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Hilary K. Ndambiri
Moi University

Cecilia Nyawira Ritho
University of Nairobi

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Hilary K. Ndambiri
Department of Agricultural Economics, University of Nairobi, Nairobi, Kenya,
E-mail of the corresponding author: ndambirihk@yahoo.com

Cecilia N. Ritho
Department of Agricultural Economics, University of Nairobi, Nairobi, Kenya

Stephen G. Mbogoh
Department of Agricultural Economics, University of Nairobi, Nairobi, Kenya

Abstract

The study was carried out to evaluate how farmers in Kyuso District have perceived and adapted to climate change. Data was collected from 246 farmers from six locations sampled out through a multistage and simple random sampling procedure. The Heckman probit model was fitted to the data to avoid sample selection bias since not every farmer who may perceive climate change responds by adapting. The analysis revealed that 94% of farmers in Kyuso District had a perception that climate was changing and as a result, 85% of these farmers had responded by adapting. In this regard, age of the household head, gender, education, farm experience, household size, distance to the nearest market, access to irrigation water, local agro-ecology, on and off farm income, access to information on climate change through extension services, access to credit, changes in temperature and precipitation were found to have significant influence on the probability of farmers to perceive and/or adapt to climate change. With the level of perception to climate change being more than that of adaptation, the study suggests that more policy efforts should be geared towards helping farmers to adapt to climate change.

Key words*: climate change, perceptions, adaptation, Heckman model, Kyuso District.*

1. Introduction

Kenya has climatic and ecological extremes with altitudes varying from sea level to over 5000m in the highlands. The mean annual rainfall ranges from less than 250mm in semi-arid and arid areas to more than 2000mm in high potential areas. Even though certain areas of Kenya endure arid and semi-arid conditions (Obunde, 2007), most cropping systems are rain-fed with irrigation activities remaining limited. Over the last decade, Kenya has faced a number of drought and flood episodes, which have affected a number of sectors such as agriculture, livestock production, energy, roads, tourism, wildlife, education and health (GoK, 2007; Maitima *et al.*, 2009).

In response, the Government of Kenya has embarked on deliberate policy efforts aimed at adapting the nation to climate change. A key policy that has been formulated with a bearing on climate change issues is the Economic Recovery Strategy for Wealth and Employment Creation (ERS). It is a strategy that provides policy guidelines that ensure environmental conservation and sustainable development, including fight against desertification and flood control (GoK, 2007). Recently, a government blue print, the Vision 2030, has also been formulated. The blue print recognizes climate change as one of the key challenges facing sustainable development in Kenya. This policy document has specifically provided measures to be undertaken to improve the capacity for adaptation to global change.

In the agricultural sector, there is the Strategy for Revitalizing Agriculture (SRA) which was formulated and launched for implementation in 2004. Unlike previous agricultural sector policies, the SRA has sought to lay foundation for sustainable exploitation of arid and semi arid lands through a number of climate change adaptation strategies such as irrigation development, water harvesting, agro-forestry, development and promotion of early maturing, drought and pest tolerant crop varieties and improved livestock marketing in the Arid and Semi Arid Lands (ASALS).

While the afore mentioned efforts have constituted government-driven measures of adaptation, farmer-driven measures of adapting to climate change especially in regard to the arid and semi arid regions in Kenya are not very well known. This is despite the fact that that some of these places have in the past one decade been affected by severe drought arising from abnormal changes in temperature and precipitation (Maitima *et al.*, 2009). As a result, this study was carried out in order to fill this information gap with particular reference to Kyuso District. The district is located in the ASAL areas of the country and it was specifically chosen because it has in the past one decade witnessed recurrent droughts and floods owing to climate change (GoK, 2007; UNDP, 2008; Maitima *et al.*, 2009).

As such, the remainder of the paper is organized as follows: Section two outlines the theoretical framework. Section three presents the methodology. Section four discusses the results and section five gives conclusions and policy recommendations.

2. Theoretical framework

The study is grounded on the theory of induced innovation as exposited by Netra et al (2004). The theory is used to help in examining the central role that climate has as a motivator of the farmers to innovate and to eventually adapt to climate change in Kyuso District. The fundamental insight of this theory is that investment in innovation is a function of change that enters into the farm's production function. Whereas innovations in agriculture do not evolve with respect to climatic conditions alone, non-climatic factors, such as economic and political environment, have significant implications for innovation and adaptation to new agricultural practices.

Within the induced innovation theory, the study analyzed the effects of drought and hence, the perceptions that individual farmers have about drought as a necessary trigger for the farmers to be innovative in adapting to the negative effects of climate change. One of the assumptions in the induced innovation theory holds that when farmers experience some changes in the immediate environment due to climate change, they are likely to seek new knowledge that can help them to overcome constraints arising from changing environment. Changes in the immediate environment therefore act to ignite certain adaptation responses, in which case farmers adjust land uses and farm management strategies so as to offset the adverse effects of climate change.

In this study, it is argued that with non-climatic factors held constant, innovations towards farm production in Kyuso District are made in response to variable climatic conditions. It is thus assumed that perceptions of the variability in climate prompts the adaptation process among the households so as to cope with the negative impacts of climate change in the farm. The study first hypothesized that climate change in Kyuso District is an important limitation towards the productive capacity of farming households and that adaptive responses would amount to innovative measures created by farmers so as to minimize farming risks stemming from climate change.

It was also hypothesized that when pressure to grow food from climatically stressed environment increases, the marginal cost of production goes up. Eventually, the farmer gets to a point where adaptive responses become the only means available to enhance farm incomes. This may entail the creation and use of knowledge that accommodates climate change through a combination of land use and farm management practices such as irrigation or through the adoption of area specific crop varieties and livestock. Therefore, undertaking this study in Kyuso District would provide important insights about the relationships between climate change, farmers' perceptions of and adaptations to climate change, which would safeguard the local people against adverse effects of climate change.

3. Overview of Literature

Adoption of agricultural technologies in agriculture is considered to be synonymous with the adaptation strategies that farmers undertake in fight against the adverse effects of climate change (Nhemachena and Hassan, 2007) and as a result, the adoption literature can be applied in studies regarding climate change adaptation. Empirical literature is also wide on farmer characteristics that affect the adoption of agricultural technologies.

For instance, studies on agricultural technology adoption by Gbetibouo (2009) and Adesina and Forson (1995) observe that there is no consensus in the literature as to the exact effect of age in the adoption of farming technologies because the age effect is generally location or technology specific and hence , an empirical question. On one hand, age may have a negative effect on the decision to adopt new farming technologies simply because older farmers may be more risk-averse and therefore, less likely to be flexible than younger farmers. On the other hand, age may have a positive effect on the decision of the farmer to adopt because older farmers may have more experience in farming and therefore, better able to assess the features of a new farming technology than the younger farmers.

In relation to gender, Asfaw and Admassie (2004) note that households headed by males have a higher probability of getting information about new farming technologies and also undertake more risky ventures than female headed households. A similar observation is made by Tenge and Hella (2004) who point out that female headed households are less likely to adopt soil and water conservation measures since women may have restricted access to information, land, and other resources due to traditional social barriers. Nonetheless, Nhemachena and Hassan (2007) have contrary results to the effect that female headed households are more likely to adopt different methods of climate change adaptation than male headed households.

With regard to education, Norris and Batie (1987) argue that farmers with more education are more likely to have enhanced access to technological information than poorly educated farmers. Furthermore, Igoden *et al.* (1990) and Lin (1991) observe a positive relationship between the education level of the household head and the adoption level of improved technologies and climate change adaptation. As such, farmers with higher levels of education are more likely to perceive climate change and adapt better. Related studies by Maddison (2006) and Nhemachena and Hassan (2007) indicate that farming experience, just like farmers' education level, increases the probability of uptake of adaptation measures to climate change.

As for the household size, Croppenstedt *et al.* (2003) argue that larger households have a larger pool of labor and as a result, they are more likely to adopt agricultural technologies than smaller households. Moreover, Yirga (2007) notes that the size of the household influences individuals' adaptation to climate change in two perspectives. In the first perspective, households with large families may be forced to divert part of the labor force from farm to off-farm activities in an attempt to earn some income that can ease the consumption pressure imposed by a large family in the face of climate change. In the second perspective, households with a large family size are considered to have a larger pool of cheap labor resource, which can readily be employed on the farm for crop and/or livestock production, unlike families with smaller household size. Therefore, households with large families are more likely to adapt to climate change than households with small families.

Access to climate change information and other extension services by farmers is another essential factor, which may influence the adoption of farming technologies. In their respective studies, Maddison (2006) and Nhemachena and Hassan (2007) observed that the awareness by farmers of climate change attributes - whether precipitation or temperature or both, is of essence in as far as their adaptation decision-making process is concerned. In this study, it was therefore expected farmers with access to climate change information were more likely to observe changes in climate and were therefore more likely to adapt than those without access to climate change information.

Income of the farmers, whether farm or nonfarm, represents the wealth of individual households. Empirical evidence by Franzel (1999) and Knowler and Bradshaw (2007) indicate that farmers' income has a positive relationship with the uptake of farming technologies since any adoption/adaptation process requires that the farmer has sufficient financial wellbeing.

As for the role of credit in the uptake of farming technologies, Yirga (2007), Pattanayak *et al.* (2003) and Caviglia-Harris (2002) observe that a positive relationship exists between the level of adoption and the availability of credit since credit eases the cash constraints and allows farmers to buy inputs such as fertilizer, improved crop varieties and irrigation facilities. As well, this study also hypothesized that there would be a positive relationship between availability of credit and adaptation to climate change.

Another factor that influences the adoption of agricultural technologies is farmers' accessibility to the market places. A study by Maddison (2006) notes that long distances to market centres decrease the likelihood of farm adaptation and that market places provide important avenues for farmers to congregate and share information. In addition, Nyangena (2007) shows that in Kenya, distance to market places has a negative and significant effect on the adoption and use of soil and water conservation technologies.

Finally, with respect to agro-ecological zones in which households dwell or practice their farming, Nhemachena and Hassan (2007) and Maddison (2006) agree that different agro-ecological zones impact differently on different households such that different households differ in the uptake of adaptation methods. The primary reason for the differences is that environmental factors, climatic conditions, and soil composition vary across different agro-ecologies, which may affect the way different farmers perceive climate change and their respective decisions to adapt. It was therefore hypothesized in the study that farmers would perceive and/or adapt to climate change depending on the agro-ecological zones in which they dwell or carry out their farming.

4. Methodology

4.1 Study area

The study was carried out in Kyuso District, which is one of the twenty-eight districts in the Eastern Province of Kenya, with an area of 4,814.90 Km^2. It has four administrative divisions, that is: Ngomeni, Mumoni, Tseikuru and Kyuso; 16 locations and 53 sub-locations. It is bordered to the South by Mwingi Central District; to the West by Mbeere District; to the North West by Tharaka District and to the East by Tana River District. The district comprises of arid and semi-arid eco-climatic zones of Kenya with a transitional part in between. It has an altitude that ranges between 400 and 1,747 m above sea level. Therefore, the district's topography covers both the eastern part of Kyuso with lower and drier climate that is popular with livestock production and the western part of Kyuso with higher climate that offers more rainfall and increased crop cultivation. Kyuso is hot and dry for most part of the year with temperatures ranging from a minimum of 14-22° centigrade to a maximum of 26-34° centigrade. The months of February and September are the hottest months in the year generally with low and unreliable rainfall. The long rains are experienced between March and May and short rains between October and December. The short rains are considered more reliable than the long rains since it is during the short rains that farmers get their main food production opportunity.

Kyuso district is made up of three main livelihood zones, namely: the formal employment/casual waged labour found in Kyuso town and in other market centres; the marginal mixed farming, which is found in Kyuso, Ngomeni and Tseikuru Divisions located on the eastern part of Kyuso; and the mixed farming which is found in Mumoni Division located on the western side of the district. All farmers in eastern part of Kyuso rear livestock - cattle, sheep and goats, which they sell, depending on climatic conditions, to buy food. The major crops grown by farmers include pigeon peas, maize, cowpeas, green grams, sorghum, beans, millet, cassava and sweet potatoes. Although there has been a lot of emphasis on growing hybrid maize, the uptake has been problematic since it requires a lot of rainfall. Beekeeping is a traditional activity in this area and it is only in the recent past that the Government of Kenya has started promoting it as an alternative economic activity (Kyuso District Development Report, 2008).

4.2 Study population

Kyuso District Development Report (2008) estimates that the district has a population of 138,040 persons that grows at an annual rate of 2.4%. The proportion of the urban population is about 5% of the total population in the district with 95% of the total population residing in the rural areas. Kyuso's population derives its livelihood from three main economic activities, namely: formal employment/casual waged labour, marginal mixed farming and the mixed farming. Consequently, the study population was primarily drawn from households deriving their livelihood from two economic activities, that is: the marginal mixed farming and the mixed farming activities whose people reside in the rural areas.

4.3 Sampling procedure

The study employed the multiple-stage and simple random sampling procedure to select a sample of 246 respondents from the district. All the four administrative divisions in the district, that is: Tseikuru, Kyuso, Mumoni and Ngomeni, were initially classified into two: those from the marginal mixed farming economic zone (eastern side) and those from the mixed farming economic zone (western side). Subsequently, the simple random sampling process was employed in order to select two divisions - one from the marginal mixed farming zone and the other from the mixed farming zone. In this case, Kyuso and Mumoni divisions were selected. In the second stage, six locations - three from each of the two economic zones - were thereafter selected in a random manner for the interviews. These locations were: Mutanda, Katse and Kakuyu from the mixed economic zone; and Kamuwongo, Kyuso and Kamangao from the marginal mixed economic zone. As a result, 41 households from each of the six locations were randomly selected for the interview process. The study adopted these sampling techniques because they ensure a high degree of sample representativeness by providing respondents with equal chances of being chosen as part of the study sample.

4.4 The Analytical Framework: The Heckman's two-step procedure

In studies where the decision to adopt a new technology involves a process requiring more than one step, models with two-step regressions are employed to correct for the selection bias generated during the decision making processes. For instance, Stan and William (2003) employ the Heckman's two - step procedure to analyze the factors affecting the awareness and adoption of new agricultural technologies in the United States of America. In their study, the first stage is the analysis of factors affecting the awareness of new agricultural technologies and the second stage is the adoption of the new agricultural technologies.

Similarly, Yirga (2007) and Kaliba *et al.* (2000) employ the Heckman's selection model to analyze the two-step processes of agricultural technology adoption and the intensity of agricultural input use in Ethiopia. The same methodology is employed by Maddison (2006) to analyze farmers' adaptation to climate change in Southern Africa. He argues that the adaptation to climate change is a two-step process which involves perceiving that climate is changing in the first step and then responding to changes through adaptation in the second step.

In Ethiopia, Deressa *et al.* (2008) used the Heckman's two-step procedure to analyze farmers' perceptions of climate change in the first step and then farmers' adaptations to climate change in the second step. And more recently, Gbetibouo (2009) also used the Heckman model to analyze farmers' perceptions and adaptations to climate change and variability in the Limpopo basin, South Africa. In the first stage, farmers' perceptions were analyzed followed by farmers' adaptations in the second stage.

Following Maddison (2006), the current study employed the Heckman's two-step procedure to analyze the perceptions of and adaptation to climate change by farmers in Kyuso District, Kenya. The Heckman's model has two equations of interest that are modeled, namely: the selection (participation) equation, and the response (outcome) equation. In this study, the selection equation was used to model the perceptions that farmers have towards climate change while the response equation was used to model the adaptations that farmers have undertaken in response to the effects of climate change.

Maddison (2006), Deressa *et al.* (2008) and Gbetibouo (2009) have specified the Heckman's sample selectivity model based on two latent variables as follows:

$$y_1 = b'x + u_1 \qquad 1)$$
$$y_2 = g'z + u_2 \qquad (2)$$

where x is a k-vector of regressors; z is an m-vector of regressors, possibly including 1's for the intercepts; and the error terms u_1 and u_2 are jointly normally distributed, independently of X and Z, with zero expectations. y_1 and y_2 are the regressands denoting adaptation to and perceptions of the farmers to climate change. Although the study would primarily be interested in the first model, the latent variable y_1 is only observed if $y_2 > 0$. Thus, the actual dependent variable is:

$$y = y_1 \ if \quad y_2 > 0; \ y \ is \ a \ missing \ value \ if \ y_2 \leq 0 \qquad (3)$$

Here, y_2 is taken as a latent variable, which is not observable, but only its sign. A conclusion is made that $y_2 > 0$ if y is observable and that $y_2 \leq 0$ if y is unobservable. As a result, and without any loss of generality, u_2 can be normalized so that it has a variance that is equal to 1. Suppose the self selection problem is disregarded and y regressed on x based on the observed y values, then the resulting ordinary least squares (OLS) estimator of β would be biased, since:

$$E[y_1|y_2 > 0, x, z] = b'x + rs\frac{f(g'z)}{F(g'z)} \qquad (4)$$

where F is the cumulative distribution function of the standard normal distribution, f is the corresponding density, s^2 is the variance of u_1, and r is the correlation between u_1 and u_2. Thus:

$$E[y_1|y_2 > 0, x] = b'x + rsE[\frac{f(g'z)}{F(g'z)}|x] \qquad (5)$$

The last term gives rise to self selection bias when r is nonzero. In order to avoid the self selection bias and to obtain estimators that are asymptotically efficient, the maximum likelihood procedure was used to estimate the model parameters. STATA software v11.0 was used in this analysis.

4.5 Empirical models for the study

Heckman's probit selection model and the Heckman's probit outcome model were the two models estimated in the study. In the Heckman's selection model, the regressand was a binary variable concerned with whether or not a farmer perceived climate change. It was regressed on a set of explanatory variables, namely: age of the farmer, gender, education, farming experience, farm income, off-farm income, access to extension services, access to climate information, household size, local agro-ecology, distance to input/output market, perceived fertility of the soil, access to credit and access to water for irrigation. The algebraic representation of the Heckman's probit selection model was gives as:

$$M_i = (\phi X_i) + \varepsilon \qquad (6)$$

where: M_i = the perception by the i^{th} farmer that climate is changing.
X_i = the vector of explanatory variables of probability of perceiving climate change by the i^{th} farmer.
ϕ = the vector of the parameter estimates of the regressors hypothesized to influence the probability of farmer i_s perception about climate change.

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

$$M_i = \phi_0 + \phi_1 age + \phi_2 gender + \phi_3 education + \phi_4 fexperience + \phi_5 hhsize + \phi_6 irrigawater + \phi_7 marketdistance + \phi_8 agroecology + \phi_9 farmincome + \phi_{10} soilfertility + \phi_{11} climinform + \phi_{12} extenservice + \phi_{13} credit + \phi_{14} offarmincome + \varepsilon$$

In the Heckman's probit outcome model, the regress and was also a binary variable - whether a farmer has adapted to climate change or not. It was also regressed on a set of relevant explanatory variables, namely: age of the farmer, gender, education, farming experience, farm income, off-farm income, access to extension services, access to climate information, household size, local agro-ecology, distance to input/output market, access to credit, precipitation and temperature. The algebraic specification of the Heckman's probit outcome model was given as:

$$T_i = (\phi X_i) + \varepsilon \qquad (7)$$

where: T_i = the adaptation by the i[th] farmer to climate change.
X_i = the vector of explanatory variables of probability of adapting to climate change by the i[th] farmer.
ϕ = the vector of the parameter estimates of explanatory variables hypothesized to influence the probability of farmer i_s adaptation to climate change.

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

$$T_i = \phi_0 + \phi_1 age + \phi_2 gender + \phi_3 education + \phi_4 fexperience + \phi_5 hhsize + \phi_6 marketdistance + \phi_7 agroecology + \phi_8 farmincome + \phi_9 climinform + \phi_{10} extenservice + \phi_{11} credit + \phi_{12} offarmincome + \phi_{13} precipitation + \phi_{14} temperature + \varepsilon$$

5. Empirical Results and Discussion

5.1.1 Descriptive Analysis: Farmers' perceptions of climate change

In order to understand farmers' perception towards climate change in Kyuso District, farmers were asked to indicate what they had noted regarding long term changes in temperature and precipitation. They were asked to specify whether or not they had noted: (i) changes in climate (ii) increases in temperature (iii) decreases in temperature (iv) extended periods of temperature (v) no change in temperature levels (vi) increases in precipitation (vii) decreases in precipitation (viii) changes in the timing of rains (ix) increases in the frequency of droughts and (x) no change in precipitation patterns. The results of this analysis are presented below and furthermore in Table 2.

Table 1. Variables hypothesized to affect perception and adaptation decisions by farmers with regard to climate change

Variables and variable Measurement	Mean	Std. Dev.	Min	Max	Expected sign
Age of the head of the farm household in years.	45.29	11.13	25	75	±
Gender of the head of the farm household - dummy (1=male; 0=otherwise).	0.74	0.44	0	1	±
Education attained by the head of the household in years.	9.88	4.20	0	15	+
Farming experience of the household head in years.	20.48	8.86	7	50	+
Household size - number of family members of a household.	5.76	2.12	2	13	±
Access to water for irrigation - dummy (1=access; 0=otherwise).	0.30	0.46	0	1	+
Market distance in kilometers.	2.42	1.54	1	7	+
Local agro-ecology - highland or lowland - dummy (1=highland; 0=otherwise).	0.39	0.49	0	1	+
Farm income of the household in Kenya shillings.	2.61	1.38	1	6	+
Perceived fertility of the soil by household head in dummy (1=fertile; 0=otherwise).	0.10	0.30	0	1	+
Access to climate information - dummy (1=access; 0=otherwise).	0.68	0.47	0	1	+
Access to extension services - dummy (1=access; 0=otherwise).	0.13	0.34	0	1	+
Access to credit - dummy (1=access; 0=otherwise).	0.25	0.44	0	1	+
Off-farm income in Kenya shillings.	0.67	0.47	0	1	±
Temperature – whether farmers perceives affected by changes in annual average temperature - dummy (1=affected; 0=otherwise).	0.57	0.50	0	1	+
Precipitation – whether farmers perceives affected by changes in annual average precipitation - dummy (1=affected; 0=otherwise).	0.39	0.49	0	1	_

Overall, the established that 94% of the farmers in the district had noted changes in climate while 6% had not. While 43% of the respondents noted an increase in the levels of temperature, about 70% observed a decrease in precipitation. Nobody is reported to have either perceived a decrease in temperature or an increase in precipitation. Considering patterns of precipitation, 61% of the respondents pointed out that they had observed changes in the timing of rains while 70% noted that the frequency of droughts had increased overtime. This implies that majority of farmers in the district are well aware of climate change.

A cross tabulation between the age of the household head and the farmers' perceptions of climate change elucidated that majority of farmers who perceived changes in climate were in the age group between 31 and 60 years (80%), compared to farmers below the age of 30 years (6%) or above the age of 60 years (8%). While 36% of farmers in the age group 31-60 years observed an increase in the levels of temperature, only 3% and 4% of farmers in the age group below 30 years and above 60 years, respectively, noted increases in temperature. In contrast, no one from the three age groups indicated to have either observed a decrease in temperature or an increase in precipitation. Regarding patterns of precipitation, 51% of farmers in the age group 31-60 years agreed that they had observed changes in the timing of rains, compared to 4% and 6% of the farmers in the age groups below 30 years and above 60 years, respectively.

The study further established that most farmers who perceived climate change had attained post primary (61%) education compared to 33% who had up to primary education. While 34% of farmers with post primary education noted increases in temperature, only 9% of farmers with up to primary education noted that there was an increase in the levels of temperature. Regarding perceptions about extended periods of temperature, 47% of farmers with post primary education indicated to have observed long periods of temperature compared to only 8% of farmers with up to primary education.

With regard to the farming experience, the study found out that the majority (83%) of farmers who perceived that climate was changing had high farming experience (above 10 years) compared to 11% who had low farming experience (1-10 years). As 51% of the farmers with high farming experience observed that there was considerable change in the levels of temperature, only 6% of farmers with low farming experience indicated to have noticed change in temperature levels. Concerning the frequency of droughts, majority (62%) of farmers with high farming experience indicated to have observed an increased number of droughts in the last decade compared to their counterparts (8%) with low farming experience.

On the relationship between farmers' perception to climate change and the distance to the nearest input and output market, the study established that majority (77%) of farmers who lived close (1-15 Kms) to the nearest input/output market perceived that climate was change, compared to those farmers (17%) who resided in places longer than 15Kms to the nearest market. Regarding precipitation patterns, about 54% of farmers residing between 1-15Kms to the nearest market noted that the timing of rains had changed while another 62% observed that the number of recurring droughts had increased. In contrast, only 7% and 8% of farmers residing longer than 15 Kms distance to the nearest input/output market had noted changes in the timing of rains and increased frequency in the occurrence of droughts, respectively.

Table 2: Farmers' Perception to Changes in Temperature and Precipitation by age, education, farming experience and distance to the nearest input-output market (as a % of respondents)

	Farmers' perceptions by age (as a % of respondents)				Farmers' perceptions by education (as a % of respondents)		Farmers' perceptions by farming experience (as a % of respondents)		Farmers' perceptions by distance to the input/output market (as a % of respondents)	
Farmers' perceptions	% of respondent	0-30 years	31-60 years	60+ years	Upto Standard education (1 - 8 years)	Post standard education (9+ years)	Low farming experience (1 -10 years)	High farming experience (10+years)	Distance to the nearest market (1 - 15Kms)	Distance to the nearest market (15+ Kms)
Changes in climate	94	6	80	8	33	61	11	83	77	17
Increases in temperature	43	3	36	4	9	34	6	37	39	4
Decreases in temperature	0	0	0	0	0	0	0	0	0	0
Extended periods of temperature	55	4	45	6	8	47	3	52	48	7
Change in temperature levels	57	5	47	5	13	44	6	51	51	6
Increases in precipitation	0	0	0	0	0	0	0	0	0	0
Decreases in precipitation	70	4	59	7	16	54	8	62	58	12
Changes in the timing of rains	61	4	51	5	13	48	11	50	54	7
Increases in the frequency of droughts	70	5	59	6	16	54	8	62	62	8
Change in precipitation patterns	39	3	32	4	14	25	4	35	29	10

N = 246

5.1. 2 Descriptive Analysis: Farmers' adaptation to climate change

In order to establish whether or not farming households in Kyuso District had adapted to their own perceptions about climate change, farmers were asked to indicate the adaptation strategies they had adopted in their farms in order to cope with the adverse effects of changes in temperature and precipitation. Farmers were asked to indicate whether or not they had adapted using any of the following methods: (i) growing different varieties (ii) growing different crops (iii) use of different planting dates (iv) practicing crop diversification (v) migration to a different site (vi) lessening the length of growing season (vii) switching from crops to livestock farming (viii) changing land area under cultivation (ix) adjusting the number and livestock management strategies (x) switching from livestock to crops farming (xi) switching from farming to non-farming activities (xii) use of prayers (xiii) increased use of irrigation (xiv) increased use of fertilizers and pesticides (xv) increased use water conservation technologies (xvi) enhanced use of shading/sheltering/tree planting (xvii) practicing soil conservation, mulching and use of manure and (xviii) switching from non-farming to farming activities. Table 3 and 4 give further results of this analysis.

It was revealed in the study that 85% of farmers in the district had actually adapted to climate change compared to 15% who chose not to adapt. Several adaptation strategies were undertaken by farmers, with the most popular methods being growing different crops and changing land area put under cultivation, with each comprising 64% of the respondents. The least popular adaptation methods employed by farmers were switching from non-farming to farming activities (9%) and the increased use of irrigation farming (8%).

In addition, analysis of the farmers' characteristics in the study revealed that most (71%) farmers who adapted to changes in climate were in the age group between 31 and 60 years. Only a handful, 6% and 8%, were in the age group below 30 years and above 60 years, respectively. Moreover, most farmers in the age group between 31 and 60 years adapted to changes in temperature and precipitation using various methods. The most popular adaptation methods were growing different crops (54%) and changing land area under cultivation (54%). The least popular adaptation strategies were switching from non-farming to farming (6%) and the increased use of irrigation farming (5%).

As for the education level, the study established that majority (63%) of the farmers who adapted in various ways to changes in temperature and precipitation had reached post primary education when compared to those who had up to primary level education (22%). The most common adaptation strategies among farmers having post primary education, besides growing different crops (50%) and changing land area under cultivation (50%), were diversifying crops under cultivation (43%) and migrating to a different site (44%). The least common methods of adaptation, other than switching from non-farming to farming (7%) and the increased use of irrigation (6%), was switching from livestock to crop farming (8%).

In relation to farming experience, the study found out that majority (74%) of the farmers who adapted to climate change had farming experience of more than 10 years in comparison to 11% of the farmers who had low experience of about 10 years and below. Among the common adaptation strategies for farmers with more farming experience included: growing different crops (56%), changing land area under cultivation (56%), diversifying crops under cultivation (49%), growing different crop varieties (46%), lessening length of growing season (46%) and the increased use of shading, sheltering or tree planting (45%). However, the increased use of fertilizers and pesticides (20%),

Table 3: Farmers' Adaptation to Changes in Temperature and Precipitation by age and education (as a % of respondents)

	Farmers' perceptions by age (as a % of respondents)				Farmers' perceptions by education (as a % of respondents)	
Farmers' Adaptation Methods	% of respondent	0-30 years	31-60 years	60+ years	Up to Primary education (1 - 8 years)	Post Primary education (9+yrs)
Adapted to climate change.	85	6	71	8	22	63
Planting different crops.	64	4	54	6	14	50
Planting different varieties.	51	3	41	7	12	39
Crop diversification.	55	5	45	5	12	43
Different planting dates.	49	4	40	5	10	39
Shortening length of growing season.	51	3	43	6	11	40
Migrating to a different site.	54	5	44	5	10	44
Changing land under cultivation.	64	5	54	5	14	50
Switching from crops to livestock.	48	4	40	4	10	38
Switching from livestock to crops.	12	1	10	1	4	8
Adjusting number and management of livestock.	49	2	40	7	10	39
Switching from farming to non-farming.	44	1	38	5	8	36
Switching from non-farming to farming.	9	1	6	2	2	7
Increased use of irrigation.	8	1	5	2	2	6
Increased use of fertilizers and pesticides.	22	2	19	1	5	17
Increasing water conservation practices.	46	4	38	4	8	38
Soil conservation, mulching and use of manure.	34	2	29	3	6	28
Increasing shading/ sheltering/tree planting.	50	4	41	5	10	40
Use of prayers.	52	3	42	7	17	35

N = 246

Source: Field data, 2010

Table 4: Farmers' Adaptation to Changes in Temperature and Precipitation by farming experience and distance to the nearest input output market (as a % of respondents)

	Farmers' perceptions by farming experience (as a % of respondents).		Farmers' perceptions by distance to the input/output market (as a % of respondents).	
Farmers' Adaptation Methods	Low farming experience (1 -10 years).	High farming experience (10+years).	Distance to the nearest market (1 - 15Kms).	Distance to the nearest market (15+ Kms).
Adapted to climate change.	11	74	76	9
Planting different crops.	8	56	61	3
Planting different varieties.	5	46	49	2
Crop diversification.	6	49	52	3
Different planting dates.	6	43	47	2
Shortening length of growing season.	6	46	48	3
Migrating to a different site.	8	46	52	2
Changing land under cultivation.	8	56	61	3
Switching from crops to livestock.	6	42	45	3
Switching from livestock to crops.	2	10	8	4
Adjusting number and management of livestock.	5	44	46	3
Switching from farming to non-farming.	4	40	42	2
Switching from non-farming to farming.	1	8	9	0
Increased use of irrigation.	0	8	8	0
Increased use of fertilizers and pesticides.	2	20	21	1
Increasing water conservation practices.	5	41	44	2
Soil conservation, mulching and use of manure.	3	31	32	2
Increasing shading/ sheltering/tree planting.	5	45	47	3
Use of prayers.	5	47	44	8
N = 246				

Source: Field data, 2010

switching from non-farming to farming (8%) and increased use of irrigation (8%) were some of the adaptation methods that were least employed by the highly experienced farmers.

With regard to distance that a farmer resides from the nearest market centre, the study established that most (76%) farmers who undertook adaptation lived closer (1-15Kms) to a market centre. Only a few farmers (9%) living further away from a market centre (beyond 15Km range) had adapted to climate change. Growing different crops (61%), changing land area under cultivation (61%), migration to a different site (52%), crop diversification (52%), growing different crop varieties (49%) and lessening the length of growing season (48%) were the main adaptation methods adopted by farmers residing closer (1-15Km) to a market centre. On the other hand, shifting from livestock to crop farming (8%), shifting from non-farming to farming (9%) and the increased use of irrigation (8%) constituted the least common adaptation strategies employed by the farmers in the district.

5.2 Econometric Analysis

5.2.1 Econometric estimation of model parameters

The study employed the Heckman's probit model to estimate the parameters of the study in order to avoid sample selection bias. To start with, the model was tested for its appropriateness in the study by comparing the dependence of the error terms in the outcome and selection equations. The results showed evidence of a sample selection problem since *rho* was significantly different from zero *(Wald test for independent equations = 23.46, with P = 0.0000).* It was therefore justified to use the Heckman probit model. Besides, the likelihood function of the Heckman probit model was also found to be significant (*Wald for zero slopes = 2180.17, with P = 0.0000*) meaning that the model had a strong explanatory power. Table 5 presents results from the ML estimation together with the marginal effects, which is the expected change in the probability of perceiving and/or adapting to climate change given a unit change in an independent variable from the mean value, *ceteris paribus.* Only results that were statistically significant at the 10 percent level or greater are reported.

5.2.2 Results of the Heckman probit model

As in the selection equation where the regressand was binary, representing whether or not a farmer perceived climate change, the regressand in the outcome equation was also binary indicative of whether or not a farmer reacted to the perceived changes through adaptation. These dependent variables were regressed on a set of explanatory variables as discussed in the previous section.

The results from the selection model indicated that age of the household head, gender, education, farming experience, household size, access to irrigation water, distance to the nearest market, local agro-ecology, access to information on climate change, access to extension services and off farm income influenced the possibility of a farmer to perceive climate change. As for the outcome model, the results showed that age of the household head, education, farming experience, household size, distance to the nearest market, local agro-ecology, farm income, access to information on climate change, access to credit and changes in temperature and precipitation influenced the possibility of a farmer to adapt to climate change.

Table 5: Results of the Heckman's Probit Model of Farmers' Perception of and Adaptation to climate change in Kyuso District

	Perception model				Adaptation model			
Explanatory variables	Regression model		Marginal effects		Regression model		Marginal effects	
	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value	Coefficient	p-value
Age	0.099***	0.000	0.0041***	0.009	0.014***	0.010	0.0030**	0.022
Gender	0.939***	0.000	0.0262**	0.035	0.007**	0.033	-0.0028*	0.068
Education	0.125***	0.000	0.0146**	0.046	0.047***	0.001	0.0103***	0.003
Farm experience	0.123***	0.000	0.019***	0.001	0.013**	0.043	0.0040**	0.039
Household size	-0.124**	0.048	-0.0460**	0.027	-0.031*	0.083	-0.0012*	0.086
Irrigation water	1.190***	0.000	-0.0531**	0.016				
Distance to market	0.011	0.891	-0.0051***	0.002	0.003**	0.020	-0.0014***	0.003
Local agro-ecology	1.445***	0.001	0.0270**	0.048	0.050**	0.041	0.0028***	0.012
Farm income	-0.554	0.103	-0.0772	0.684	0.073	0.207	0.0097***	0.000
Fertility of the soil	0.467	0.430	0.0570	0.653				
Climate information	0.404**	0.028	0.0212*	0.071	0.079*	0.070	0.0057**	0.042
Extension services	-1.750***	0.001	0.0577**	0.024	-0.005	0.935	0.0014	0.493
Access to credit	-1.510***	0.000	-0.0213	0.212	-0.155***	0.007	-0.0085**	0.038
Off farm income	-0.266	0.333	-0.0326***	0.001	0.015	0.733	0.0010	0.194
Change in temperature					0.057**	0.033	0.0140**	0.023
Change in precipitation					-0.025**	0.015	-0.0148***	0.001
Diagnostics								
Wald test for zero slopes	*2180.17, p > Chi2(15) = 0.0000*							
Wald test for independent equations	*23.46, p > Chi2(1) = 0.0000*							
Total observations	*246*							
Censored	*14*							
Uncensored	*232*							

Note: *** significant at 1% level; ** significant at 5% level; * significant at 10% level.

In relation to the age of the household head, the results came out as expected i.e. the age of the household head would be positively and significantly related to farmers' perception and adaptation to climate change. The study found out that the probability of perceiving climate change was higher for older farmers than it is for younger farmers ($\phi = 0.0041, p<0.01$). The probability to adapt was also found to be higher for the older farmers compared to the younger farmers ($\phi = 0.0030, p<0.05$). Adesina and Forson (1995) and Gbetibouo (2009) attest to these findings when, in their respective studies, they observed a positive relationship between age of the household head and the adoption of improved agricultural technologies. They have noted that older farmers have more experience in farming and are better able to assess the attributes of modern technology than younger farmers. Hence, older farmers have a higher probability of perceiving and adapting to climate change.

As for the gender of the household head, the study established that the probability of a male headed household to perceive climate change was higher than that of a female headed household ($\phi = 0.0262, p<0.05$). This finding is similar to that by Asfaw and Admassie (2004) and Tenge and Hella (2004) who noted that male headed households were more likely to perceive changes in the surrounding than female headed households. The possible reason is that male headed households have a higher probability of acquiring information than female headed households. However, as for the adaptation, the study found out that the probability to adapt of the male headed households was lower than that of the female headed households ($\phi = -0.0028\ p<0.1$). A similar finding is found in Nhemachena and Hassan (2007) who assert that a lot of farming activities in the rural areas are carried out by women as men are in most cases based in the urban areas. Given that women do much of the farm work, they are therefore more likely to adapt to climate change than males on the basis of the available information on climate and markets conditions and food needs of the households.

In relation to the education level of the farmers, the study established that the probability of more educated farmers to perceive climate change was higher than that of less educated farmers ($\phi = 0.0146, p<0.05$). More educated farmers were also more likely to adapt to climate change than farmers with not as much education by points ($\phi = 0.0103, p<0.01$). This is because higher education was likely to expose farmers to more information on climate change. These findings agree with the findings by Norris and Batie (1987) and Igoden et al (1990) who have noted that higher levels of education is likely to enhance information access to the farmer for improved technology up take and higher farm productivity. They have also observed that education is likely to enhance the farmers' ability to receive, decipher and comprehend information relevant to making innovative decisions in their farms.

As for the farming experience, the study established that the more experienced farmers were, the more likely they were to perceive climate change than farmers with low farming experience ($\phi = 0.0190, p<0.01$). In addition, more experienced farmers were also more likely to adapt to climate change than the low experienced farmers ($\phi = 0.004, p<0.05$). These findings are similar to those unveiled by Nhemachena and Hassan (2007) that farming experience enhances the probability of uptake of adaptations as experienced farmers have better knowledge and information on changes in climatic conditions, crop and livestock management practices. Since the experienced farmers have high skills in farming techniques and management, they may be able to spread risk when faced with climate variability across crop, livestock and off farm activities than less experienced farmers.

With regard to household size, the study revealed that larger households had less chances of perceiving climate change than smaller households points ($\phi = -0.0460$,

$p<0.05$). It was also discovered that larger households were less likely to adapt to climate change than the smaller households (ϕ = *-0.0012, $p<0.1$*). As Teklewold *et al.* (2006) and Tizale (2007) note, household size is a proxy to labor availability. Therefore, larger households are likely to have a lower probability to adopt new agricultural practices since households with many family members are likely to divert labor force to off-farm activities in an attempt to earn more income to ease the consumption pressure imposed by a large family size.

The study established an inverse relationship between farmers' perception to climate change and their access to irrigation water. It was found out that farmers with access to irrigation water were less likely to perceive climate change than farmers without access to irrigation water (ϕ = *-0.0531, $p<0.05$*). This is because the warming factor and the lack of irrigation water enhances the vulnerability of farmers to risks associated with climate change and hence their probability to perceive that climatic conditions are changing. With climate change, droughts in Kyuso district have become more frequent than before (Maitima *et al.*, 2009). This has made farm lands drier and thus creating a greater need for irrigation water so as to change the current farming systems to those that are better adapted to changes in temperature and precipitation.

With regard to the distance to the nearest input/output market, the study results indicate that farmers residing further away from the nearest input/output market were less likely to perceive that climate was changing than farmers residing closer to the market (ϕ = *-0.0051, $p<0.01$*). In addition, farmers residing longer distances to the nearest market were less likely to adapt than farmers residing shorter distances to the nearest market (ϕ = *-0.0014, $p<0.01$*). These results are in line with an observation made by Madison (2006) that long distances to markets decrease the probability of farm adaptation in Africa and that markets provide an important platform for farmers to gather and share information. Even Nyangena (2007) made a similar observation that in Kenya, long distances to the markets negatively and significantly influence the adoption of agricultural technologies of soil and water conservation.

Also established by the study was a positive relationship between local agro-ecological conditions and farmers' perception of and adaptation to climate change. It was revealed that farmers living in lower agro-ecological zones were more likely to perceive changes in climate than farmers living higher agro-ecological zones (ϕ = *0.0270, $p<0.05$*). Farmers in lower agro-ecological zones were also more likely to adapt to climate change than their counterparts in higher agro-ecological zones (ϕ = *0.0028, $p<0.01$*). Maddison (2006) and Nhemachena and Hassan (2007) made the same observation that local agro-ecological conditions had a higher likelihood of influencing a farmer to perceive climate change and hence his decision to adapt or not. However, the researchers noted that farmers' decision to adapt or not could vary across different agro-ecologies as each agro-ecology has its own set of conditions.

As to the farm income, the study produced mixed results. The study had hypothesized a positive relationship between farm income and the likelihood of farmers to perceive and adapt to climate change. However, the study results showed a negative though not significant relationship between farm incomes and the probability of farmers to perceive climate change, on one hand, and a positive relationship between farm income and farmers' adaptation, on the other. On the latter relationship, the study found out that farmers with high farm incomes were more likely to adapt climate change compared to farmers with lower farm incomes (ϕ = *0.0097, $p<0.01$*). This observation is similar to that by Franzel (1999) and Knowler and Bradshaw (2007) who noted that farmers' incomes (whether farm or off-farm income) have a positive relationship with the adoption of agricultural technologies since it requires sufficient financial wellbeing to be undertaken. Nonetheless, off-farm income generating activities may sometimes present a constraint to adoption of agricultural technology because they compete with on-farm activities, thus hindering on-farm adaptation by farmers.

In addition, the study revealed that the accessibility of climate change information by farmers' through farm extension services had higher chances of influencing farmers to perceive and adapt to changes in climate. Farmers with access to information were more likely to perceive climate change than farmers without access to information ($\phi = 0.0212, p<0.1$). The same famers were also more likely to adapt to climate change compared to their counterparts without access to climate change information ($\phi = 0.0057, p<0.05$). A number of studies agree with these results such as those by Adesina and Forson (1995), Gbetibouo (2009), Maddison (2006) and Nhemachena and Hassan (2007) who have separately noted that farmers' access to information on climate change is likely to enhance their probability to perceive climate change, and hence adopt of new technologies and take-up adaptation techniques.

Though access to credit is associated with a positive effect on adaptation behavior (Caviglia-Harris 2002; Gbetibouo, 2009), access to credit in this study was found to be inversely related to farmers' adaptation to changes in climate such that farmers with access to credit were less likely to adapt to climate change compared to farmers without access to credit ($\phi = -0.0085, p<0.05$). The possible reason for this is that the adoption of an agricultural technology may demand the use of owned or borrowed funds. Since such an investment in technology adoption may be hampered by lack of borrowing capacity (El Osta and Morehart, 1999), this may negatively end up affecting any adaptation efforts of the farmers.

As expected, the study revealed a positive relationship between change in temperature and the adaptation by famers. It was found out that farmers who perceive a rise in temperature were more likely to adapt compared to those who have not perceived a rise in temperature ($\phi = 0.0140, p<0.05$). This is probably because a rise in temperature in a district that is already arid and semi-arid was more likely to hamper farm production and therefore more likely to promote the need for the farmers to adapt to climate change. Gbetibouo (2009) made the same observation in her study of farmers in Southern Africa.

As for the precipitation, the results also came out as expected. The study found a negative relationship between change in precipitation and farmers' adaptation. That is, farmers who noted a rise in precipitation were less likely to adapt compared to those farmers who noted a decline in precipitation ($\phi = -0.0148, p<0.01$). The possible reason for this negative relationship is that farming in Kyuso District is already water scarce and therefore, increased precipitation in such a water scarce area was unlikely to constrain farm production and therefore unlikely to promote the need to adapt to the changing climate. Gbetibouo (2009) also agrees with these results from her study conducted among smallholder farmers in Southern Africa.

6. Conclusions and Recommendations

The study set out to evaluate farmers' perceptions of and adaptation to climate change in Kenya with special reference to Kyuso District. It was found out that majority of the farmers were well aware that climate was changing and it was the cause of the recurrent droughts that were ravaging the district. Majority of the farmers noted that there was an increase in temperature, extended periods of temperature, a decrease in precipitation, changes in the timing of rains and an increase in the frequency of droughts.

As such, most farmers had undertaken necessary adaptation measures to counter the adverse effects of climate change.

The most common adaptation strategies among farming households who perceived increases in temperature were: crop diversification, planting different crops, varying land area under cultivation, and migration to a different site. Adaptation methods used by those who perceived extended periods of temperature were: planting different crops, crop diversification, increasing water conservation practices, adjusting the number and management of livestock and changing the size of land under cultivation. On the other hand, adaptation measures least employed by farmers who perceived changes in temperature included: switching from livestock to crops, switching from non-farming to farming and increased use of irrigation technology.

With regard to precipitation, most farmers who observed an increase in the frequency of droughts and a decrease in precipitation migrated to new sites and also adjusted the number of livestock and livestock management practices. As for the farmers who noted a change in the timing of rains, a majority opted to migrate to a different site while a few others decided to adjust the number of livestock and livestock management practices. The least popular adaptation methods among all farmers who either noted a decrease in precipitation or a change in timing of rains were switching from non-farming to farming and the use of irrigation technology due to scarcity of irrigation water.

The results from the study also show that the age of the household head, gender, education, farming experience, household size, access to irrigation water, distance to the nearest market, local agro-ecology, access to information on climate change, access to extension services and off farm income were crucial factors in influencing the likelihood of farmers to perceive climate change. Similarly, factors such as the age of the household head, education, farming experience, household size, distance to the nearest market, local agro-ecology, farm income, access to information on climate change, access to credit and changes in temperature and precipitation were also found to determine farmers' adaptation to climate change in the district. Any policy aimed at enhancing the adaptive capacity of the farmers in the study area should thus consider making use the factors mentioned afore.

It was also discovered in the study that farming in the district is mostly carried out by women as men are based in towns carrying out off farm activities. This has important policy implication in that women would therefore need to be empowered through women groups and associations since this can have significant positive impacts for increasing the uptake of adaptation measures by the farmers. The policy framework can also consider promoting women in terms of access to education, assets, and other critical services such as credit, farming technology and inputs supply.

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