INTERNATIONAL FOOD
POLICY RESEARCH INSTITUTE
sustainable solutions for ending hunger and poverty
Supported by the CGIAR

IFPRI Discussion Paper 00798

September 2008

Analyzing the Determinants of Farmers' Choice of Adaptation Methods and Perceptions of Climate Change in the Nile Basin of Ethiopia

Temesgen Deressa

R. M. Hassan

Tekie Alemu

Mahmud Yesuf

Claudia Ringler

Environment and Production Technology Division

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

The International Food Policy Research Institute (IFPRI) was established in 1975. IFPRI is one of 15 agricultural research centers that receive principal funding from governments, private foundations, and international and regional organizations, most of which are members of the Consultative Group on International Agricultural Research (CGIAR).

FINANCIAL CONTRIBUTORS AND PARTNERS

IFPRI's research, capacity strengthening, and communications work is made possible by its financial contributors and partners. IFPRI receives its principal funding from governments, private foundations, and international and regional organizations, most of which are members of the Consultative Group on International Agricultural Research (CGIAR). IFPRI gratefully acknowledges the generous unrestricted funding from Australia, Canada, China, Finland, France, Germany, India, Ireland, Italy, Japan, Netherlands, Norway, South Africa, Sweden, Switzerland, United Kingdom, United States, and World Bank.

AUTHORS

Temesgen Deressa, University of Pretoria
Ph.D. Student, Centre for Environmental Economics and Policy for Africa

R. M. Hassan, University of Pretoria
Director, Centre for Environmental Economics and Policy for Africa

Tekie Alemu, Environmental Economics Policy Forum/Ethiopian Development Research Institute
Senior Research Fellow

Mahmud Yesuf, Environmental Economics Policy Forum/Ethiopian Development Research Institute
Senior Research Fellow

Claudia Ringler, International Food Policy Research Institute
Senior Research Fellow, Environment Production and Technology Division

Notices

[1] Effective January 2007, the Discussion Paper series within each division and the Director General's Office of IFPRI were merged into one IFPRI–wide Discussion Paper series. The new series begins with number 00689, reflecting the prior publication of 688 discussion papers within the dispersed series. The earlier series are available on IFPRI's website at www.ifpri.org/pubs/otherpubs.htm#dp.

[2] IFPRI Discussion Papers contain preliminary material and research results. They have not been subject to formal external reviews managed by IFPRI's Publications Review Committee but have been reviewed by at least one internal and/or external reviewer. They are circulated in order to stimulate discussion and critical comment.

Contents

List of Tables

List of Figures

ACKNOWLEDGMENTS

This work is supported by the Federal Ministry for Economic Cooperation and Development, Germany under the project "Food and Water Security under Global Change: Developing Adaptive Capacity with a Focus on Rural Africa," and forms part of the CGIAR Challenge Program on Water and Food. The authors would like to thank Wisdom Akpalu, Elizabeth Bryan, and Edward Kato for reviewing this report and giving constructive comments. Tim Sulser and Menale Kassie contributed much to this research by participating in the pretesting stage and adjusting the questionnaire accordingly. The views expressed are the authors' alone.

ABSTRACT

This study identifies the major methods used by farmers to adapt to climate change in the Nile Basin of Ethiopia, the factors that affect their choice of method, and the barriers to adaptation. The methods identified include use of different crop varieties, tree planting, soil conservation, early and late planting, and irrigation. Results from the discrete choice model employed indicate that the level of education, gender, age, and wealth of the head of household; access to extension and credit; information on climate, social capital, agroecological settings, and temperature all influence farmers' choices. The main barriers include lack of information on adaptation methods and financial constraints. Moreover, the analysis reveals that age of the household head, wealth, information on climate change, social capital, and agroecological settings have significant effects on farmers' perceptions of climate change."

Keywords: adaptation, perception on climate change, Nile Basin of Ethiopia

ABBREVIATIONS AND ACRONYMS

IPCC	Intergovernmental Panel on Climate Change
CSA	Central Statistics Authority
NMSA	National Meteorological Services Agency
MEDaC	Ministry of Economic Development and Cooperation
MoA	Ministry of Agriculture
CSA	Central Statistics Authority
EDRI	Ethiopian Development Research Institute
SNNP	Southern Nations Nationalities and Peoples
MoWR	Ministry of Water Resources
CIMMYT	International Maize and Wheat Improvement Center

1. INTRODUCTION

Studies indicate that Africa's agriculture is negatively affected by climate change (Pearce et al. 1996; McCarthy et al. 2001). Adaptation is one of the policy options for reducing 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 better suited to drier conditions, irrigation, crop diversification, adoption of mixed crop and livestock farming systems, and changing planting dates (Bradshaw, Dolan, and Smit 2004; Kurukulasuriya and Mendelsohn ,2006a; Nhemachena and Hassan 2007).

Agriculture is the main sector of the Ethiopian economy. It contributes about 52 percent of the GDP, generates more than 85 percent of the foreign exchange earnings, and employs about 80 percent of the population (CSA 2004). Despite its high contribution to the overall economy, this sector is challenged by many factors, of which climate-related disasters like drought and flood (often causing famine), are the major ones (Deressa 2007). Knowledge of the adaptation methods and factors affecting farmers' choices enhances policies directed toward 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 for coping with adverse impacts of climate change on crop and livestock production, but it failed to indicate the factors that dictate the choice of adaptation measures. Deressa (2007) employed the Ricardian approach to estimate the monetary impact of climate change on Ethiopian agriculture. Even though, the applied approach includes adaptation, it does not identify the determinants of each of the adaptation methods used by farmers. Additionally, adaptation to climate change is a two-step process: first, the household must perceive that the climate is changing and then respond to changes through adaptation.

Until now, no study has attempted to identify the factors that affect households' choice of adaptation methods and perceptions of climate change in Ethiopia. Thus, the objective of this study is to identify those factors in order to guide policymakers on ways to promote adaptation. This paper is organized as follows: Chapter 2 describes the agriculture sector and climate of Ethiopia. Chapter 3 discusses the study area and data. Chapter 4 describes the analytical models. Chapter 5 gives model results, and Chapter 6 presents the conclusions and policy implications.

2. AGRICULTURE AND CLIMATE IN ETHIOPIA

Agriculture

Small-scale, mixed crop and livestock farmers dominate the agricultural sector, which is the mainstay of the country's economy. Based on variations in agroecological settings, five major farming systems exist in Ethiopia. These are the highland mixed farming system, the lowland mixed agriculture, the pastoral system, shifting cultivation, and commercial agriculture (Befekadu and Berhanu 2000). The highland areas constitute about 45 percent of the total crop area, including about four–fifths of the total population and supporting about 70 percent of the livestock population of the country.

Under these diverse farming systems, different varieties of crops and species of livestock are produced. The major crops grown include cereals, pulses, oil seeds, spices and herbs, stimulants, fruits, sugarcane, fibers, vegetables, and root and tuber crops. The major livestock species raised include cattle, sheep, goats, camels, donkeys, horses, mules, poultry, and pigs. Crop production is estimated to contribute on average about 60 percent of the total agricultural value, while livestock accounts for about 27 percent and forestry and other subsectors account for about 13 percent (MEDaC 1999).

The potential for growing different varieties of crops and keeping different species of livestock across the diverse farming systems of Ethiopia is high. For instance, about 73.6 million hectares (66 percent) of the country's land area is estimated to be potentially suitable for agricultural production (MEDaC 1999). Despite this huge potential, the country has remained unable to feed its people for many years due to a number of socioeconomic and environmental constraints.

The major socioeconomic constraints in crop production include inappropriate polices; declining farm size and subsistence farming due to population growth; land degradation due to inappropriate use of land, such as cultivation of steep slopes; and over cultivation and overgrazing. Additionally, tenure insecurity, weak agricultural research and extension services, lack of agricultural marketing, inadequate transport networks, inadequate use of agricultural inputs, and the use of backward technologies are other constraints. The major causes of poor production in the livestock subsector include inadequate feed and nutrition, low level of veterinary care, occurrence of diseases, poor genetic structure, inadequate budget allocation, limited infrastructure, and limited research on livestock. The major environmental problem in both crop and livestock production is recurrent droughts, hailstorms, floods, and pest incidence (Befekadu and Berhanu 2000).

The specifically climate-related constraint, recurrent drought, is the most damaging because it has made the country dependent on food aid. Thus, future efforts should emphasize increasing understanding of the complex interdependence between the climatic conditions and Ethiopian agriculture, in addition to addressing the other socioeconomic problems.

Climate

The climate of Ethiopia is mainly controlled by the seasonal migration of the Inter-tropical Convergence Zone (ITCZ), which follows the position of the sun relative to the earth and the associated atmospheric circulation, in conjunction with the complex topography of the country (NMSA 2001). There are different ways of classifying the climatic systems of Ethiopia, including the traditional, the Köppen's, the Throthwaite's, the rainfall regimes, and the agroclimatic zone classification systems (Yohannes 2003).

The most commonly used classification systems are the traditional and the agroclimatic zones. According to the traditional classification system, which mainly relies on altitude and temperature for classification, Ethiopia has five climatic zones (Table 1).

Table 1. Traditional climatic zones and their physical characteristics

Zone	Altitude (meters)	Rainfall (mm/year)	Average annual temperature (^oC)
Wurch(upper highlands)	3200 plus	900 – 2200	>11.5
Dega(highlands)	2,300 – 3,200	900 – 1,200	17.5/16.0–11.5
Weynadega(midlands)	1,500 – 2,300	800 – 1,200	20.0–17.5/16.0
Kola(lowlands)	500 – 1,500	200 – 800	27.5 – 20.0
Berha(desert)	Under 500	Under 200	>27.5

Source: MoA 2000.

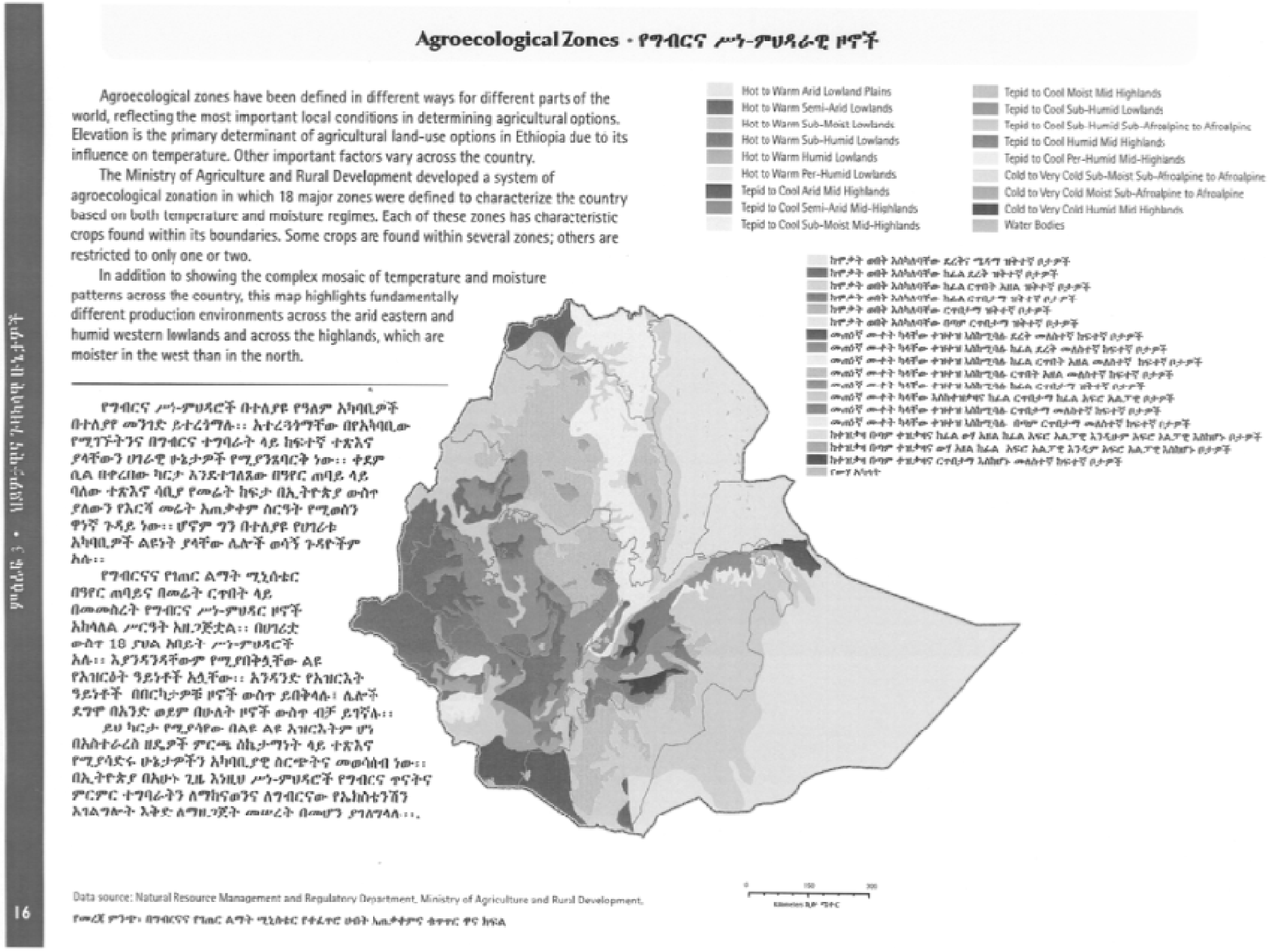
The agroecological classification method is based on combining growing periods with temperature and moisture regimes. According to the agroecological zone classification system, Ethiopia has 18 major agroecological zones, which are further subdivided into 49 subagroecological zones (Figure 1). These agroecologies are also grouped under six major categories (MoA 2000), which include the following:

1. Arid zone: This zone is less productive and pastoral, occupying 53.5 million hectares (31.5 percent of the country).
2. Semi-arid: This area is less harsh and occupies 4 million hectares (3.5 percent of the country).
3. Submoist: This zone occupies 22.2 million hectares (19.7 percent of the country), highly threatened by erosion.
4. Moist: This agroecology covers 28 million hectares (25 percent of the country) of the most important agricultural land of the country, and cereals are the dominant crops.
5. Subhumid and humid: These zones cover 17.5 million hectares (15.5 percent of the country) and 4.4 million hectares (4 percent of the country), respectively; they provide the most stable and ideal conditions for annual and perennial crops and are home to the remaining forest and wildlife, having the most biological diversity.
6. Per-humid: This zone covers about 1 million hectares (close to 1 percent of the country) and is suited for perennial crops and forests.

Over these diverse agroecological settings, mean annual rainfall and temperature vary widely. Mean annual rainfall ranges from about 2,000 millimeters over some pocket areas in the southwest to less than 250 millimeters over the Afar lowlands in the northeast and Ogaden in the southeast. Mean annual temperature varies from about 10^0C over the high table lands of the northwest, central, and southeast to about 35^0C on the northeastern edges.

In addition to variations in different parts of the country, the Ethiopian climate is also characterized by a history of climate extremes, such as drought and flood, and increasing and decreasing trends in temperature and precipitation, respectively. The history of climate extremes, especially drought, is not a new phenomenon in Ethiopia. Recorded history of drought in Ethiopia dates back to 250 BC, and since then droughts have occurred in different parts of the country at different times (Webb, von Braun, and Yohannes 1992). Even though there has been a long history of drought, studies show that the frequency of drought has increased over the past few decades, especially in the lowlands (Lautze et al. 2003).

Figure 1. Agroecological zones of Ethiopia



Source: IFPRI, CSA, and EDRI 2006

Studies also indicate that mean temperature and precipitation have been changing over time. According to NMSA (2001), the average annual minimum temperature over the country has been increasing by about 0.25^{o}C every 10 years, while average annual maximum temperature has been increasing by about 0.1^{o}C every decade. Even though the change in precipitation is not as pronounced as the change in temperature, there is a decreasing trend (NMSA 2001).

Knowledge of the climatic conditions of the country and the adaptation options available to farmers will assist policy aimed at decreasing vulnerability of farmers to future climate changes. The next chapter discusses the data sources, study area, and the methods employed to analyze the determinants of farmers' choice of adaptation methods and perceptions of climate change.

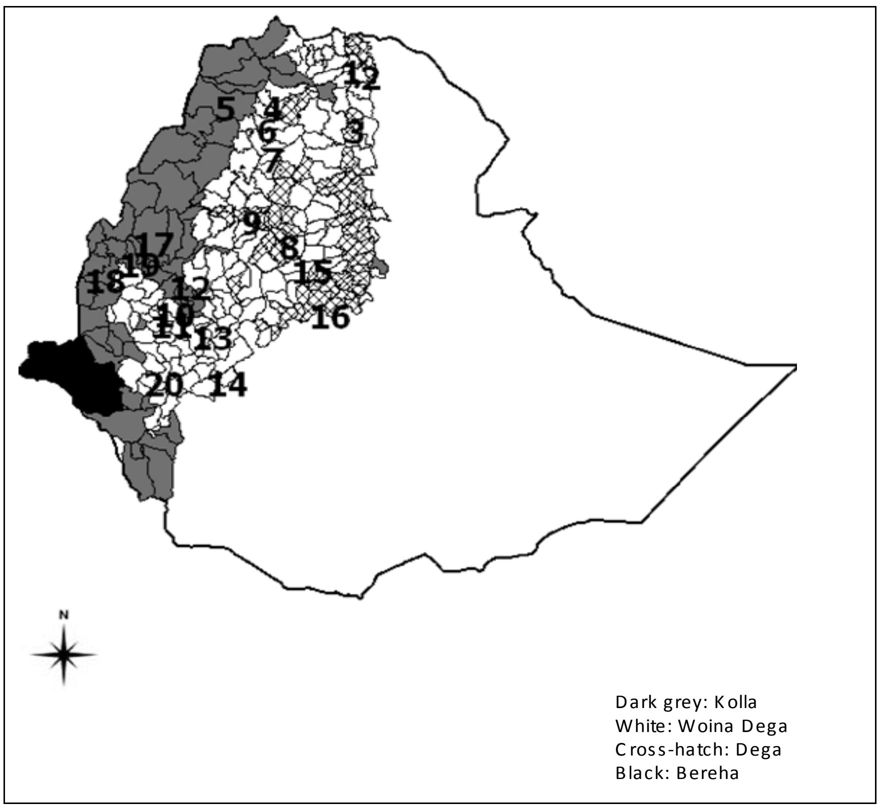
3. STUDY AREA AND DATA

Study Area

The study area for this research is the Nile Basin of Ethiopia, which covers a total area of about 358,889 square kilometers—equivalent to 34 percent of the total geographic area of the country. Moreover, about 40 percent of the population of Ethiopia lives in this basin. The basin covers six regional states of Ethiopia in different proportions: 38 percent of the total land area of Amhara, 24 percent of Oromiya, 15 percent of Benishangul-Gumuz, 11 percent of Tigray, 7 percent of Gambella, and 5 percent of Southern Nations Nationalities and Peoples (SNNP) Regional States (MoWR 1998).

This basin consists of three major rivers: the Abbay River, which originates in the central highlands; Tekeze River, which originates in the northwest; and Baro-Akobo River, which originates in the southwestern part of the country. The total annual surface runoff of the three rivers is estimated at 80.83 billion cubic meters per year, which amounts to nearly 74 of Ethiopia's 12 river basins (MoWR 1998). Almost all of the traditional agroecological zones of Ethiopia are also found in the Nile Basin of Ethiopia (Figure 2).

Figure 2. Nile Basin of Ethiopia, its traditional agroecological classifications, and survey districts



Data

The International Food Policy Research Institute (IFPRI) in collaboration with the Ethiopian Development Research Institute (EDRI) collected the data for this study. A cross-sectional household survey of farmers was conducted during the 2004/05 production year in the Nile Basin of Ethiopia. The household survey covered five regional states of Ethiopia, 20 districts, and 1,000 households (Table 2). The sample districts were purposely selected to include different attributes of the basin, including the traditional typology of agroecological zones in the country, the degree of irrigation activity (percent of cultivated land), average annual rainfall, rainfall variability, and vulnerability (the food aid-dependent population).

Table 2. Survey districts and peasant associations

Region	Zone	Districts	Peasant associations	Number of households
Tigray	East Tigray	Hawzein	Selam	50
		Atsbi Wonberta	Felege Woinie	50
	South Tigray	Endamehoni	Mehan	50
Amhara	North Gondar	Debark	Mekara	50
		Chilga	Teber Serako	50
		Wogera	Sak Debir	50
	South Gondar	Libo Kemkem	Angot	50
	East Gojam	Bichena	Aratband Bichena	50
	West Gojam	Quarit	Gebez	50
Oromiya	West Wellega	Gimbi	Were Sayo	50
		Haru	Genti Abo	50
	East Shoa	Bereh Aleltu	Welgewo	50
	East Shoa	Hidabu Abote	Sira marase	50
	East Wellega	Limu	Areb Gebeya	50
		Nunu Kumba	Bachu	50
	Jimma	Kersa	Merewa	50
Benishangul Gumuz	Metekel	Wonbera	Addis Alem	50
	Asosa	Bambasi	Sonka	50
	Kamashi	Sirba Abay	Koncho	50
SNNP	Zone 1	Gesha Daka	Kicho	50
Total				1,000

Peasant associations (administrative units smaller than districts) were also purposely selected to include households that irrigate their farms. One peasant association is selected from every district, making a total of 20 each. Once the peasant associations were chosen, 50 farmers were randomly selected from each peasant association, making 1,000 the total number of households interviewed.

The data set collected has 10 major parts, which include household characteristics, incidence of different climatic and other shocks over the past five years, food aid, land tenure, machinery ownership, rainfed and irrigated agriculture, livestock production, access to credit, market and extension, expenditure on food and income, perceptions of climate change, adaptation options, and social capital.

4. ANALYTICAL METHODS

Two types of analytical models are adopted for this study. The first model analyzes what determinates the method farmers choose to adapt to climate change, whereas the second model examines the farmers perceptions of and adaptations to climate change in the Nile Basin of Ethiopia.

Analysis of the Determinants of Farmers' Choice of Adaptation Methods

Analytical Framework

The decision on whether or not to adopt a new technology (an adaptation method in this case) is considered under the general framework of utility or profit maximization (Norris and Batie 1987; Pryanishnikov and Katarina 2003). It is assumed that economic agents, including smallholder subsistence farmers, use adaptation methods only when the perceived utility or net benefit from using such a method is significantly greater than is the case without it. Although utility is not directly observed, the actions of economic agents are observed through the choices they make. Suppose that Y_j and Y_k represent a household's utility for two choices, which are denoted by U_j and U_k , respectively. The linear random utility model could then be specified as:

$$U_j = \beta' X_i + \varepsilon_j \ and\ U_k = \beta'_k X_i + \varepsilon_k \tag{1}$$

where U_j and U_k are perceived utilities of adaptation methods *j* and *k*, respectively, X_i is the vector of explanatory variables that influence the perceived desirability of the method, B_j and B_k are parameters to be estimated, and ε_j and ε_k are error terms assumed to be independently and identically distributed (Green 2000).

In the case of climate change adaptation methods, if a household decides to use option *j*, it follows that the perceived utility or benefit from option *j* is greater than the utility from other options (say *k*) depicted as:

$$U_{ij}(\beta_j' X_i + \varepsilon_j) > (U_{ik}(\beta_k' X_i + \varepsilon_k), k \neq j \tag{2}$$

The probability that a household will use method *j* among the set of climate change adaptation options could then be defined as

$$\begin{aligned} & P(Y=1 \mid X) = P(U_{ij} > U_{ik} \\ & P(\beta_j' X_i + \varepsilon_j - \beta_k' X_i - \varepsilon_k > 0 \mid X) \\ & P(\beta_j' X_i - \beta_k' X_i + \varepsilon_j - \varepsilon_k > 0 \mid X) \\ & P(X^* X_i + \varepsilon^* > 0 \mid X = F(\beta^* X_i) \end{aligned} \tag{3}$$

where *P* is a probability function, U_{ij}, U_{ik}, and X_i are as defined above, $\varepsilon^* = \varepsilon_j - \varepsilon_k$ is a random disturbance term, $\beta_j^* = (\beta_j' - \beta_k')$ is a vector of unknown parameters that can be interpreted as a net influence of the vector of independent variables influencing adaptation, and $F(B^* X_i)$ is a cumulative distribution function of ε^* evaluated at $B^* X_i$. The exact distribution of *F* depends on the distribution of the random disturbance term, ε^*. Depending on the assumed distribution that the random disturbance term follows, several qualitative choice models can be estimated (Green 2000).

Empirical Model

The multinomial logit (MNL) model is used for this analysis. This method can be used to analyze crop (Kurukulasuriya and Mendelsohn 2006b) and livestock (Seo and Mendelsohn 2006) choices as methods to adapt to the negative impacts of climate change. The advantage of the MNL is that it permits the analysis of decisions across more than two categories, allowing the determination of choice probabilities for different categories (Madalla 1983; Wooldridge 2002). Moreover, Koch (2007) emphasizes the usefulness of this model by describing the ease of interpreting estimates from this model.

To describe the MNL model, let y denote a random variable taking on the values $\{1,\ 2...J\}$ for J, a positive integer, and let ***x*** denote a set of conditioning variables. In this case, y denotes adaptation options or categories and ***x*** contains household attributes like age, education, income levels, and so forth. The question is how cetirus paribus changes in the elements of ***x*** affect the response probabilities $P(y = j / x),\ \ j = 1,\ 2,....J$. Since the probabilities must sum to unity, $P(y = j / x)$ is determined once we know the probabilities for $j = 2,...J$.

Let ***x*** be a $1 \times K$ vector with first element unity. The MNL model has response probabilities:

$$P(y = j \mid x) = \exp(x\beta_j) / \left[1 + \sum_{h=1}^{J} \exp(x\beta_h),\ \ j = 1,.....J \right] \tag{4}$$

where $B_j\ is\ K \times 1,\ \ j = 1.....J.$

For this study, the adaptation options or response probabilities are six:

1. No adaptation
2. Soil conservation
3. Use of different crop varieties
4. Planting trees
5. Changing planting dates
6. Irrigation

Unbiased and consistent parameter estimates of the MNL model in equation (1) require the assumption of independence of irrelevant alternatives (IIA) to hold. More specifically, the IIA assumption requires that the probability of using a certain adaptation method by a given household needs to be independent from the probability of choosing another adaptation method (that is, P_j/P_k is independent of the remaining probabilities). The premise of the IIA assumption is the independent and homoscedastic disturbance terms of the basic model in equation (1).

The parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent (response) variable, but estimates do not represent either the actual magnitude of change nor probabilities. Differentiating equation (1) with respect to the explanatory variables provides marginal effects of the explanatory variables given as:

$$\frac{\partial P_j}{\partial x_k} = P_j (\beta_{jk} - \sum_{J=1}^{J-1} P_j \beta_{jk}) \tag{5}$$

The marginal effects or marginal probabilities are functions of the probability itself and measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable from the mean (Green 2000; Koch 2007).

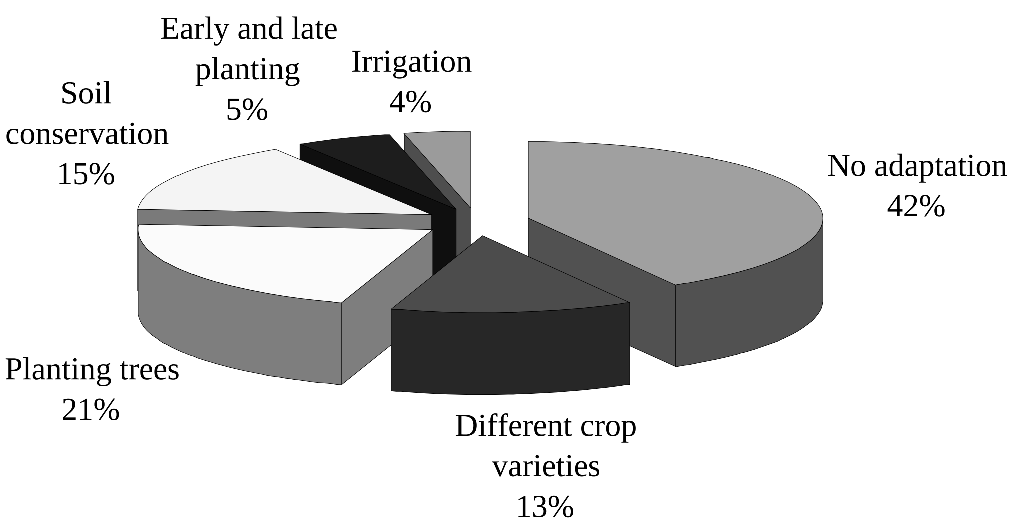
Model Variables

Dependent Variables (Adaptation Options)

The climate change research community has identified different adaptation methods. The adaptation methods most commonly cited in literature include the use of new crop varieties and livestock species that are more suited to drier conditions, irrigation, crop diversification, mixed crop livestock farming systems, change of planting dates, diversification from farm to nonfarm activities, increased use of water and soil conservation techniques, changed use of capital and labor, and trees planted for shade and shelter (Bradshaw, Dolan, and Smit 2004; Kurukulasuriya and Mendelsohn 2006a; Maddison 2006; Nhemachena and Hassan2007).

The adaptation methods for this study are based on asking farmers about their perceptions of climate change and the actions they take to counteract the negative impacts of climate change (Figure 3). The adaptation measures that farmers report may be profit driven, rather than climate change driven. Despite this missing link, we assume that their actions are driven by climatic factors, as reported by farmers themselves in the studies by Maddison (2006) and Nhemachena and Hassan (2007).

Figure 3. Farmers adapting to climate change

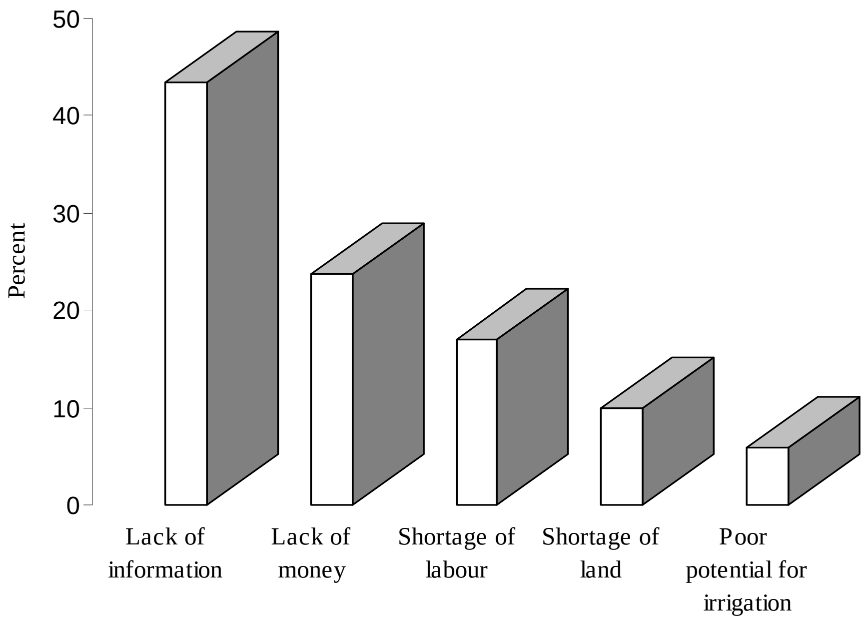


As indicated in Figure 3, use of different crop varieties is the most commonly used method, whereas use of irrigation is the adaptation least practiced among the major adaptation methods identified in the Nile Basin of Ethiopia. Greater use of different crop varieties as an adaptation method could be associated with the lower expense and ease of access by farmers, while the limited use of irrigation could be attributed to the need for more capital and low potential for irrigation. Moreover, about 42 percent of the surveyed farmers reported not to have taken any adaptation method for a number of reasons, discussed below.

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 labor, shortage of land, and poor potential for irrigation (Figure 4). Most of these constraints are associated with poverty. For instance, lack of information on appropriate adaptation options could be attributed to the dearth of research on climate change and adaptation options in the country. Lack of money hinders farmers from getting the necessary resources and technologies that facilitate adapting to climate change. Adaptation to climate change is costly (Mendelson 2004), and the need for intensive labor use may contribute to this cost. Thus, if farmers do not have sufficient family labor or the financial means to hire labor, they cannot adapt. Shortage of land has been associated with high population pressure, which forces farmers to intensively farm a small plot of land and makes them unable to prevent further damage by using practices, such as planting trees that compete for agricultural land. Given the fact that the Nile Basin in Ethiopia is very rich in water resources (FAO 1997), poor irrigation potential is most likely associated with the inability of farmers to use the water that is already there, due to technological incapability. Farmers in Ethiopia in general are very poor and cannot afford to invest in irrigation technology to adapt to climate change or sustain their livelihoods during harsh climatic extremes, such as drought.

Figure 4. Barriers to adaptation



Independent Variables

Different household and farm characteristics, infrastructure, and institutional factors influence the use of adaptation methods by farmers. The most commonly cited household characteristics include age, education, farming experience, marital status, gender of the head of household, and wealth. Farm characteristics include farm size, fertility, and slope; institutional factors include access to extension and credit; and infrastructure includes distance to input and output markets (Maddison 2006; Nhemachena and Hassan 2007).

The explanatory variables for this study include household characteristics such as education, gender, age of the household head, household size, farm and nonfarm income, and livestock ownership; institutional factors such as extension services on crop and livestock production, information on climate, access to credit, social capital, which includes farmer-to-farmer extension services and the number of relatives in the "g*ot*;"[1] the local area, and agroecological characteristics such as temperature and rainfall.

Higher level of education is believed to be associated with access to information on improved technologies and higher productivity (Norris and Batie 1987). Evidence from various sources indicates

[1] "*Got*" means "a local place."

that there is a positive relationship between the education level of the household head and the adoption of improved technologies (Igoden, Ohoji, and Ekpare 1990; Lin 1991) and adaptation to climate change (Maddison 2006). Therefore, farmers with higher levels of education are more likely to adapt better to climate change.

Male-headed households are more likely to get information about new technologies and undertake risky businesses than female-headed households (Asfaw and Admassie 2004). Moreover, Tenge De Graffe and Heller (2004) argue that having a female head of household may have negative effects on the adoption of soil and water conservation measures, because women may have limited access to information, land, and other resources due to traditional social barriers. A study by Nhemachena and Hassan (2007) finds contrary results, arguing that female-headed households are more likely to take up climate change adaptation methods. The authors conclude that women are more likely to adapt because they are responsible for much of the agricultural work in the region and therefore have greater experience and access to information on various management and farming practices. Thus, the adoptions of new technologies or adaptation methods appear to be rather context specific.

Age of the head of household can be used to capture farming experience. On the one hand, studies in Ethiopia have shown a positive relationship between number of years of experience in agriculture and the adoption of improved agricultural technologies (Kebede, Kunjal, and Coffin 1990), while a study by Shiferaw and Holden (1998) indicates a negative relationship between age and adoption of improved soil conservation practices. On the other hand, studies by Maddison (2006) and Nhemachena and Hassan (2007) indicate that experience in farming increases the probability of uptake of adaptation measures to climate change. This study hypothesizes that experience increases the probability of adapting 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 families may be forced to divert part of the labor force to off-farm activities in an attempt to earn income in order to ease the consumption pressure imposed by a large family (Yirga 2007). The other assumption is that large family size is normally associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks. For instance, Croppenstedt, Demeke, and Meschi (2003) argue that households with a larger pool of labor are more likely to adopt agricultural technology and use it more intensively because they have fewer labor shortages at peak times. Here it is expected that households with large families are more likely to adapt to climate change.

Farm and nonfarm income and livestock ownership represent wealth. It is regularly hypothesized that the adoption of agricultural technologies requires sufficient financial wellbeing (Knowler and Bradshaw 2007). Other studies that investigate the impact of income on adoption found a positive correlation (Franzel 1999). Higher-income farmers may be less risk averse and have more access to information, a lower discount rate, and a longer-term planning horizon (CIMMYT 1993).

Livestock plays a very important role by serving as a store of value and by providing traction (especially oxen) and manure required for soil fertility maintenance (Yirga 2007). Thus, for this study, farm and nonfarm income 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 the decision to adapt to climate change. Various studies in developing countries, including Ethiopia, report a strong positive relationship between access to information and the adoption behavior of farmers (Yirga 2007), and that access to information through extension increases the likelihood of adapting to climate change (Maddison 2006; Nhemachena and Hassan 2007). Thus, this study also hypothesizes that access to information increases probability 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. Research on adoption of agricultural technologies indicates that there is a positive relationship between the level of adoption and the availability of credit (Yirga 2007; Pattanayak et al. 2003). Likewise, this study also hypothesizes that there is a positive relationship between availability of credit and adaptation.

Social capital is represented by the number of relatives of a household in the local area and farmer-to-farmer extension. Informal institutions and private social networks play three distinct roles in adoption of agricultural technologies (Hogest 2005, cited in Katungi 2007). First, they act as conduits for financial transfers that may relax the farmer's credit constraints. Second, they act as conduits for information about new technology. Third, social networks can facilitate cooperation to overcome collective action dilemmas, where the adoption of technologies involves externalities. Isham (2002) shows that ethnically based and participatory social affiliations act as forms of social capital in the decision to adopt fertilizer. Thus, this study hypothesizes that social capital positively influences adaptation to change.

Studies on adoption of agricultural technologies indicate that farm size has both negative and positive effects on adoption, showing that the effect of farm size on technology adoption is inconclusive (Bradshaw, Dolan, and Smit 2004). However, because farm size is associated with greater wealth, it is hypothesized to increase adaptation to climate change.

It is hypothesized that as distance to output and input markets increases, adaptation to climate change decreases. 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).

It is also hypothesized that different households living in different agroecological settings use different adaptation methods. This is due to the fact that climatic conditions, soil, and other factors vary across different agroecologies, influencing farmers' perceptions of climate change and their decisions to adapt. Detailed analysis of the relationships between climatic variables such as temperature and rainfall and choice of adaptation methods requires time series data on 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, the analysis includes controls for variations in temperature and rainfall across farm households over the 2004/05 survey period. Table 3 gives the descriptive statistics of the independent variables hypothesized to affect adaptation measures in this study.

Table 3. Description of the independent variables

Explanatory variable	Mean	Std. Dev.	Description
Years of education	1.7035	2.7777	Continuous
Size of household	6.1493	2.2206	Continuous
Gender of the head of household	0.8963	0.3051	Dummy, takes the value of 1 if male and 0 otherwise
Age of the head of household	44.2915	12.6248	Continuous
Farm income	4374.7610	7018.6360	Continuous
Nonfarm income	218.2594	790.9987	Continuous
Livestock ownership	0.9488	0.2205	Dummy takes the value of 1 if owned and 0 otherwise
Extension on crop and livestock	0.5455	0.4982	Dummy, takes the value of 1 if visited and 0 otherwise
Information on climate change	0.3731	0.4839	Dummy takes the value of 1 if there is and 0 otherwise

Table 3. Continued

Explanatory variable	Mean	Std. Dev.	Description
Farmer-to-farmer extension	0.4833	0.5000	Dummy takes the value of 1 if there is and 0 otherwise
Credit	0.2191	0.4138	Dummy takes the value of 1 if there is access and 0 otherwise
Number of relatives in *got*	13.3725	19.4420	Continuous
Farm size in hectares	2.02	1.18	Continues
Distance to output market in kilometers	5.70	4.14	Continues
Distance to input market in kilometers	5.61	4.22	Continues
Local agroecology *kola*(lowlands)	0.25	0.43	Dummy takes the value of 1 if *kola* and zero otherwise.
Local agroecology *weynadega*(midlands)	0.50	0.50	Dummy takes the value of 1 if *weynadega* and zero otherwise.
Local agroecology *dega(highlands)*	0.25	0.43	Dummy takes the value of 1 if *dega* and zero otherwise.
Temperature	18.61	1.34	Continuous, annual average over the 2004–05 survey period
Precipitation	115.64	35.57	Continuous, annual average over the 2004–05 survey period

Analysis of Farmers' Perceptions of and Adaptation to Climate Change

Empirical Model

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, whereas we need to make an inference about adaptation 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 an underlying relationship exists, the latent equation given by

$$y_j^{*} = x_j\beta + u_{1j} \ , \qquad (6)$$

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

$$y_j^{probit} = (y_j^{*} > 0)\,. \qquad (7)$$

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

$$y_j^{select} = (z_j\delta + u_{2j} > 0) \qquad (8)$$

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

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

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

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 (6) 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 analyze 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 considers whether the farmer perceived a climate change; this is the selection model. The second-stage model looks at whether the farmer tried to adapt to climate change, and it is conditional on the first stage, that is, a perceived change in climate. This second stage is the outcome model. The variables hypothesized as affecting perceptions and adaptations to changes in climatic conditions, along with their respective dependent variables, are indicated in Table 4.

Table 4. 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 to have adapted (%)	Description	Farmers perceived change in temperature/ rainfall (%)	Farmers did not perceive 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 household head	44.2915	12.6248
Gender	0.8963	0.3051	Farm income	4374.7610	7018.6360
Nonfarm income	218.2594	790.9987	Nonfarm 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 local relatives	13.3725	19.4420
Farm size in hectares	2.02	1.18	Local agroecology *kola*	0.25	0.43
Distance to output market	5.70	4.14	Local agroecology *dega*	0.25	0.43
Distance to input market	5.61	4.22			
Temperature	18.61	1.34			
Precipitation	115.64	35.57			

Explanatory Variables for the Selection Equation

For the selection equation, it is hypothesized that, education, age of the head of household, farm and nonfarm income, information on climate, farmer-to-farmer extension, number of relatives in the *got* and agroecological setting influence farmers' awareness of climate change. More education is believed to be associated with access to information on improved technologies and higher productivity (Norris and Batie 1987); here, it is hypothesized that farmers with a higher level of education will have more information on climate change. Age of the head of household is assumed to represent farming experience. More experienced farmers are more likely to observe the change in climatic conditions over time.

Higher income (both farm and nonfarm) is often associated with access to information, lower discount rates, and a longer-term planning horizon by farmers (CIMMYT 1993). Therefore, it is hypothesized that higher income increases awareness of climate change. Obviously, access to information on climate change from either extension agents or any other organization is likely to create awareness of climate change. 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 in information sharing (Isham 2002), and hence, it is hypothesized that more social capital is associated with greater awareness of climate change. Moreover, farmers living in lowland areas are hypothesized to be more likely to have perceived climate change than farmers in the midlands and highlands. This is because the lowlands are already hotter and a marginal change in temperature can be perceived more easily.

Explanatory Variables for the Outcome Equation

The variables hypothesized to influence adaptation include education of the head of household, size of household, gender of the head of household, nonfarm income, livestock ownership, extension on crop and livestock production, credit, farm size, and distance to input and output markets. The justification for the inclusion of these variables along with the hypothesized direction of relationship with adaptation has been explained in the first section of this chapter and omitted here to avoid redundancy.

5. MODEL RESULTS AND DISCUSSION

The Determinants of Farmers' Choice of Adaptation Methods

The estimation of the multinomial logit model for this study was undertaken by normalizing one category, which is normally referred to as the "reference state," or the "base category." In this analysis, the first category (no adaptation) is the reference state.

In the initial run, farm size and distance to input and output markets were added to the model, but they were dropped, as they were not significant. Finally, the model was run and tested for the validity of the independence of the irrelevant alternatives (IIA) assumptions by using both the Hausman test for IIA and the seemingly unrelated postestimation procedure (SUEST)[2]. Both tests failed to reject the null hypothesis of independence of the climate change adaptation options, suggesting that the multinomial logit (MNL) specification is appropriate to model climate change adaptation practices of smallholder farmers (χ^2 ranged from –4.63 to 40.73, with probability values ranging from 0.85 to 1.00 in the case of the Hausman test and χ^2 ranging from 13.07 to 20.49, with a P value of 0.20 to 0.67 in the case of SUEST). The estimated coefficients of the MNL model, along with the levels of significance, are presented in Table 5. The likelihood ratio statistics as indicated by χ^2 statistics are highly significant ($P <$ 0.00001), suggesting the model has a strong explanatory power.

As indicated earlier, the parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent (response) variable: estimates do not represent actual magnitude of change or probabilities. Thus, the marginal effects from the MNL, which measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable, are reported and discussed. In all cases the estimated coefficients should be compared with the base category of no adaptation. Moreover, the MNL is run with and without the explanatory variables, such as extension on crop and livestock production and information on climate change and credit availability, assuming these variables to be endogenous, as they are in many studies. The results indicate that the inclusion of these variables does not significantly change the parameters of the estimates (the Hausman test has been employed to compare the models with and without these variables). Table 6 presents the marginal effects along with the levels of statistical significance.

Household Characteristics

Education. Education of the head of household increases the probability of adapting to climate change. As can be observed in Table 6, education significantly increases soil conservation and changing planting dates as an adaptation method. A unit increase in number of years of schooling would result in a 1 percent increase in the probability of soil conservation and a 0.6 percent increase in change in planting dates to adapt to climate change. Moreover, almost all of the marginal values of education are positive across all adaptation options indicating the positive relationship between education and adaptation to climate change.

Household size. For most of the adaptation methods, increasing household size did not significantly increase the probability of adaptation, though the coefficient on the adaptation options has a positive sign. Even though it is not significant, it can be inferred that the larger the size of the household, the better the chance of adapting to climate change.

Gender of the head of household. The results indicate that male-headed households adapt more readily to climate change. Male-headed households were 7.6 percent more likely to plant trees and 2.4 percent more likely to change planting dates. .

Age of the household head. Age of the household head, which represents experience, affected adaptation to climate change. For instance, a unit increase in age of the household head results in a 9 percent increase in the probability of soil conservation, a 12 percent increase in changing of crop varieties, and a 10 percent increase in tree planting.

---

[2] SUEST is a generalization of the classical Hausman specification test useful for intramodel and cross-model hypothesis tests.

Table 5. Parameter estimates of the multinomial logit climate change adaptation model

Explanatory variables	Soil Conservation		Crop varieties		Planting trees		Changing planting date		Irrigation	
	Coefficients.	P level	Coefficients	P level	Coefficients.	P level	Coefficients.	P level	Coefficients.	P level
Education	0.155***	0.003	0.115**	0.017	0.139	0.007	0.223	0.000	0.217	0.011
Household size	0.063	0.270	0.043	0.422	0.074	0.213	-0.113	0.200	0.113	0.275
Gender of household head	1.545**	0.002	1.238***	0.003	1.533	0.003	1.265	0.121	1.277	0.133
Age of household head	0.011	0.294	0.010	0.301	0.042	0.000	0.025	0.095	0.045	0.017
Farm income	6.84E-05***	0.004	8.01E-05	0.000	5.00E-07	0.983	0.000109	0.000	9.52E-05	0.002
Nonfarm income	-0.00012	0.621	4.55E-05	0.817	0.000315	0.087	0.000358	0.07	0.000314	0.153
Livestock ownership	0.632	0.427	-0.166	0.783	0.138	0.833	0.249	0.777	-2.054	0.011
Extension on crop & livestock	0.765**	0.028	0.987	0.002	1.902	0.000	0.466	0.373	1.380	0.063
Information on climate change	0.059	0.874	1.032	0.001	0.173	0.604	0.839	0.079	1.246	0.042
Farmer-to-farmer extension	0.925***	0.007	1.234	0.000	1.554	0.000	1.323	0.012	1.544	0.011
Credit availability	1.278***	0.000	0.487	0.112	0.392	0.231	1.213	0.003	1.942	0.000
Number of relatives in *got*	0.008	0.341	0.010	0.220	0.002	0.814	0.013	0.247	0.003	0.803
Local agroecology *klla*	-0.055	0.881	-1.774	0.000	-1.758	0.000	-0.976	0.055	-2.622	0.001
Local agroecology d*ega*	0.495	0.154	0.352	0.254	-0.353	0.334	0.958	0.093	-0.780	0.253
Temperature	0.414***	0.000	0.445	0.000	0.155	0.240	0.490	0.001	0.571	0.003
Precipitation	-0.047***	0.000	-0.029	0.000	-0.020	0.000	-0.003	0.719	-0.039	0.000
Constant	-8.064***	0.000	-8.939	0.000	-7.009	0.008	-15.315	0.000	-13.515	0.000
Diagnostics										
Base category	No adaptation									
Number of observations	803									
LR Chi- Square	648.24***									
Log likelihood	-901.62									
Pseudo R-Square	0.26									

Notes: ***, **, * = significant at 1%, 5%, and 10% probability level, respectively.

Table 6. Marginal effects from the multinomial logit climate change adaptation model

Explanatory variables	Soil Conservation		Crop varieties		Planting trees		Changing planting date		Irrigation		No adaptation	
	Coeff..	P-level	Coeffi.	P-level	Coeff.	P-level	Coeffi.	P-level	Coeffi.	P-level	Coeff.	P-level
Education	0.010*	0.066	0.007	0.321	0.008	0.144	0.006**	0.013	0.002	0.123	-0.034***	0.000
Household size	0.005	0.412	0.004	0.647	0.007	0.293	-0.006*	0.074	0.001	0.385	-0.011	0.291
Gender of household head	0.088***	0.004	0.116**	0.019	0.096***	0.005	0.022	0.304	0.008	0.346	-0.330***	0.000
Age of household head	-0.0001	0.9010	-0.0006	0.6990	0.0046***	0.000	0.001	0.350	0.0006*	0.0880	-0.0050***	0.0080
Farm income	4.46E-06*	0.0720	1.09E-05***	0.0000	-5.44E-6**	0.0400	3.36E-06***	0.000	1.00E-06**	0.0490	-1.4E-05***	0.0000
Nonfarm income	-2.5E-05	0.2940	-4.84E-06	0.8650	3.83E-05**	0.0310	1.34E-05**	0.049	4.22E-06	0.1810	-2.6E-05	0.5220
Livestock ownership	0.070	0.184	-0.030	0.781	0.027	0.6930	0.012	0.670	-0.099	0.155	0.020	0.855
Extension on crop & livestock	0.011	0.743	0.072	0.129	0.181***	0.000	-0.009	0.659	0.011	0.318	-0.266***	0.000
Information on climate change	-0.042	0.201	0.176***	0.001	-0.031	0.346	0.022	0.306	0.017	0.201	-0.142**	0.021
Farmer-to-farmer extension	0.021	0.525	0.113**	0.017	0.120***	0.002	0.025	0.256	0.013	0.204	-0.291***	0.000
Credit availability	0.129***	0.002	-0.008	0.848	-0.019	0.564	0.038*	0.099	0.038**	0.039	-0.178***	0.000
Number of relatives in *got*	0.0005	0.483	0.001	0.192	-0.0004	0.640	0.0004	0.353	-2.7E-05	0.860	-0.002	0.317
Local agro-ecology *kola*	0.089*	0.055	-0.210***	0.000	-0.128***	0.000	-0.013	0.439	-0.023**	0.014	0.285***	0.000
Local agro-ecology *Dega*	0.050	0.208	0.049	0.320	-0.069**	0.036	0.045	0.181	-0.013	0.117	-0.062	0.316
Temperature	0.026**	0.011	0.055***	0.001	-0.011	0.475	0.012**	0.035	0.006*	0.077	-0.089***	0.000
Precipitation	-0.004**	0.000	-0.003***	0.000	-0.0004	0.394	0.001**	0.020	-0.0004**	0.020	0.007***	0.000

Notes: ***, **, * = significant at 1%, 5%, and 10% probability level, respectively.

Wealth

Farm income. The farm income of the households surveyed has a positive and significant impact on conserving soil, using different crop varieties, and changing planting dates. A unit increase in farm income increases these probabilities by less than 0.01 percent.

Nonfarm income. In addition to farm income, nonfarm income also significantly increases the likelihood of planting trees, changing planting dates, and using irrigation as adaptation options. A unit increase in nonfarm income increases the probability of planting tress and changing planting dates by 0.004 and 0.001 percent, respectively. Nonfarm income showed a negative relationship with the adoption of soil conservation practices and the use of different crop varieties, although these results are not statistically significant.

Livestock ownership. The ownership of livestock is also positively related to most of the adaptation options, even though the marginal impacts are not significant. It is positively related to the adoption of adaptation methods such as conserving soil, planting trees, and changing planting dates. Livestock ownership is negatively related to the use of different crop varieties and irrigation, although not significantly.

Institutional Factors

Crop and livestock extension. As expected, access to crop and livestock extension has a positive and significant impact on planting trees. Having access to crop and livestock production increases the probability of planting trees by 18 percent. Planting trees counteracts different types of environmental damage and provides shade for livestock.

Information on climate change. Information on temperature and rainfall has a significant and positive impact on the likelihood of using different crop varieties: it increases the likelihood of using different crop varieties by 17.6 percent.

Access to credit. Access to credit has a positive and significant impact on the likelihood of using soil conservation, changing planting dates, and using irrigation. This result implies the important role of increased institutional support in promoting the use of adaptation options to reduce the negative impact of climate change

Social Capital

Farmer-to-farmer extension. Having access to farmer-to-farmer extension increases the likelihood of using different crop varieties by 11.3 percent and planting trees by 12 percent. It also appears to increase the use of the other adaptation methods, although the results are not statistically significant.

Number of relatives. Having more relatives in the *got* is also positively related to the likelihood of adoption of most of the adaptation methods, although the coefficients are not statistically significant. The implication of this result is that social networks increase awareness and use of climate change adaptation options.

Environmental factors

Agroecological setting. As expected, different farmers living in different agroecological settings employ different adaptation methods. For instance, farming in the kola zone significantly increases the probability of soil conservation by 8.9 percent, compared with farming in weynadega. However, farming in kola significantly reduces the probability of using different crop varieties, planting trees, and irrigation by 21, 13 and 2.3 percent, respectively, compared with farming in weynadega. Moreover, farming in dega significantly decreases the probability of planting trees by 7 percent, compared with farming in weynadega.

Temperature. Households with higher annual mean temperature over the survey period were more likely to adapt to climate change through the adoption of different practices. A rise in temperature one degree higher than the mean increases the probability of using soil conservation (2.6 percent), different crop varieties (5.5 percent), irrigation (0.6 percent), and changing planting dates (1.2 percent). These results indicate that, with more warming, farmers will conserve soil to preserve the moisture content and use drought-tolerant varieties to cope with increased temperature. Moreover, farmers will vary planting dates so that critical crop growth stages do not coincide with peak temperature periods, and they will irrigate to supplement rain water and to compensate for loss of water associated with increased evapo-transpiration due to increased temperature.

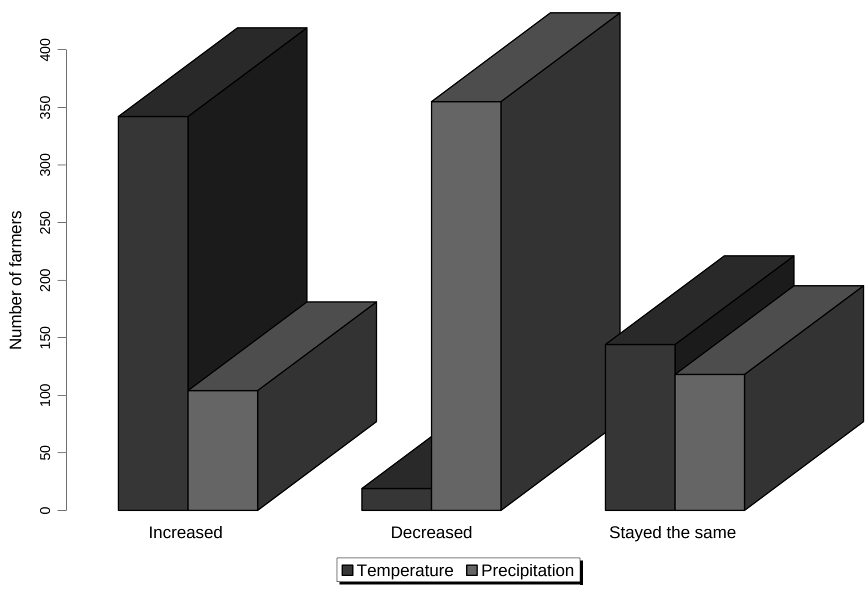
Precipitation. Unlike rising temperatures, higher levels of precipitation over the survey period appear to work in the opposite direction with regard to the likelihood of adoption of adaptation techniques. This indicates that increasing precipitation relaxes the constraints imposed by increased temperature on soil moisture content and thus crop growth. Conversely, the results of this analysis reconfirm that decreasing precipitation significantly increases the likelihood of using soil conservation, changing crop varieties, changing planting dates, and irrigating.

Analysis of Farmers' Perceptions of and Adaptation to Climate Change

Farmer's Perceptions of Climate Change

The analysis of farmers' perceptions of climate change indicates that most of the farmers in this study are aware of the fact that temperature is increasing and the level of precipitation is declining (Figure 5). To get information on their perceptions of climate change, farmers were asked if they have observed any change in temperature or the amount of rainfall over the past 20 years. (To clarify, farmers were also asked whether the number of hot or rainy days had increased, decreased, or stayed the same over the past 20 years.) The responses from the farmers are in line with the report by the National Meteorological Services Agency (NMSA 2001), which depicted an increasing trend in temperature and decreasing trend in precipitation.

Figure 5. Farmers' perceptions of climate change



Perceptions and Adaptation to Climate Change

Although the majority of the farmers interviewed claimed that they had perceived at least one change in climatic attributes, some of these farmers did not respond by taking adaptation measures. Here it is argued that farmers who perceived climate change but did not adapt had some common characteristics.

Examining these characteristics could improve our understanding of the reasons underlying their failure to respond to perceived climate changes, based on the results of the Heckman probit model.

Regression Results

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

The results from the regression indicate that most of the explanatory variables affect the probability of adaptation as expected, except farm size. Variables that positively and significantly influence adaptation to climate change include education of the head of household, household size, and gender of the head of household, livestock ownership, extension on crop and livestock production, and availability of credit and temperature. A one- year increase in the education of the head of household raises the probability of adaptation to climate change by 1.9 percent. Similarly, increasing the size of the household by one person increases the probability of adaptation to climate change by 1.8 percent. This result is in line with the argument assuming that large family size is normally associated with a higher labor endowment, which would enable a household to accomplish various agricultural tasks, especially during peak seasons (Croppenstedt et al. 2003).

Male-headed households are 18 percent more likely to adapt to climate change. This result is in line with the argument that male-headed households are often considered to be more likely to get information about new technologies and take on risk than female-headed households (Asfaw and Admassie 2004). Likewise, increasing livestock ownership, providing extension on crop and livestock production and access to credit, and increasing temperature by one degree increases the probability of adapting to climate change by 31, 30, 13 and 5.5 percent, respectively. The fact that adaptation to climate change increases with higher temperatures is in line 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 because 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. Thus, future research, which accounts for farm characteristics, could reveal more information about factors dictating adaptation to climate change at farm or plot levels. Moreover, the probable reason for the negative relationship between average annual precipitation and adaptation could be due to the fact that, like any African country, Ethiopia's agriculture is water- scarce, and higher levels of precipitation, therefore, will not constrain agricultural production and promote the need to adapt (at least using the main adaptation options considered in this study).

As expected, the likelihood of perceiving 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 the household head by one year increases the probability of perceiving a change in climate by 0.4 percent, whereas increasing farm income by one unit increases perception by 0.13 percent. Likewise, factors that are believed to create awareness of climate change, such as access to information on climate change, access to farmer-to-farmer extension, and number of relatives in the g*ot*, increase the likelihood of adaptation by 8.0, 15.5, and 0.3 percent, respectively.

Contrary to prior expectations, farmers living in *dega* (highlands) were 15.5 percent more likely to perceive changes in climate than farmers in *weynadega*. The model results along with the marginal impacts for both the outcome and selection models are presented in Table 7.

Table 7. 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
Nonfarm 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 *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 agroecology *kola*					0.047	0.761	0.011	0.757
Local agroecology *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 ***							

Notes: ***, **, * = Significant at 1%, 5%, and 10% probability levels, respectively

6. CONCLUSIONS AND POLICY IMPLICATIONS

Farmers adapted to climate change by using different methods, of which the major ones are included in this study. Those who did not use any of the methods considered described lack of information on adaptation methods and lack of money as major constraints to adaptation. The study uses the multinomial logit (MNL) model to investigate the factors guiding household choices of climate change adaptation methods. In the model, the dependent variables include six adaptation options and the explanatory variables include different household, institutional, and social factors. The MNL was run and tested for the assumption of the independence of irrelevant alternatives (IIA) There was no evidence that this assumption was violated when the Heckman and the seemingly unrelated post-estimation procedures (SUEST) were run, justifying the application of the MNL specification to the data.

The marginal effects from the MNL, which measure the expected change in probability of a particular choice being made with respect to a unit change in an independent variable, were presented for their ease of interpretation. The results from the marginal analysis indicate that most of the household variables, wealth attributes, institutional factors (availability of information), social capital, agroecological features, and temperature influence adaptation to climate change in the Nile Basin of Ethiopia.

The analysis of farmers' perceptions of climate change indicates that most of the farmers in the study are aware that temperature is increasing and the level of precipitation is declining. The Heckman probit selection model is employed to analyze the two-stage process of adaptation—perceiving changes in climate conditions in the first stage and then adapting to perceived climate changes in the second stage. The results further indicate that age of the household head, wealth, information on climate change, and social capital positively influence farmers' perceptions of changes in climatic attributes, while factors affecting adaptation are similar to and support the results of the choice model employed earlier. Moreover, farmers living in dega (highlands) places perceived more changes in climate.

These analyses of the constraints to adaptation and the factors that influence farmers' perceptions of and adaptation to climate change in the Nile Basin of Ethiopia suggest a number of different policy options. These options include raising awareness of climate change and the appropriate adaptation methods, facilitating the availability of credit, investing in yield-increasing technology packages to increase farm income, creating opportunities for off-farm employment, conducting research on use of new crop varieties and livestock species that are better suited to drier conditions, encouraging informal social networks, and investing in irrigation.

REFERENCES

Adger, W. N., S. Huq, K. Brown, D. Conway, and M. Hulme. 2003. Adaptation to climate change in the developing world. *Progress in Development Studies* 3: 179–195.

Asfaw, A., and A. Admassie. 2004. The role of education on the adoption of chemical fertilizer under different socioeconomic environments in Ethiopia. *Agricultural Economics* 30 (3): 215–228

Befekadu, D., and N. Berhanu. 2000. *Annual report on the Ethiopian economy*, Vol.1. Ethiopian Economic Association. Addis Ababa, Ethiopia.

Bradshaw B., H. Dolan, and B. Smit. 2004. Farm-level adaptation to climatic variability and change: Crop diversification in the Canadian prairies. *Climatic Change* 67: 119–141.

CIMMYT (International Maize and Wheat Improvement Center). 1993. The adoption of agricultural technology: A guide for survey design. Economics Program. Mexico City, Mexico.

Croppenstedt , A., M. Demeke, and M. M. Meschi. 2003. Technology adoption in the presence of constraints: The case of fertilizer demand in Ethiopia. *Review of Development Economics* 7 (1): 58–70.

CSA (Central Statistics Authority). (2004). *The Federal Democratic Republic of Ethiopia Statistical abstract for 2003.* Addis Ababa.

Deressa, T. 2007. *Measuring the economic impact of climate change on Ethiopian agriculture: Ricardian approach*. World Bank Policy Research Paper No. 4342. Washington D.C.: World Bank.

FAO (Food and Agriculture Organization of the United Nations). 1997. Irrigation potential in Africa: A basin approach. Available at http://www.fao.org/docrep/W4347E/w4347e00.htm#Contents. Accessed June 5, 2008.

Franzel, S. 1999. Socioeconomic factors affecting the adoption potential of improved tree fallows in Africa. *Agroforestry Systems* 47(1–3): 305–321.

Green, W. H. 2000. *Econometric analysis*, 4th ed. Prentice Hall, Upper Saddle River, New Jersey: Prentice-Hall.

IFPRI, CSA, and EDRI. [International Food Policy Research Institute (Washington, D.C.), Central Statistical Agency (Addis Ababa), Ethiopian Development Research Institute (Addis Ababa)]. 2006. Atlas of the Ethiopian rural economy. Available on-line:www.ifpri.org/pubs/books/oc54.asp.

Igoden, C., P. Ohoji, and J. Ekpare. 1990. Factors associated with the adoption of recommended practices for maize production in the Lake Basin of Nigeria. *Agricultural Administration and Extension* 29 (2): 149–156.

IPCC (Intergovernmental Panel on Climate Change). 2001. Climate change: The scientific basis. <http://www.ipcc.ch/>.

Isham, J. 2002. The effect of social capital on fertilizer adoption: Evidence from Rural Tanzania. *Journal of African Economies* 11: 39–60.

Katungi, E. M. 2007. Social capital and technology adoption on small farms: The case of banana production technology in Uganda. PhD. thesis. Department of Agricultural Economics, Extension, and Rural Development, University of Pretoria, South Africa.

Kebede Y., K. Kunjal, and G. Coffin. 1990. Adoption of new technologies in Ethiopian agriculture: The case of Tegulet-Bulga District, Shewa Province. *Agricultural Economics* 4: 27– 43.

Knowler, D., and B. Bradshaw. 2007. Farmers' adoption of conservation agriculture: A review and synthesis of recent research. *Food Policy* 32(1): 25–48.

Koch, S. 2007. Lecture notes presented to students in EKT 816 at the University of Pretoria in South Africa during the fall semester of 2006. University of Pretoria, Pretoria.

Kurukulasuriya, P., and R. Mendelsohn. 2006a . *A Ricardian analysis of the impact of climate change on African crop land.* CEEPA Discussion Paper No. 8. Centre for Environmental Economics and Policy in Africa. Pretoria, South Africa: University of Pretoria.

———. 2006b. *Crop selection: Adapting to climate change in Africa.* CEEPA Discussion Paper No. 26. Centre for Environmental Economics and Policy in Africa. Pretoria, South Africa: University of Pretoria.

Lautze S., Y. Aklilu, A. Raven-Roberts, H. Young, G. Kebede, and J. Learning. 2003. Risk and vulnerability in Ethiopia: Learning from the past, responding to the present, preparing for the future. Report prepared for the U.S. Agency for International Development. Addis Ababa, Ethiopia

Lin, J. 1991. Education and innovation adoption in agriculture: Evidence from hybrid rice in China. *American Journal of Agricultural Economics* 73 (3): 713–723.

Madalla, G. 1983. *Limited dependent and qualitative variables in econometrics*. Cambridge: Cambridge University Press.

Maddison, D. 2006. *The perception of and adaptation to climate change in Africa.* CEEPA. Discussion Paper No. 10. Centre for Environmental Economics and Policy in Africa. Pretoria, South Africa: University of Pretoria.

McCarthy, J., O. F. Canziani, N. A. Leary, D. J. Dokken, and C.White, eds. 2001. *Climate change 2001: Impacts, adaptation, and vulnerability.* Contribution of Working Group II to the third assessment report of the Intergovernmental Panel on Climate Change. Cambridge: Cambridge University Press.

MEDaC (Ministry of Economic Development and Cooperation). 1999. *Survey of Ethiopian economy.* Addis Ababa, Ethiopia.

MoA (Ministry of Agriculture). 2000. *Agroecological zonations of Ethiopia.* Addis Ababa, Ethiopia.

MoWR (Ministry of Water Resources). 1998. Tekeze River Basin Integrated Development Master Plan Project. Executive Summary, FDRE [SPELL OUT] Addis Ababa.

Nhemachena, C., and R. Hassan. 2007. Micro-level analysis of farmers' adaptation to climate change in Southern Africa. IFPRI Discussion Paper No. 00714. International Food Policy Research Institute, Washington, D.C.

NMSA (National Meteorological Services Agency). 2001. Initial national communication of Ethiopia to the United Nations Framework Convention on Climate Change (UNFCCC), Addis Ababa, Ethiopia.

Norris, E., and S. Batie. 1987. Virginia farmers' soil conservation decisions: An application of Tobit analysis. *Southern Journal of Agricultural Economics* 19(1): 89–97.

Pattanayak, S. K., D. E. Mercer, E. Sills, and Y. Jui-Chen. 2003. Taking stock of agroforestry adoption studies. *Agroforestry Systems* 57(3): 173—186.

Pearce, D, W. Cline, A Achanta, S Fankhauser, R Pachauri, R Tol, and P Vellinga 1996. The social costs of climate change: Greenhouse damage and benefits of control. In *Climate change 1995: Economic and social dimensions of climate change,* ed. J. Bruce, H. Lee, and E. Haites. Cambridge: Cambridge University Press.

Pryanishnikov, I., and Z. Katarina. 2003. Multinomial logit models for Australian labor market. *Australian Journal of Statistics* 4: 267–282.

Seo, N., and R. Mendelsohn. 2006. *Climate change adaptation in Africa: A microeconomic analysis of livestock choice.* CEEPA Discussion Paper No. 19. Centre for Environmental Economics and Policy in Africa. Pretoria, South Africa: University of Pretoria.

Shiferaw, B., and S. Holden. 1998. Resource degradation and adoption of land conservation technologies in the Ethiopian highlands: Case study in Andit Tid , North Shewa. *Agricultural Economics* 27 (4): 739–752.

StataCorp. 2003. *Stata base reference manual,* Vol. 4, G – M, release 8. College Station, Tex., USA: Stata Corporation.

Tenge, J. De Graaff, and J. P. Hella . 2004. Social and economic factors affecting the adoption of soil and water conservation in West Usambara highlands, Tanzania. *Land Degradation and Development* 15(2): 99 –114.

Webb, P., J. von Braun, and Y. Yohannes. 1992. *Famine in Ethiopia: Policy implications of coping failure at national and household levels.* Research Report No. 92. Washington, D.C.: International Food Policy Research Institute.

Wooldridge, J. M. 2002. *Econometric analysis of cross section and panel data.* Cambridge, Mass.: MIT Press.

Yirga, C. T. 2007. The dynamics of soil degradation and incentives for optimal management in Central Highlands of Ethiopia. PhD thesis. Department of Agricultural Economics, Extension, and Rural Development. University of Pretoria, South Africa.

Yohannes, G. 2003. Ethiopia in view of the National Adaptation Program of Action. National Meteorological Services Agency, Addis Ababa, Ethiopia.

RECENT IFPRI DISCUSSION PAPERS

For earlier discussion papers, please go to www.ifpri.org/pubs/pubs.htm#dp.
All discussion papers can be downloaded free of charge.

797. *Economic transformation in theory and practice. What are the messages for Afric?* Clemens Breisinger and Xinshen Diao, 2008.

796. *Biosafety at the crossroads: An analysis of South Africa's marketing and trade policies for genetically modified products.* Guillaume P. Gruère and Debdatta Sengupta, 2008.

795. *Publish or patent? Knowledge dissemination in agricultural biotechnology*. An Michiels and Bonwoo Koo, 2008.

794. *Agricultural growth and investment options for poverty reduction in Malawi.* Samuel Benin, James Thurlow, Xinshen Diao, Christen McCool, Franklin Simtowe, 2008.

793. *China: Shadow WTO agricultural domestic support notifications*. Fuzhi Cheng, 2008.

792. *India: Shadow WTO agricultural domestic support notifications*. Munisamy Gopinath, 2008.

791. *Agricultural growth and investment options for poverty reduction in Zambia.* James Thurlow, Samuel Benin, Xinshen Diao, Henrietta Kalinda, and Thomson Kalinda, 2008.

790. *Agricultural growth and investment options for poverty reduction in Uganda*. Samuel Benin, James Thurlow, Xinshen Diao, Allen Kebba, Nelson Ofwono, 2008.

789. *Agricultural public spending in Nigeria*. Tewodaj Mogues, Michael Morris, Lev Freinkman, Abimbola Adubi, and Simeon Ehui; *with* Chinedum Nwoko, Olufemi Taiwo, Caroline Nege, Patrick Okonji, and Louis Chete, 2008.

788. *Choosing sensitive agricultural products in trade negotiations*. Sébastien Jean**,** David Laborde, and Will Martin, 2008.

787. *An Updated Look at the Recovery of Agricultural Productivity in Sub-Saharan Africa*. Alejandro Nin Pratt and Bingxin Yu. 2008

786. *Migration, Poverty, and Inequality: Evidence from Burkina Faso*. F.S. Wouterse. 2008

785. *Insecticide use on vegetables in Ghana: Would GM seed benefit farmers?* Daniela Horna, Melinda Smale, Ramatu Al-Hassan, José Falck-Zepeda, and Samuel E. Timpo, 2008.

784. *Agriculture for development in Ghana: New opportunities and challenges*. Clemens Breisinger, Xinshen Diao, James Thurlow, and Ramatu M. Al-Hassan, 2008.

783. *Understanding the investment and abandonment behavior of poor households: An empirical investigation*. Ruth Vargas Hill, 2008.

782. *Access to irrigation and the escape from poverty: Evidence from Northern Mali*. Andrew Dillon, 2008.

781. *Structural changes in the Philippine pig industry and their environmental implications*. Maria Angeles O. Catelo, Clare A. Narrod, and Marites M. Tiongco, 2008.

780. *Evaluating alternative policy responses to higher world food prices: The case of increasing rice prices in Madagascar*. David Coady, Paul Dorosh, and Bart Minten, 2008.

779. *Contract farming of swine in Southeast Asia as a response to changing market demand for quality and safety in pork.* Marites Tiongco, Maria Angeles Catelo, and Ma. Lucila Lapar, 2008.

778. *On-site and off-site long-term economic impacts of soil fertility management practices: The case of maize-based cropping systems in Kenya.* Ephraim Nkonya, Patrick Gicheru, Johannes Woelcke, Barrack Okoba, Daniel Kilambya, and Louis N. Gachimbi, 2008

777. *Development under conditions of inequality and distrust: Social cohesion in Latin America*. Marco Ferroni, Mercedes Mateo, Mark Payne, 2008.

776. *Exploring strategic priorities for regional agricultural R&D investments in East and Central Africa.* Liangzhi You and Michael Johnson, 2008.

775. *Reforming the agricultural extension system in India: What do we know about what works where and why?* Katharina Raabe, 2008.

774. *An experimental inquiry into the effect of yardstick competition on corruption*. Angelino Viceisza, 2008.

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE

www.ifpri.org

IFPRI HEADQUARTERS

2033 K Street, NW
Washington, DC 20006-1002 USA
Tel.: +1-202-862-5600
Fax: +1-202-467-4439
Email: ifpri@cgiar.org

IFPRI ADDIS ABABA

P. O. Box 5689
Addis Ababa, Ethiopia
Tel.: +251 11 6463215
Fax: +251 11 6462927
Email: ifpri-addisababa@cgiar.org

IFPRI NEW DELHI

CG Block, NASC Complex, PUSA
New Delhi 110-012 India
Tel.: 91 11 2584-6565
Fax: 91 11 2584-8008 / 2584-6572
Email: ifpri-newdelhi@cgiar.org