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CLIMATE CHANGE AND AGRICULTURE PAPER

Perception of and adaptation to climate change by farmers in the Nile basin of Ethiopia

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SUMMARY

The present study employed the Heckman sample selection model to analyse the two- step process of adaptation to climate change, which initially requires farmers' perception that climate is changing prior to responding to changes through adaptation. Farmers' perception of climate change was significantly related to the age of the head of the household, wealth, knowledge of climate change, social capital and agro-ecological settings. Factors significantly affecting adaptation to climate change were: education of the head of the household, household size, whether the head of the household was male, whether livestock were owned, the use of extension services on crop and livestock production, the availability of credit and the environmental temperature.

INTRODUCTION

Climate change affects agriculture and agriculture also affects climate change. Higher temperatures, reduced rainfall and increased rainfall variability reduce crop yield and threaten food security in low income and agriculture-based economies. Thus, the impact of climate change is detrimental to countries that depend on agriculture as the main livelihood, many located in Tropical Africa (Dixon *et al*. 2001; Houghton *et al*. 2001; IAC 2004). Agriculture affects climate change through the emission of greenhouse gases (GHG) from different farming practices (Maraseni *et al*. 2009; Edwards-Jones *et al*. 2009).

Agriculture is the main sector of the Ethiopian economy. It comprises about 0·52 of gross domestic product (GDP), employs about 0·80 of the population and generates more than 0·85 of the foreign exchange earnings (CSA 2005). This sector is dominated by small-scale mixed crop and livestock production, with very low productivity. The major factors responsible for the low productivity include reliance on traditional farming techniques, soil degradation caused by overgrazing and deforestation, poor complementary services such as extension, credit, marketing, infrastructure as well as climatic factors such as drought and flood (Devereux 2000; Alene 2003; Belay 2003; Yirga 2007). These factors reduce the adaptive capacity or increase the vulnerability of farmers to future changes, including climate change, which negatively affect the performance of the already weak agriculture.

Studies by the National Meteorological Services (Tadege 2007) indicate that the average minimum and maximum temperatures have been increasing by about 0·25 °C and 0·1 °C, respectively, over the past decade, whereas the rainfall is characterized by very high levels of variability over the past 50 years. Although models predicting precipitation give contradictory suggestions of increasing or decreasing precipitation, most climate prediction models agree that temperatures in Ethiopia will increase over the coming years (Strzepek & McCluskey 2006). Additionally, forecasts by Tadege (2007) indicate that temperatures in Ethiopia will increase in the range of 1·7–2·1 °C by the year 2050 and 2·7–3·4 °C by the year 2080.

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Moreover, studies show that the frequency and spatial coverage of drought have increased over the past few decades and this is expected to continue in the future (Lautze *et al*. 2003).

The fact that climate has changed in the past and will continue to change in the future underlines the need to understand how farmers perceive and adapt to climate change. Such information is necessary to guide future adaptation strategies. Studies have indicated indeed that farmers perceive that the climate is changing and also adapt to reduce the negative impacts of climate change (Thomas *et al*. 2007; Ishaya & Abaje 2008; Mertz *et al*. 2009). Studies further show that the perception or awareness of climate change (Semenza *et al*. 2008; Sampei & Aoyagi-Usui 2009; Akter & Bennett 2009) and taking adaptive measures (Maddison 2006; Hassan & Nhemachena 2008) are influenced by different socio-economic and environmental factors.

Some attempts have been made to analyse how farmers adapt to climate change in Ethiopia (Admassie & Adenew 2007; Deressa & Hassan 2009; Deressa *et al*. 2009). Deressa & Hassan (2009) 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 explicitly address how farmers perceive and what adaptation methods they employ. Admassie & Adenew (2007) studied perceptions of climate change and adaptation strategies in Ethiopia; although informative, it did not address the extent to which different socio-economic and environmental factors affect perceptions of climate change and adaptation in Ethiopia. Deressa *et al*. (2009) analysed the factors affecting the choice of adaptation methods, but failed to explain explicitly how farmers perceive climate change and adapt. Füssel (2007) argued that adaptation should be emphasized because human activities have already affected climate, climate change continues given past trends, the effects of emission reduction or mitigation take several decades to appear and adaptation can be undertaken at local or national levels being less dependent on the actions of others.

There are different ways of adapting to climate change in agriculture (Bradshaw *et al*. 2004; Kurukulasuriya & Mendelsohn 2008; Mertz *et al*. 2009) and different factors affect the use of any of these adaptation methods (Nhemachena & Hassan 2007; Deressa *et al*. 2009). For instance, Hassan & Nhemachena (2008) showed that better access to markets, extension and credit services, technology, farm assets (labour, land and capital) and information about adaptation to climate change, including technological and institutional methods, affect adaptation to climate change in Africa.

Adaptation to climate change is a two-step process; the first step requires the farmers to perceive a change in climate and the second step requires them to act through adaptation (Maddison 2006). Studies on the perceptions of climate change both in developing (Vedwan & Rhoades 2001; Hageback *et al*. 2005; Thomas *et al*. 2007; Ishaya & Abaje 2008; Gbetibouo 2009; Mertz *et al*. 2009) and developed (Diggs 1991; Leiserowitz 2006; Semenza *et al*. 2008; Akter & Bennett 2009) nations show that the majority of populations have already perceived climate change.

Psychometric and the cultural theory models are commonly used in analysing risk perceptions (Sjoberg 2000). Studies show that different socio-demographic factors affect the perception of climate change. For instance, Diggs (1991), Maddison (2006) and Ishaya & Abaje (2008) showed that farming experience, which is most often associated with age, plays an important role in the perception of climate change. Studies by Sampei & Aoyagi-Usui (2009) and Akter & Bennett (2009) revealed that exposure to mass media increases the awareness and concern about the damage associated with climate change. Semenza *et al*. (2008) indicated that individuals with higher incomes are more likely to know that climate is changing than individuals with lower incomes. Moreover, other factors such as gender, ethnic background, membership of environmental groups, newspaper readers (Leiserowitz 2006), education, access to extension services, geographical site and soil types (Maddison 2006; Gbetibouo 2009) may all affect perceptions of climate change.

In developing countries, the common approach to studying the perception of farmers to climate change is based on comparing farm survey or farm group discussion results with data records from meteorological stations (Vedwan & Rhoades 2001; Hageback *et al*. 2005; Thomas *et al*. 2007). Although informative in terms of understanding the level of awareness of farmers and the possibility of validating farmers' claims of perceptions of change against meteorological data, these approaches do not explicitly identify factors influencing awareness of climate change.

The present study is based on plausible methodological similarities among agricultural technology adoption, climate change adaptation methods and other related models which involve decisions on whether or not to adopt a given course of action and which indicate the steps economic agents take in the process of action. Agricultural technology adoption models are based on farmers' utility or profit-maximizing behaviours (Norris & Batie 1987; Pryanishnikov & Zigova 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 versions are employed when the number of choices available is two (whether to adopt or not) and multivariate models are employed when the number of choices available is more than two. Multivariate models of choice have advantages (Wu & Babcock 1998) by allowing the exploration of factors conditioning specific choices or combination of choices and also they take allow for self-selection and interactions between alternatives.

These models have also been employed in climate change studies pertaining to the conceptual similarities in agricultural technology adoption and climate change studies. For example, Nhemachena & Hassan (2007) employed the multivariate probit model to analyse factors influencing the choice of climate change adaptation options in Southern Africa. Kurukulasuriya & Mendelsohn (2006) employed the multinomial logit model to see if crop choice by farmers is climate sensitive. Similarly, Seo & Mendelsohn (2006) used the multinomial logit model to analyse how the choice of livestock species is climate sensitive. Additionally, Deressa *et al*. (2009) adopted the multinomial logit model to analyse factors that affect the choice of adaptation methods in the Nile basin of Ethiopia.

The age of the head of the household represents experience in farming and studies have indicated that experienced farmers are more likely to perceive climate change (Maddison 2006; Ishaya & Abaje 2008). The degree of education of the head of household is also hypothesized to be positively related to awareness of climate change. Access to information on climate change through extension agents or other sources creates awareness and favourable condition for adoption of farming practices that are suitable under climate change (Maddison 2006). Higher income positively affects public perception of climate change (Semenza *et al*. 2008). By the same token, it is hypothesized that higher farm and non-farm incomes positively influence farmers' perception of climate change. Farmer-to-farmer extension and the number of relatives in the *Got* (village) represent social capital, which plays a significant role (Isham 2002) in information exchange, and hence, it is hypothesized that social capital is associated with the perception of climate change.

The agro-ecological setting of farmers influences the perception of farmers to climate change. A study by Diggs (1991) revealed that farmers living in drier areas with more frequent droughts are more likely to describe the climate change to be warmer and drier than farmers living in a relatively wetter area with less frequent droughts. In Ethiopia, lowland areas are drier with higher drought frequency than other areas (Belay *et al*. 2005). Thus, it is hypothesized that farmers living in lowland areas are more likely to perceive climate change as compared to midland and highlands.

When a farmer's decision process about adoption of 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, McBride & Daberkow (2003) employed a two-step procedure (Heckman 1976) to analyse the factors affecting the awareness and adoption of new agricultural technologies in the USA. In the McBride & Daberkow (2003) study, the first stage was an analysis of factors influencing the awareness of new technologies and the second stage was the adoption of the new technologies. Yirga (2007) and Kaliba *et al*. (2000) also employed Heckman's selection model to analyse the processes of agricultural technology adoption and the intensity of agricultural input use.

Maddison (2006) argued that adaptation to climate change is also a two-step process that involves perceiving that climate is changing, and then responding to changes through adaptation. Maddison (2006) addressed this two-step process of adaptation in Africa at the regional level, but the results were highly aggregated and are of little help in addressing country-specific perceptions and adaptations to climate change.

The objective of the present study is to identify the major factors and quantify the extent to which the identified factors influence perceptions of and adaptation to climate change in the Nile Basin of Ethiopia. This information will guide policy-makers on ways to promote adaptation. It is hypothesized that different socio-economic and environmental factors affect the perceptions of and adaptation to climate change. This will be tested using data obtained from a household survey of a sample of 1000 mixed crop and livestock farmers in the Nile Basin of Ethiopia during the 2004/05 production year.

MATERIALS AND METHODS

Data

The current study is based on a cross-sectional household survey data of a total of 1000 mixed crop and livestock farmers collected during the 2004/05 production year in the Nile Basin of Ethiopia. The International Food Policy Research Institute (IFPRI) in collaboration with the Ethiopian Development Research Institute (EDRI) conducted this survey. The sample districts were purposely selected to represent different aspects of the agricultural activity in the basin including the agro-ecological zone (Dega (highlands), Woina Dega (mid-lands) and Kola (lowlands)), the degree of irrigation activity (the proportion of cultivated land), average annual rainfall, rainfall variability and population vulnerability (food aid-dependent population).

Peasant associations (administrative units lower than districts) were also purposely selected to include households who practice irrigation. One peasant association was selected from every district (so both the number of districts and number of peasant associations was 20). Once the peasant associations were chosen, 50 farmers were randomly selected from each peasant association, making the total number of households interviewed 1000. The temperature and rainfall data for the surveyed seasons were obtained from a global climate database developed by the University of East Anglia (Mitchell & Jones 2005).

In addition to collecting data on different socio-economic and environmental attributes, the survey also included information on farmers' perceptions of climate change and adaptation methods. The surveyed farmers were asked questions about their observation in the patterns of temperature and rainfall over the past 20 years.

Empirical model and model variables

The empirical model

In a two-stage process, the second stage of adaptation is a sub-sample of the first. Thus, it is likely that the second stage sub-sample (those who responded to change) is non-random and necessarily different from the first (which included those who did not perceive climate change), and this creates a sample selection bias. Therefore, a two-step maximum likelihood procedure (Heckman 1976) was used to correct for this selection bias.

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

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

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

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

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

$$\begin{aligned} y_j^{\text{select}} &= (z_j\delta + u_{2j} > 0) \qquad (3)\\ u_1 &\sim N(0,\ 1)\\ u_2 &\sim N(0,\ 1)\\ \operatorname{corr}(u_1,\ u_2) &= \rho \end{aligned}$$

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; δ is the parameter estimate, u_{2j} is an error term and u_1 and u_2 are error terms, which are normally distributed with mean zero and variance one. Thus, the first stage of Heckman's two-step model is the selection model (eqn 3), which represents the perception of changes in climate. The second stage is the outcome model (eqn 1), which represents whether the farmer adapted to climate change, and is conditional upon whether this has been perceived.

When the error terms from the selection and the outcome equations are correlated or when $\rho \neq 0$, standard probit techniques applied to eqn (1) yield biased results. Thus, the Heckman probit provides consistent, asymptotically efficient estimates for all parameters in such models (Van de Ven & Van Praag 1981). Hence, the Heckman probit selection model is employed to analyse the perception and adaptation to climate change in the Nile Basin of Ethiopia.

The dependent variable for the selection equation is whether a farmer has or has not perceived climate change. The explanatory variables for the selection equation include different socio-demographic and environmental factors based on the literature on factors affecting the awareness of farmers to climate change or their risk perceptions. It is hypothesized that the age and education of the head of the household, information on climate, farmer to farmer extension, number of relatives in the *Got* (village), farm and non-farm incomes and agro-ecological settings influence the awareness of farmers to climate change.

The dependent variable for the outcome equation is whether a farmer has adapted or not to climate change. The explanatory variables are chosen based on the climate change adaptation literature and data availability. These variables 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. Detailed descriptions of the hypothetical relationships between these variables and adaptation to climate change are described in Hassan & Nhemachena (2007), Deressa *et al.* (2009) and Nhemachena (2009). Tables 1 and 2 give the descriptions of model variables for the Heckman probit selection model.

RESULTS

The results indicated that 0·51 of the surveyed farmers perceived increasing temperatures, and 0·53 perceived decreasing rainfall over the past 20 years (Figs 1 and 2). The average minimum and maximum temperatures have increased by *c.* 0·25 °C and 0·1 °C, respectively, over the past decade (Tadege 2007).

Those farmers who claimed to have observed changes in climate over the past 20 years were

Table 1. *Description of model variables of the outcome equation for the Heckman probit selection model*

(a) Dependent variable		
Description	Farmers who adapted (proportion)	Farmers who did not adapt (proportion)
Adaptation to climate change (dummy: takes the value of 1 if adapted and 0 otherwise)	0·58	0·42
(b) Independent variables		
Description	Mean	S.D.
Education of the household head in years (continuous)	1·7	2·8
Size of the household (continuous)	6·1	2·2
Gender (dummy: 1 if male otherwise 0)	0·9	0·3
Non-farm income in Ethiopian currency (continuous)	218	791
Livestock ownership (dummy: 1 if livestock owned otherwise 0)	0·9	0·2
Extension advice on crop and livestock (dummy: 1 if visited otherwise 0)	0·5	0·5
Credit (dummy: 1 if there is access otherwise 0)	0·2	0·4
Farm size (ha; continuous)	2·0	1·2
Distance to output market (km; continuous)	5·7	4·1
Distance to input market (km; continuous)	5·6	4·2
Temperature (°C continuous: annual average over the 2004/05 survey period)	18·6	1·3
Precipitation (mm; continuous: annual average over the 2004/05 survey period)	115·6	35·6

Table 2. *Description of model variables of the selection equation for the Heckman probit selection model*

(a) Dependent variable		
Description	Farmers who perceived change (proportion)	Farmers who did not perceive change (proportion)
Perception of climate change (dummy: takes the value of 1 if perceived and 0 otherwise)	0·83	0·17
(b) Independent variables		
Description	Mean	S.D.
Education of the household head (years; continuous)	1·7	2·8
Age of the household head (years; continuous)	44·3	12·6
Farm income (Ethiopian currency; continuous)	4375	7019
Non-farm income (Ethiopian currency; continuous)	218	791
Information on climate (dummy: 1 if available otherwise 0)	0·4	0·5
Farmer to farmer extension (dummy: 1 if occurs otherwise 0)	0·5	0·5
Number of relatives in *Got* (village; continuous)	13·4	19·4
Local agro ecology is *Kola* (lowland) (dummy: 1 if Kola otherwise 0)	0·3	0·4
Local agro ecology is *Dega* (highland) (dummy: 1 if Dega otherwise 0)	0·3	0·4

subsequently asked if they had responded through adaptation to reduce the negative impacts of climate change and 0·58 indicated that they have adopted one of the major adaptation options identified through the survey. These include planting trees, soil conservation, use of different crop varieties, changing planting dates and irrigation (Fig. 3). Farmers who perceived climate change but failed to adapt gave many reasons as barriers to adaptation, which included lack of information on adaptation methods, lack of money, shortage of labour, shortage of land and poor potential for irrigation.

The Heckman probit model was run and tested for its appropriateness over the standard probit model (i.e. a probit model that does not account for selection). 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 $\chi^2 = 10{\cdot}84$, with $P = 0{\cdot}001$).

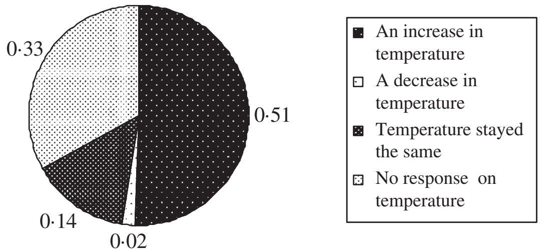

Fig. 1. Farmers' perception of long-term temperature changes.

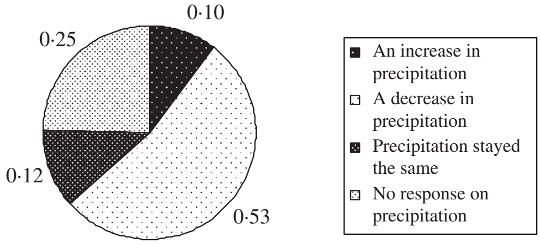

Fig. 2. Farmers' perception of long-term precipitation changes.

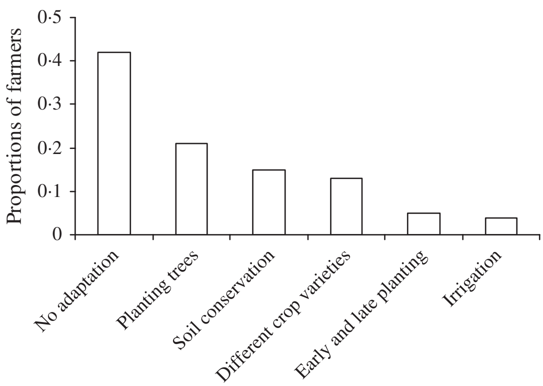

Fig. 3. Farmers' adaptation strategies.

Moreover, the likelihood function of the Heckman probit model was significant (Wald $\chi^2 = 86{\cdot}45$, with $P < 0{\cdot}001$), showing its strong explanatory power. Additionally, results show that most of the explanatory variables and their marginal values are statistically significant at $P < 0{\cdot}05$ and generally in the directions that would be expected (Table 3). The calculated marginal effects measure the expected changes in the probability of both perception of climate change and adaptation with respect to a unit change in an independent variable.

The results from the selection model, which analyses the factors affecting the perception of climate change, indicate that age of the head of the household, farm income, information on climate change, farm-to-farm extension, number of relatives in a *Got* and agro-ecological settings affect the perception of climate change positively.

The results from the outcome model, which analyses the factors affecting adaptation, indicated that most of the explanatory variables affected the probability of adaptation as expected, except the farm size. Variables that positively and significantly influenced adaptation to climate change include education of the head of the household, the household size, whether the head of the household was male, livestock ownership, advice received on crop and livestock production and the availability of credit and temperature. However, larger farm size and high annual average precipitation were negatively related to adaptation.

DISCUSSION

Farmers should be able to adapt in order to reduce the negative impact of climate change. Adaptation to climate change is a two-step process which requires that farmers perceive climate change in the first step and respond to changes in the second step through adaptation. Different socio-economic and environmental factors affect the abilities to perceive and adapt to climate change.

Unlike the prior expectations, farmers living in dega (highlands) perceived more change in climate than farmers in Kola (lowland) or Woinadega (mid-land). This could either be associated with the recent drought (year 2002), with or could be linked to various environmental changes that cause reduced water availability (Meze-Hausken 2004). It might also be linked to various problems such as soil erosion, which reduces yield, or population pressure, which increases demand for food.

The fact that increasing household size increases the likelihood of adaptation is probably because 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 often have a higher probability of adopting agricultural technologies (Buyinza & Wambede 2008) and here adapted better to climate change. The incidence of adaptation to climate change increased with temperature, as has also been shown by Kurukulasuriya & Mendelsohn (2006).

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 that accounts for farm characteristics could reveal more information about factors

Table 3. *Results of the Heckman probit selection model*

	Adaptation model				Selection model			
	Regression		Marginal values		Regression		Marginal values	
Explanatory variables	Coefficients	*P*-value	Coefficients	*P*-value	Coefficients	*P*-value	Coefficients	*P*-value
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 the household head	0·580	0·010	0·177	0·012				
Age of the household head					0·018	0·000	0·004	0·000
Farm income					0·0000566	0·000	0·000013	0·000
Non-farm income	0·000149	0·143	0·0000455	0·144	−0·000011	0·911	−0·00000254	0·911
Livestock ownership	1·012	0·003	0·309	0·004				
Extension on crop and 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 *Got*					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 *Kola*					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, $P<0·001$							
Wald Chi square (independent equations)	10·84, $P=0·001$							

dictating adaptation to climate change at the farm or plot level. The negative relationship between average annual precipitation and adaptation probably reflects that increasing precipitation relaxes the constraint imposed by increasing temperature on crop growth.

Most of the above factors identified as affecting the perception of and adaptation to climate change in the Nile basin of Ethiopia are directly related to the development of institutions and infrastructure. This is in line with the current Ethiopian government policy of poverty reduction and accelerated development through investment in education to enhance human capacity, infrastructure, such as roads and telecommunications, and institutions, such as credit facilities both in urban and rural areas (Ministry of Finance and Economic Development: MoFED 2007). Although the current effort by the government assists in enhancing adaptive capacity, more needs to be done in terms of effective adaptation to climate change to protect the already weak agricultural sector. Future policy could focus on creating awareness of climate change and facilitating the development and adoption of adaptation technologies.

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