (Yirga, 2007). The other assumption is that large family size is normally associated with a higher labour endowment, which would enable a household to accomplish various agricultural tasks. For instance Croppenstedt et al. (2003) argue that households with a larger pool of labour should be more likely to adopt agricultural technology and use it more intensively because they have fewer labour shortages at peak times. Here it is expected that households with large family size to be more likely to adapt to climate change.

Male-headed households are often considered to be more likely to get information about new technologies and take risky businesses than female-headed households (Asfaw and Admassie, 2004). More over, Tenge et al. (2004) argued that female-headed households may have negative effects on the adoption of soil and water conservation measures because they have limited access to information, land and other resources due to traditional social barriers. The result of Nhemachena and Hassan (2007) study indicated a contrary result to the above argument by showing that female-headed households are more likely to take up climate change adaptation methods. This study follows the prior argument that indicates that male-headed households are more likely to take up adaptation methods as they have more access to resources and information.

Non-farm income, farm size and livestock ownership represent wealth. It is regularly hypothesized that the adoption of agricultural technologies requires sufficient financial well-being (Knowler and Bradshaw, 2007). On this line of argument, other studies, which investigate the impact of income on adoption, revealed a positive correlation (Franzel, 1999). Higher income farmers may be less risk averse, have more access to information, have a lower discount rate and longer term planning horizon (CIMMYT, 1993). Farm size is associated with greater wealth and it is hypothesized to increase adaptation to climate change. Studies on

adoption of agricultural technologies indicate that farm size has both negative and positive effect on the adoption showing that the effect of farm size on technology adoption is inconclusive (Bradshaw et al., 2004). Livestock plays a very important role by serving as a store of value, source of traction (specially oxen) and provision of manure required for soil fertility maintenance (Yirga, 2007). Thus, for this study, farm and non-farm incomes, and livestock ownership are hypothesized to increase adaptation to climate change.

Extension on crop and livestock production and information on climate represent access to the information required to make decision on adaptation to climate change. Various studies in developing countries including Ethiopia reported a strong positive relationship between access to information and the adoption behaviours of farmers (Yirga 2007). More over, Maddison (2006) and Nhemachena and Hassan (2007) showed that access to information through extension increase the chance of adapting to climate change. Thus, this study also hypothesizes that access to information increases chance of adapting to climate change.

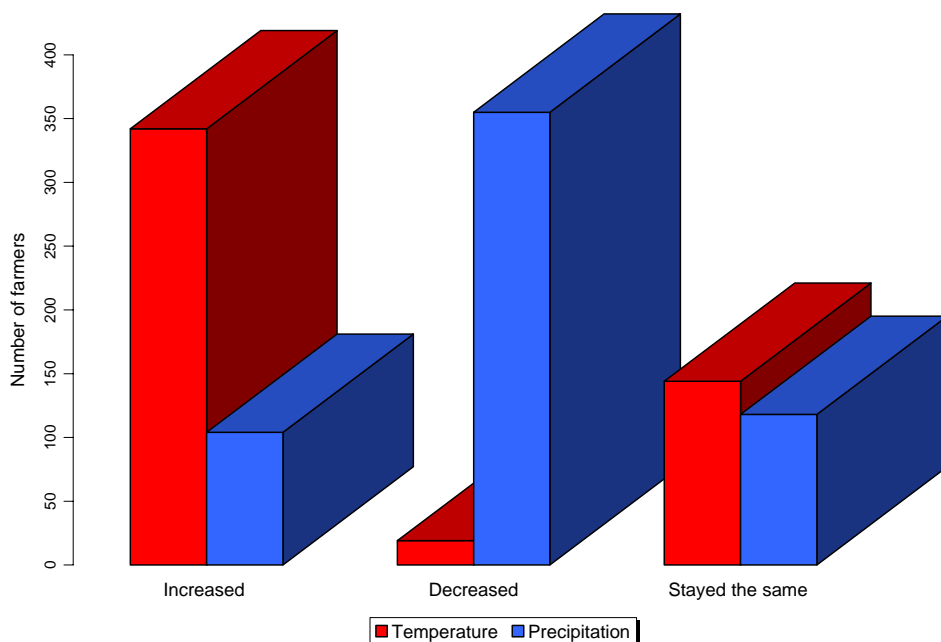
Availability of credit eases the cash constraints and allows farmers to buy purchased inputs such as fertilizer, improved crop varieties and irrigation facilities. Researches on adoption of agricultural technologies indicate that there is a positive relationship between the level of adoption and the availability of credit (Yirga, 2007; Pattanayak et al., 2003). Like wise, this study also hypothesizes that there is positive relationship between availability of credit and adaptation. It is also hypothesized that the lesser the distance to output and input markets, the more adaptation to climate change. Proximity to market is an important determinant of adaptation, presumably because the market serves as a means of exchanging information with other farmers (Maddison, 2006).

Detailed analysis of the relationships between climatic variables such as temperature and rainfall on adaptation requires a time serious data of how farmers have behaved over time in response to changing climatic conditions. As this type of data is not available for this study, it is assumed that cross- sectional variations can proxy temporal variations. Thus, given the farming situation in Ethiopia, it is hypothesized that farmers adapt to increasing temperature, as more warming adds more pressure on the already water scarce agriculture.

Dependent variable for the selection Equation

The analyses of the perception of farmers to climate change indicate that most of the farmers for this study are aware of the fact that temperature is increasing and the level of precipitation is declining (figure 3). To get information on their perceptions to climate change, farmers were asked two sets of questions. The first was asking farmers if they have observed any change on the amount of temperature or rainfall over the past twenty years. The second set consisted of asking farmers if the number of hot or rainy days have increased or decreased over the past twenty years. The responses from the farmers are in line with the report by the National Metrological Services Agency (NMSA, 2001), which depicted an increasing trend in temperature and decreasing trend in precipitation.

Figure 3 perceptions of farmers to climate change



Explanatory variables for the Selection equation

For the selection equation, it is hypothesized that, education, age of head of the household, farm and non farm incomes, information on climate, farmer to farmer extension, number of relatives in the ‘Got’ and agro ecological settings influence the awareness of farmers to climate change. The argument on the likely impact

of education, age of head of the household, farm and non farm incomes on perception is more or less similar to the case with adaptation; in they make farmers to access more information. Thus, the likely relationships follow the same argument as put in the outcome equation and thus are omitted here to reduce redundancy.

The case of information on climate change from either extension agents of any other organization is self-explanatory in that it is meant to create awareness. Farmer- to- farmer extension and the number of relatives in the 'Got' represent social capital. In technology adoption studies, social capital plays a significant role (Isham, 2002), in information exchange, and hence, it is hypothesized that more social capital is associated with the perception of climate change. More over, farmers living in lowland areas are hypothesized to have perceived climate change as compared to midland and highlands. This is due to the fact that lowlands are already hotter and a marginal change in temperature could be perceived easily.

4 Model results and discussion

Despite the fact that the majority of the farmers interviewed claimed that they have perceived at least one change in climatic attributes, some of the farmers who perceived climate change did not respond by taking adaptation measures. Here it is argued that farmers who perceive and responded (did not respond) share some common characteristics, which assist in better understanding the reasons underlying their response (failure to respond) as captured by the Heckman probit model.

The Heckman probit model was run and tested for its appropriateness over the standard probit model. The results indicated the presence of sample selection problem (dependence of the error terms from the outcome and selection models) justifying the use of Heckman probit model with rho significantly different from zero (Wald $\chi^2 = 10.84$, with $p = 0.001$). Moreover, the likelihood function of the Heckman probit model was significant (Wald $\chi^2 = 86.45$, with $p < 0.0000$) showing strong explanatory power of the model.

The results from regression indicated that most of the explanatory variables affected the probability of adaptation as expected, except farm size. Variables that positively and significantly influenced adaptation to climate change include education of the head of the household, household size, and gender of the head of the household being male, livestock ownership, extension on crop and livestock production, availability of credit and temperature. A unit increase in the education of the head of the household will have the impact of raising the probability of adaptation to climate change by 1.9 %. Similarly, increasing the size of the household by one unit increases the probability of adaptation to climate change by 1.8%. This result is inline with the argument which assumes that large family size is normally associated with a higher labour endowment, which would enable a household to accomplish various agricultural tasks especially during peak seasons (Croppenstedt et al. 2003).

Male headed households have more probability of adapting to climate change which is revealed by the fact that a unit change from being headed by a female household to male increases the probability of adapting to climate change by 18 %. This result is inline with the argument that male-headed households are often considered to be more likely to get information about new technologies and take risky businesses than female-headed households (Asfaw and Admassie, 2004). Likewise, increasing livestock ownership, extension to crop and livestock production, access to credit and increasing temperature by one unit increases the probability of

adapting to climate change by 31%, 30%, 13% and 5.5 % respectively. The fact that adaptation to climate change increases with increasing temperature is inline with the expectation that increasing temperature is damaging to African agriculture and farmers respond to this through the adoption of different adaptation methods (Kurukulasuriya and Mendelsohn 2006).

Farm size and annual average precipitation are negatively related to adaptation. The probable reason for the negative relationship between adaptation and farm size 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 dictates the need for a specific adaptation method to climate change. Thus future research, which accounts for farm characteristics, could reveal more information about factors dictating adaptation to climate change at farm or plot level. Moreover, the probable reason for the negative relationship between average annual precipitation and adaptation could be due to the fact that like any African county, Ethiopia's agriculture is water scarce and increasing precipitation will not constrain agricultural production or does not promote the need to adapt (at least using the main adaptation options considered in this study).

As expected, the likelihood of perception of climate change is positively related to age, farm income, and information on climate, farmer-to-farmer extension and the number of relatives in 'Got'. Increasing the age of household head by one unit increases the probability of perceiving change in climate by 0.4 % where as increasing farm income by one unit increases perception by 0.13%. Likewise, increasing factors which are believed to create awareness to climate change such as information on climate change, farmer-to-farmer extension and number of relatives in the 'Got' by one unit, increase the likelihood of adaptation by 8 %, 15.5% and 0.3% respectively.

Unlike the prior expectations, farmers living in dega (highlands) perceived more change in climate than farmers in Kolla (low land) when compared with Woinadega (midland). For instance, a unit change from farming in woinadega to farming in dega significantly increases the probability of perception of climate change by 15.5 %. The model results along with the marginal impacts for both the outcome and selection models are presented below (Table 2).

Table 2 Results of the Heckman probit selection model

Explanatory variables	Adaptation model				Selection model			
	Regression		Marginal impacts		Regression		Marginal values	
	Coefficients	P-level	Coefficients	P-level	Coefficients	P- level	Coefficients	P-level
Education	0.061**	0.017	0.019**	0.017	0.021	0.393	0.005	0.388
Household size	0.058*	0.053	0.018*	0.051				
Gender of household head	0.580***	0.010	0.177**	0.012				
Age of household head					0.018***	0.000	0.004***	0.000
Farm income					5.66E-05***	0.000	0.000013** *	0.000
Non-farm income	0.000149	0.143	4.55E-05	0.144	-1.1E-05	0.911	-2.54E-06	0.911
Livestock ownership	1.012***	0.003	0.309***	0.004				
Extension on crop & livestock	1.024***	0.000	0.303***	0.000				
Information on climate change					0.372**	0.014	0.080***	0.009
Farmer to farmer extension					0.707***	0.000	0.155***	0.000
Credit availability	0.479***	0.003	0.131***	0.001				
Number of relatives in 'Gote'					0.011**	0.038	0.003**	0.035
Farm size in hectares	-0.140**	0.011	-0.043**	0.013				
Distance to output market	-0.053	0.310	-0.016	0.310				
Distance to input market	0.075	0.143	0.023	0.141				
Local Agro ecology "Kolla"					0.047	0.761	0.011	0.757
Local Agro ecology "Dega"					0.849***	0.000	0.155***	0.000
Temperature	0.178***	0.000	0.055***	0.000				
Precipitation	-0.012***	0.000	-0.004***	0.000				
Constant	-3.670	0.000			- 0.821***	0.001		
Total observations	608							
Censored	126							
Uncensored	482							
Wald Chi square (Zero slopes)	86.45***							
Wald Chi square	10.84 ***							

***, **, * = Significant at 1%, 5% and 10% probability level, respectively

5 Conclusion policy implications

Farmers indicated that they adapted to climate change by using different methods, of which the major ones were included for this study. Those who did not use any of the methods considered under this study described lack of information on adaptation methods and lack of money as major constraints to adaptation. The analyses of the perception of farmers to climate change indicate that most of the farmers for this study are aware of the fact that temperature is increasing and the level of precipitation is declining. The Heckman probit selection model was employed to analyse the two-stage process of adaptation, which includes the perception of changes in climate conditions in the first stage, and then adaptation in the second stage.

The analysis of perception of farmers to climate change revealed that age of the household head; wealth, information on climate change, social capital and agro ecological settings have significant impact on the perception of farmers to climate change. Moreover, the analysis of factors affecting adaptation to climate change indicates that education of the head of the household, household size, gender of the head of the household being male, livestock ownership and extension on crop and livestock production, availability of credit and temperature have positive and significant impact on adaptation to climate change.

Based on the analysis of constraints to adaptation, factors that dictate adaptation to climate change and perception of farmers to climate change in the Nile Basin of Ethiopia, different policy options could be suggested. These policy options include, awareness creation on climate change and adaptation methods, facilitating the availability of credit, investment on yield increasing technology packages to increase farm income, creating opportunities for off-farm employment, research on use of new crop varieties and livestock species that are more suited to drier conditions, encourage informal social networks and investment on irrigation.

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