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Farmers' Adaptation Mechanisms to Climate Change and Variability: The Case of La'Ilay Maichew Woreda, Central Tigray, Ethiopia

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Abstract
Climate change and variability is rapidly emerging as one of the most serious global problems affecting many sectors in the world and is considered to be one of the most serious threats to sustainable development. The impact of climate change depends on severity of the natural resource degradation and the technological capacity of the people to cope up the changes in climate. La'ilay Maichew woreda in Tigray regional state, is not an exception in this context. Farmers have been making efforts to cope up the adverse impact of climate change and variability by using different adaptation methods. Adaptation method is largely site-specific and site-specific issues that require site specific knowledge. Thus, this research was initiated to address the knowledge gab: to identify the adaptation methods and factors that affect farmers' choice of adaption strategies. Quantitative design was primarily employed for the study. The essential data were collected from 130 randomly selected farm households using semi-structured interview schedule. Descriptive statistics and MNL logit model were used for analyzing quantitative data. The study has established that rainfall and temperature in study area have been decreasing and increasing respectively. To adapt this climate change the farmers have been using a combination of adaptive strategies, which include agronomic practices, livestock management and water and soil conservation. The results from MNL highlighted that sex, age, education, family size; farm income, farm size, TLU, extension visit, credit use, and access to climate information were the significant factors that influenced farmers' choice of adaptation option to climate change in the study area. In general, increasing farmers' awareness on climate change and variability risk perception, improve farmers' income-earning opportunities, Moreover, access to extension and credit services are essential to cope up the adverse impact of climate change and variability in La'ilay Maichew Woreda. It was, thus, recommended that policy aimed to reduce adverse impact of climate change in the area could be successful if these factors mentioned above are taken into consideration with respect to the intrinsic nature of climate change adaptation options.

1. INTRODUCTION

The occurrence and distribution of climatic variables in Ethiopia varies from region to region.It has been observed that rainfall trend in Ethiopia during the last half century significantly reduced towards North and South, and South-east of the country while an increasing trend has been observed in the central part of Ethiopia during the dry season (NMA, 2009). Rainfall in Ethiopia is projected to continue the trend that has been observed. Likewise, both mean maximum and minimum temperature have shown positive trend and on average a 1.3°C increase has observed between 1960 and 2012. Temperature projection on the coming decades shows an average increase of 1.1 to 3.1°C by the 2060s, and 1.5 to 5.1°C by the 2090s (McSweeney *et al*., 2009).

Climate change will, therefore, affect merely the poor farmers in the world as a whole and Africans in particular. Because, most of the rural poor rely on rainfed crop production, pastoral herding and direct harvesting of natural services of ecosystems such as forests and wetlands, which all are sensitive to climate vagaries (Mitchell and Tanner, 2006). Thus, the livelihood base of the poor is highly vulnerable to climate-related stresses such as changes in temperature, precipitation and increased frequency of droughts and floods (IPCC, 2007).

Rosenzweig *et al.* (2002) indicated that developing countries are and will be affected more by climate change and variability as a greater fraction of their economy is in climate sensitive sectors and the economy relies on labor intensive technologies with fewer adaptation opportunities. The agronomic (climate, soils, crops and livestock) and economic (material, labor, and energy inputs; food and services outputs) impact of climate change depends on the rate and magnitude of climate variables and their effect on agriculture as well as the ability of agricultural production to adapt to changing environmental conditions (IPCC, 2001).

Tigray region is the most affected region in Ethiopia due to climate change and variability. The overall natural resources base of the region is highly degraded. This initial potential together with the current global warming aggravates the vulnerability of the people to climate change impacts. Various reports agree that the region has been facing all droughts that have occurred in the country indicating susceptibility of the region to climate change and variability. Deressa *et al*. (2008) indicated that the most significant climate change impact in Tigray is due to drought and flood. Even a mild water stress during the crop growth period has resulted in complete failure in this region (Oxfam, 2010). Thus, people in the region, the study area is not the exception, are facing a variety of shocks and become vulnerable.

Adaptation can be viewed as reducing the severity of many impacts if adverse conditions prevail. That is, adaptation reduces the level of damages that might have otherwise occurred. However, adaptation is a risk-management strategy that is not free of cost. The success of adaptation depends critically on the availability of necessary resources, not only financial and natural resources, but also knowledge, technical capability, and institutional resources (PCGCC, 2004). In addition, many social, economic, technological and environmental trends also critically shape the ability of farmers to adapt to climate change. Knowledge of the adaptation methods and factors affecting farmers' choices enhances efforts directed towards tackling the challenges that climate change is imposing on farmers (Deressa *et al*., 2008). Hence, farmers' traditional and/or introduced mechanism that used to cope with, and factors that affect farmers' choice of adaption strategies and barriers that hinder to take adaptation options is not studied well in the study area. Thus, this research was initiated to address this knowledge gap and the general objective was to identify the types and determinants of adjustments (adaptations) they have made in their farming practices in response to these changes.

2. RESEARCH METHODOLOGY

2.1. Description of the Study Area

2.1.1. Location

Tigray is one of the national regional states of Ethiopia which is located in the North part of the country between $12^0$15'N and $14^0$57'N latitude and $36^0$27'E and $39^0$59'E longitude and covers an area of 53,000 square kilometers. The region is bounded by Eritrea to the North, the Sudan to the West, and the Ethiopian regions of Amhara and Afar to the South and the East respectively. The study area, La'ilay Maichew woreda, is one of the 36 woreda in Tigray regional state of Ethiopia, part of central Tigray zone.

2.1.2. Demography

La'ilay Maichew woreda is inhabited by a total population of 82098, of which 40599 are men 41499 are women (TEPALUAA, 2012). The female and male population of the woreda accounts for 50.5% and 49.5% of the total population respectively. According to the CSA (2007) no urban inhabitant is in the woreda. With an area of 566.5 square kilometer, the woreda has a population density of 144.9 persons per km^2. Generally, this population density is higher than Tigray regional state, 92 persons per km^2, and that of the country, 67 persons per km^2. According to the same report, the household size of the woreda is 4.7. This is almost the same to the country level average household size of 4.9 for rural. The number of households in the woreda accounts 15001 of which 27.6 are female headed households and 72.4 are male headed households (TEPALUAA, 2012).

2.1.3. Climate and agro-ecology

The rain season of the study area, La'ilay Maichew woreda, is monomodal (concentrated in one season which is from July to September) and receives from 354.6 to 1037.0 mm of rain fall per annual for the years 1961-2010. The mean minimum and maximum monthly temperature ranges from 8.7^0c to 13.2^oc and 24.4 ^{o}c to 31.4^oc respectively (NMA, 2010). The woreda is classified in semi arid tropical belt with a 'Woina Dega' (middle altitude) agro climatic zone. According to the new agro-ecological classification the woreda is grouped under SM2-5D2. There are different soil types in the woreda, which exist in combination of 70% clay silt 70%, and 12.26%) sand (LMWBoARD, 2012).

2.1.4. Socio-economic condition

In the specific study area, La'ilay Maichew woreda, agriculture is the mainstay of the community. Like in other parts of the country, the farming techniques used by the rural communities are traditional. The study area is characterized as mixed farming system where the livelihood of the rural community depends both on livestock and crop farming. Crop production is almost dependent on rain fed. teff, wheat, maize, sorghum barley, and pluses (field pea, bean, and lentil) are the dominant crops grown in the study area. Wheat and teff are the major sources of daily foodstuffs. The dominant sources of the livelihood of the rural community is agriculture that accounts about 90 % of the total population, while different secondary livelihood strategies such as trade accounts about 7 % , salary employments and other miscellaneous activities cover for about 3 % of the yearly incomes earned (TEPALUAA, 2012). The agricultural production is predominantly subsistent and it is difficult to estimate the household yearly income. Nevertheless, it is clear that most of the produced crops and livestock or livestock products are used for household consumption. The remaining used for seed and sold to pay credits, government obligations, purchase of fertilizer, household financial expenses. Government and NGOs food aid and moving to adjacent areas such as Humera are also alternative food or income sources of the study area.

Nowadays farmers of La'ilay Maichew woreda are in process of adjusting their farm system by focusing on irrigation agriculture. According to woreda Bureau of Agriculture and rural development, the coverage of irrigation agriculture has tremendously improved to about 1200 ha (7.7%). In the year 2010/11 woreda wide it was planned to raise the irrigation agriculture to about 4694 ha (31.9%) of the total cultivated land (15467 ha).

2.2. Survey Design and Data Collection

Two stage sampling procedure was used. In the first stage, out of the total of 15 *tabias* (the smallest administrative unit) of the woreda four *tabias* were randomly selected using simple random sampling technique. In the second stage, a total of 130 household heads were sampled randomly from the respective list of farmers in the selected four *tabias* using probability proportional to the size of the population of each *tabias* from which the sample households were to be drawn (see Table 1).

Table 1: Distribution of sampled households in the study area

Tabia list	Total No of households	%	No of Sampled HHs
Aditsahafi	955	18.5	24
Durra	882	17.7	23
Hatsebo	1638	31.5	41
Mahibereselam	1683	32.3	42

Source: Own survey result, 2012

Secondary data about the physical, socio-economic and demographic variables of the Woreda were gathered from the Agricultural and Rural Development Office of the Woreda, BoFED, TEPLUAA and NMA. Additional information about climate condition, adaptation options and farmers' perception were gathered from journals and books.

Semi-structured interview schedule was used to collect primary data from the sampled households about the socio-economic characteristics and institutional factors of the household. To collect all the information both formal and informal methods were employed.

2.3. Methods of Data Analysis

The present study employed descriptive statistics and econometric model to analyze the data. Qualitative data obtained from interview and group discussion and the review of documents were compiled, organized, summarized and interpreted through concepts and opinions.

Econometric analysis

The decision of whether or not to use any adaptation option could fall under the general framework of utility and profit maximization. Consider a rational farmer who seeks to maximize the present value of expected benefits of production over a specified time horizon, and must choose among a set of *j* adaptation options. Farmer *i* decides to use *j* adaptation option if the perceived benefit from option *j* is greater than the utility from other options (say, *k*) depicted as:

$$U_{ij}(\beta'_j X_i + \varepsilon_j) > Uik(\beta' kXj + \varepsilon k), k \neq j \quad (1)$$

Where U_{ij} and U_{ik} are the perceived utility by farmer *i* of adaptation options *j* and *k,* respectively; X_i is a vector of explanatory variables that influence the choice of the adaptation option; β_j and β_k are parameters to be estimated; and ε_j and ε_k is the error term.

The probability that farmer *i* will choose adaptation option *j* among the set of adaptation options could be defined as follows:

$$\begin{aligned} P(Y=1/X) &= P(U_{ij} > U_{ik}/X) \\ &= P(\beta'_j X_i + \varepsilon_j - \beta'_k X_i - \varepsilon_k > 0/X \\ &= P(\beta'_j - \beta'_k)X_i + \varepsilon_j - \varepsilon_k > 0/X \\ &= P(\beta^* X_i + \varepsilon^* > -0/X) = F(\beta^* X_i) \end{aligned} \quad (2)$$

Where ε^* is a random disturbance term, β^* is a vector of unknown parameters that can be interpreted as the net effect of the vector of explanatory variables influencing adaptation, and F ($\beta^* X_i$) is the cumulative distribution of ε^* evaluated at $\beta^* X_i$. Depending on the assumed distribution that the random term follows, the appropriate econometric model would, thus, be either a multinomial logit (MNL) or multinomial probit (MNP) regression model. Both models estimate the effect of explanatory variables on a dependent variable involving multiple choices with unordered response categories.

The advantage of using a MNL model is its computational simplicity in calculating the choice probabilities that are expressible in analytical form (Tse, 1987). This model provides a convenient closed form for underlying choice probabilities, with no need of multivariate integration, making it simple to compute choice situations characterized by many alternatives. In addition, the computational burden of the MNL specification is made easier by its likelihood function, which is globally concave (Hausman and McFadden, 1984). In this study, therefore, MNL specification is adopted to model climate change adaptation behavior of farmers involving discrete dependent variables with multiple choices.

Specification of the MNL Model

Multinomial logit model was employed to estimate the effect of the hypothesized explanatory variables on the choice of adaptation options of climate change and variability. The model is normally estimated using the iterative maximum likelihood estimation procedure, which yields unbiased, efficient and consistent parameter estimates.

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 contain different household, institutional and environmental attributes. 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 x K vector with first element unity. Thus, the probability that household i with characteristics x chooses adaptation option j is specified as follows:

$$P(Y=j/x)=\frac{\exp(x\beta_j)}{\left[1+\sum_{h-1}^{j}\exp(x\beta_h), j=1....J\right]} \quad (3)$$

Where P stands for probability, j stands for adaptation options, x for explanatory variables and β is K x 1, j = 1, . . . , J.

The parameter estimates of the MNL model provide only the direction of the effect of the independent variables (explanatory variables) on the dependent (adaptation options) variable, but estimates do not represent either the actual magnitude of change nor probabilities. Differentiating the equation of multinomial logit model with respect to the explanatory variables provides marginal effects of the explanatory variables (the probability of change in the dependent variable with a unit change of the independent variable). This was calculated as follows.

$$\frac{\partial P_j}{\partial X_k}=P_j(\beta_{jk}-\sum_{j=1}^{J-1}P_j\beta_{jk}) \quad (4)$$

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, 2003).

Before running the model it is useful to look into the problem of multicollinearity among the continuous variables and verify the degree of association among the hypothesized qualitative explanatory variables. The reason for this is that the existence of multicollinearity will affect seriously the parameter estimate. If it turns out to be significant, the simultaneous presence of highly correlated variables will attenuate or reinforce the individual effect of these variables. Accordingly, Variance Inflation Factors (VIF) technique was employed to detect the problem of multicolliniarity for continuous explanatory variables (Gujarati, 1995). Each continuous variable is regressed on all the other continuous explanatory variables, the coefficients of determination R^2 being constructed in each case. If an approximately linear relation exists among the explanatory variables then this will result, in 'large value for R^2 in at least one of the test regressions. A popular measure of multicollinearity associated with the VIF is defined as:

$$VIF=\frac{1}{1-R^2} \quad (5)$$

A rise in the value of R^2, that is increase in the degree of multicollinearity, does indeed lead to an increase in the variances and standard error of the OLS estimates. A VIF greater than 10 is used as a signal for existence of severe multicollinearity (Gujarati, 1995). Similarly, there may also be an interaction between qualitative variables, which can be lead to the problem of multicollinearity or strong association. To detect this problem, coefficients of contingency were computed from the survey data. The contingency coefficients are calculated as follows:

$$C=\sqrt{\frac{\chi^2}{n+\chi^2}} \quad (6)$$

Where C is the contingency, χ^2 is chi-square and n= total sample size

2.4. Definition of Variables and Working Hypothesis

2.4.1. Dependent variables of the model

The dependent variable in the empirical estimation for this study is the choice of an adaptation option from the set of adaptation measures used by the farmers' in response to climate change. Changing planting date, changing crop varieties, changing other crop types, irrigation and in *situ* moisture conservation practice are some of the adaptation options for climate change in rainfed agriculture of many African countries (Hassan and Nhemachena, 2008). In this research, changing/adjusting planting date, use of crop diversification, use of improved variety, use of irrigation and use of soil and water conservation practice are considered as the adaptation options followed by farmers. The variables are specified as follows:

Y=1, if the choice lies in changing/adjusting planting date
Y=2, if the choice lies in use of crop diversification
Y=3, if the choice lies in use of improved variety
Y=4, if the choice lies in use of irrigation
Y=5, if the choice lies in use of soil and water conservation practice

2.4.2. Independent variables of the model

Explanatory variables			
variable	Type	Definition and measurement	Expected sign
AGE	Continuous	Age of household head in years	Positive
SEX	Dummy	Sex of household head (0=female; 1=male)	Positive
EDUCTN	Continuous	Education level of household head in years of schooling	Positive
FMLSIZE	Continuous	Family size of household in numbers	Positive
LNDSIZE	Continuous	Land holding size of household in hectare	Positive
FRMINCM	Continuous	Farm income of household in Birr	Positive
OFFNFRIN	Continuous	Off/non farm income of household in Birr	Positive
TTLU	Continuous	Total livestock owned by household in TLU	Positive
NOEXC	Continuous	Number of extension contact per year	Positive
CINFOA	Dummy	Access to climate information by the household (0= no; 1= yes)	Positive
FTFEXTN	Dummy	Agricultural input and information from farmers around by household head (0= no; 1= yes)	Positive
CREDIT	Dummy	Credit use by the of household (0= no; 1= yes)	Positive
DISMKT	Continuous	Distance of woreda market from the residence	Negative

3. RESULTS AND DISCUSSION

3.1. Climate Change Adaptation Strategies of Farmers in La'ilay Maichew Woreda

This section focuses on the various adjustments that farmers in the study area made in their farming activities if they perceived changes in the climate, particularly rainfall. Based on the household survey data collected from 130 households during 2010/2012 production season 86.2% of them have observed change in both climate parameters (temperature and rainfall) over the past 20 years. They able to recognize that temperatures have increased and there has been a reduction in the volume of rainfall. All farmers (112) who perceive change on climate are responding in the face of climate change and variability by taken at least one remedial action. Different adaptation strategies that farmers consider appropriate to adapt climate change and variability was identified.

3.1.1. Farmers' responses in the face of climate change and variability

Climate is an important resource in the growth of a crop. Moreover, when climate variability disrupts the delivery of climate resources, such as in periods of drought, production costs may rise, causing a decrease in farm revenues. Persistent disruption of climate resources induces farmers to substitute more reliable resources for riskier ones. Farmers who claimed to have observed changes in climate over the past 20 years were subsequently asked if they have responded through adaptation to counteract the impact of the climate change. Accordingly, they noticed that they are using different adaptation strategies to cope with the negative impact of climate change and variability. The adaptation strategies used by farmers in the study area include changing/adjusting planting date, use of irrigation agriculture, use soil and water conservation techniques, changing from local late maturing to early mature crop (use of improved crop varieties), destocking (decrease the number of livestock rearing), and change local breed to improved livestock breed (Table 18).

A. Irrigation agriculture

Irrigation agriculture has become a widely used substitute for inadequate or unreliable precipitation in the woreda since recent years. It is providing a large comparative advantage to farmers of the woreda. However, availability, accessibility, and scarcity of irrigation were a great problem as reported by farmers during the survey. In the study area, about 47% of the respondents who have the perception of climate change had irrigation access and about 29.5% of them has experienced in using irrigation agriculture as most effective and efficient adaptation strategies to reduce the adverse effect of climate change. Personal preference and economic considerations such as the price of the crop influence farmers' choices which crops to grow in their irrigated land.

Most of them, however, grow vegetable and legume crops.

B. Use of improved varieties

Teff (DZ-01-974, DZ-01-196 and DZ-01-CR-37), Wheat (HAR-2501 and HAR-1865), Maize (*Zama*, *Toga* and *Melikasa A5-11*), Finger millet (*Tadesse*) and vegetable seeds are among the different improved varieties introduced in the study area. About 71% of the sampled farmers who have the perception of climate change were users of different improved crop varieties. From the total sampled households who perceived change on climate, 37.5%, 50.9%, 6.2%, and 17.9% used improve varieties of teff, wheat, maize, and vegetable seed respectively in 2010-2012 production year. Moreover, in the study area, 23.2% of those who have the perception of climate change had used improved crop varieties as most effective and efficient adaptation strategies to reduce the adverse effect of climate change in their farm condition (Table 17).

Table 2: Users of improved varieties adaptation method of sampled farmers

Improved varieties	Number of users	
	N(112)	%
Teff	42	37.5
Wheat	57	50.9
Maize	7	6.2
Vegetable seed	20	17.9

Source: Own survey result, 2012

C. Crop diversification

Crop diversification (mixed cropping, intercropping and dividing farm lands in to varying crops) is one of the most common practices in the study area. The system is commonly practiced in La'ilay Maichew woreda where cereals (maize, teff, and wheat), legumes (beans) and vegetable (onion, tomato, and pepper) are grown together. From discussions with farmers, it was noted that they have wide field knowledge on advantages of mixing crops with varying attributes in terms of maturity period, drought tolerance, input requirements and end users of the product (e.g. maize as food and vegetable for cash). From the total sampled households who perceived change on climate, about 70.5% use crop diversification method. Moreover, about 24% of them used crop diversification as most effective and efficient adaptation strategies to reduce the adverse effect of climate change in their farm condition (Table 18). Their main reasons for crop diversification in the study area were to minimize risk of drought, market interest such as the price of the crops, soil fertility improvement, and to fulfill their own consumption. The study also revealed that farmers diversify crop types as a way of spreading risks on the farm (Orindi and Eriksen, 2005). Crop diversification can serve as insurance against rainfall variability (Lema and Mjule, 2009).

D. Soil and water conservation

One of the major challenges facing in the study area in striving for development is environmental degradation, manifested in the degradation of land and water resources. Berhanu *et al*. (2000) has clearly notes the severity of resource degradation of Tigray in reference to soil erosion, soil nutrient depletion, moisture stress, deforestation and overgrazing are the major environmental problems in the region. Considering the magnitude of the moisture stress in the woreda, soil and water conservation techniques are widely adopted by farmers. Of the total sampled households who perceive change in climate condition about 91 % were used different soil and water conservation techniques (Table 18). Moreover, out of those who perceived change on climate about 13 % of them used soil and water conservation as most effective and efficient adaptation strategies to reduce the adverse effect of climate change in their farm condition. Soil/stone bunds, tied ridging, ridging diverting flood, mulching manure, application inorganic fertilizer application, and maintenance of proper seed rate are among soil and water conservation techniques which are commonly used by farmers of the study area.

E. Livestock management

With agricultural productivity increases lagging behind population growth rates, the gap between availability and demand for agricultural land continues to grow, resulting in severe land-use conflicts between crop farming and animal grazing. As revealed from the survey animal feed shortage is of the major challenges facing farmers of the study area. Following these challenging problem, farmers of La'ilay Maichew woreda undergo strategic adaptation which include destocking (decrease the number of livestock) and change the local breed to improved livestock breeds. Of the total sampled households who perceive change in climate condition about 75 % decreased the number of their livestock number where as 39.3% of them introducer improved livestock breeds as adaptation strategies for adapting the environmental change.

Table 3: Adaptation strategies of sampled farmers in La'ilay Maichew woreda

Adaptation options	Number of users		As best option	
	N(112)	%	N(112)	%
Access to irrigation	53	47.3	33	29.5
Changing planting date	52	46.4	11	9.8
Crop diversification	79	70.5	27	24.1
Soil and water conservation	102	91.1	15	13.4
Improved crop varieties	80	71.4	26	23.2
Destocking	84	75.0	0	0
Use of improved livestock breed	44	39.3	0	0

Source: Own survey result, 2012

F. Changing/Adjusting planting date

One of the most adaptation methods used to cope with adverse effect of climate change in the study area, La'ilay Maichew woreda, is adjusting crop production period that is from early planting to late planting or vice versa. In the study area, about 46% of those who had the perception of climate change have used changing planting adaptation method. In addition 9.8% of them use changing planting date adaptation option as most effective and efficient adaptation strategies to reduce the adverse effect of climate change in their farm condition (Table 18).

3.1.2. Perceived barriers of adaptation to climate change in La'ilay Maichew woreda

The necessity of coping with adverse impacts from climate change will force adaptations, but farmers may miss many opportunities to adapt more effectively and efficiently due to different socio economical and institutional barriers. Even if farmers do perceive that the climate has changed they may still, because of any number of barriers, be unable to respond in the way that they themselves would wish. The group discussion revealed that society has a lack of capacity to adapt to climate change and many farmers fall short of using the adaptation options to its full extent. This section focuses on the various barriers farmers face for adjustments in their farming activities while they have the perception change in climate.

A large number of farmers interviewed noticed changes in climate, almost all farmers who perceive change on climate did undertake at least one remedial action. However, more than 83 %, 68% and 63% of farmers cited shortage and lack of access to water for irrigation, finance, and lack of weather or climate information respectively, as the main barriers to better cope the adverse impact of climate change. Lack of labour force, lack of improved crop varieties and lack of technical knowledge of appropriate technologies are also cited by 58%, 36% and 12% respectively, as significant barriers to better adjustments in the changing condition of climate (Figure 5).

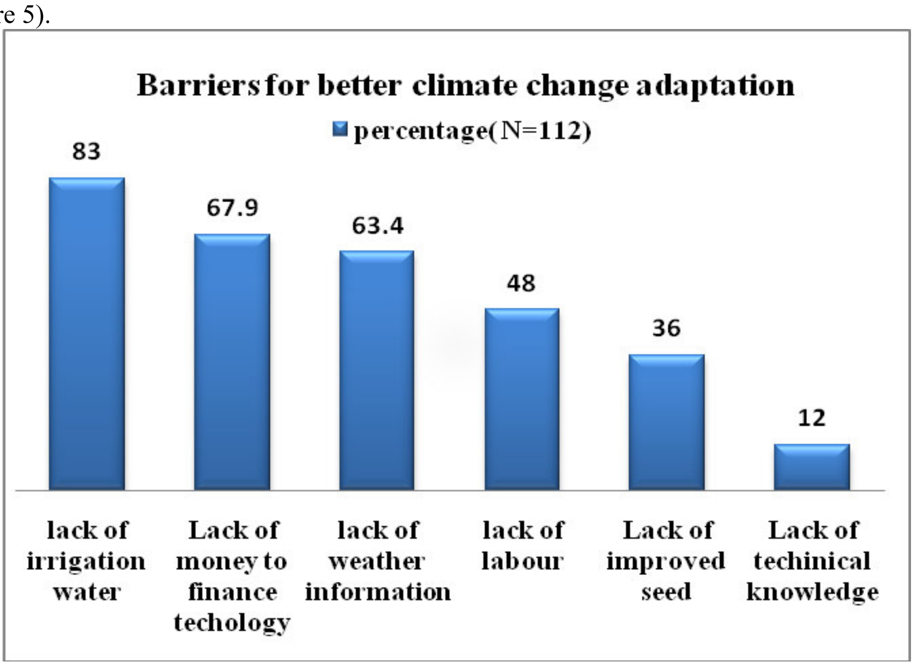

Figure 1: Perceived barriers of climate change adaptation in La'ilay Maichew woreda

3.2. Determinants of Farmers' Choice of Adaptation Methods to Climate Change in La'ilay Maichew Woreda

Multinomial Logistic Regression Model was used to identify determinants of farmers' choice of climate change adaptation options. The model was selected based on the justification illustrated earlier in the methodology part. Therefore, in this section, procedures followed to select independent variables (continuous and dummy) and result of logistic regression analysis conducted to identify determinants of farmers' choice of climate change adaptation options is presented.

3.2.1. Model results and discussion

This section reports results of the analyses of determinants of farmers' choice of adaptation methods to climate change in the study area and discuss the important socioeconomic and institutional influencing farmers' choice of adaption decisions to reduce the negative impact of climate change.

Before running the model it is useful to look into the problem of multicollinearity among the continuous variables and verify the degree of association among the hypothesized qualitative explanatory variables. To this effect the eight continuous explanatory variables were checked for multicollinearity using Variance Inflation Factors (VIF) while Contingency Coefficients were used to detect the degree of association among five qualitative explanatory variables. The variance inflation factors for all variables are less than 10 (1.04 - 2.36) (Appendix II), while contingency coefficients are not more than 0.75 (Appendix III), which indicate that multicollinearaity is not a serious problem in this model. According to the results no significant problems of multicollinearity and very high degree of association were observed. Therefore, all the hypothesized continuous and discrete explanatory variables were included in the model. The estimated coefficients of the MNL model along with the levels of significance are presented in Table 19.

3.2.2. Interpretation of econometric results

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 fourth category (use of irrigation adaptation method) is the reference state. The likelihood ratio statistics as indicated by chi square 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 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 (irrigation).

Table 4: Parameter estimates of the multinomial logit climate change adaptation model

Explanatory variables	Adjusting planting date		Crop diversification		Improved variety		Soil and water conservation	
	P- value	Marginal effect	P-value	Marginal effect	P - value	Marginal effect	P-value	Marginal effect
Sex	0.528	-0.001	0.090	-0.382*	0.859	0.083	0.644	-0.012
Age	0.015	5.18e-06**	0.042	.008**	0.927	0.001	0.060	-0.015*
Education	0.174	8.03e-06	0.082	0.019*	0.328	0.026	0.245	-0.025
Family size	0.005	-0.0001***	0.027	-0.033**	0.221	-0.081	0.049	0.077*
Land size	0.979	-0.0001	0.340	0.041	0.220	0.215	0.065	0.308*
TLU	0.020	0.0001**	0.050	0.033*	0.884	0.004	0.322	-0.027
Farm income	0.018	-5.92e-09**	0.020	-7.63e-06**	0.014	-0.0001**	0.054	-7.06e-06
Off/non farm income	0.722	3.40e-09	0.363	0.0001	0.196	-0.0001	0.341	-.00002
Use credit	0.016	0.0001**	0.415	0.021	0.652	0.090	0.811	.0102
Extension visit	0.010	-3.71e-06*	0.219	-0.006	0.092	0.019*	0.009	-0.010***
Farmer to Farmer ext	0.493	.0000154	0.219	0.045	0.158	-0.160	0.121	-0.128
Market Distance	0.127	-4.43e-06	0.209	-0.006	0.245	0.016	0.342	0.007
Climate Information	0.043	-0.0001**	0.157	-0.072	0.078	0.311*	0.579	.0197
Constant			0.581		0.531		0.105	
	Diagnostics							
	Base category				Irrigation			
	Number of observation				112			
	LR chi^2 (52)				197.67			
	Log likelihood				-73.555845			
	Prob > chi^2				0.00000			
	Pseudo R^2				0.5733			

***, ** And * represent level of significance at 1%, 5% and 10% respectively

I. Socio economic determinants of choices of climate change adaptation options

Sex

As compared to use of irrigation, being male-headed household decreases the probability of using crop diversification by 0.38 at 10% significant level. This result indicates that male headed households prefer using more irrigation adaptation method to crop diversification adaptation method as compared to female headed households. It is clear that irrigation is the strongest adaptation measure against climate change, but it requires high investment. Descriptive analysis result also shows that female headed households are less endowed with farm size, family size, and livestock ownership than male headed households. Thus, wealth may be the reason why male headed household prefer irrigation adaptation option to crop diversification adaptation option.

Age

Age of the household head affected climate change adaptation options significantly. For instance, a year increase in age of the household head results in 8% increase in the probability of use of crop diversification. As compared to irrigation use (the base category) an increase in age by one year decrease the probability of use of soil and water conservation adaptation option to climate change by 1.5% at 10 % significant level. An increase in age by one year also has a positive relation in changing/adjusting planting date as compared to irrigation use.

Education

Education of the head of household increases the probability of adapting to climate change. As can be observed from Table 19, education significantly increases use of crop diversification as an adaptation method. An increase in education by one year of schooling results in a 1.9 % increase in the probability of use of crop diversification to adapt to climate change. Moreover, almost all of the marginal values of education have positive relationship, except soil and water conservation which has negative sign as compared to the probability of the base category (use of irrigation) adaptation option.

Family size

Family size of the households has significantly impact on the probability of adaptation options to climate change. As compared to irrigation use (the base category) a unit increase in the family size would result in decrease in the probabilities of using adjusting planting date and crop diversification as adaptive options by 0.0001 and 0.033 at 1% and 5% significant level respectively. A unit increase in family size is also increases in the probabilities of using soil and water conservation adaptive options by 0.08 at 5% significant level as compared to irrigation use adaptation method.

Size of landholding

The size of landholding of the households has significantly impact on the probability of adaptation options to climate change. As compared to irrigation method (the base category) one hectare increase in the size of land holding would result in increase the probability of using soil and water conservation adaptation option to climate change by 0.31 at 10% significant level. One hectare increase in size of landholding also appears to increase the probability of using crop diversification and improved crop variety and to decrease the probability of using adjusting planting date adaptation methods to climate change as compared to irrigation method (the base category), although the results are not statistically significant.

Livestock ownership

The ownership of livestock of the households has significantly impact on the probability of adaptation options to climate change. As compared to irrigation use (the base category) a unit increase in the TLU would result in increase in the probabilities of using changing/adjusting planting date and use of crop diversification as adaptive options by 0.0001 and 0.033 respectively at 5% significant level. The ownership of livestock is also positively related to the use of improved crop variety and negatively related to the use of soil and water conservation adaptation methods as compared to irrigation use adaptation method, even though the marginal impacts are not significantly significant.

Farm income

The farm income of the households surveyed has significantly impact on the probability of adaptation options to climate change. As compared to irrigation use (the base category) an increase in farm income by one birr decrease the probabilities of adjusting planting date, use of crop diversification, improved crop variety and soil and water conservation as climate change adaptation methods by less than 0.01%. When the farm income of the households increase, farmers tend to invest more on irrigation adaptation option to cope with negative impact of climate change instead of using adjusting planting date, crop diversification, improved variety and soil and water conservation adaptation options to adapt climate change.

II. Institutional determinants of choices of climate change adaptation options

Credit use

As compared to use of irrigation method (the base category) use of credit service increases the probabilities of using adjusting planting date as adaptive option to climate change by 0.0001 at 5% significant level. Use of credit service has also a positive sign on the likelihood of using use of crop diversification, improved variety and soil and water conservation as compared to irrigation adaptation method, although the results are not statistically significant. 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.

Extension contact

As expected, extension visit to the households has significantly impact on the probability of adaptation options to reduce the negative impact of climate change. The result shows that as compared to use of irrigation method (the base category) an increase the number of extension visit reduces the probability adjusting planting date and use of soil and water conservation adaptation options by less than 0.001 and 0.01 at 1% significant level respectively and increases the probability of use of improved variety adaptation option by 0.02 at 10% significant level.

Information access on climate

Even thought service on climate information delivery is not formal, access to information from different source has significantly impact on the probability of adaptation options to climate change. As compared to use of irrigation getting information about seasonal forecasts and climate change decreases the probability of adjusting planting date by less than 0.01 at 5% significant level. Getting climate information also increases the probability of use of improved variety by 0.31 at 10% significant level.

Farmer-to-farmer extension

Having access to farmer-to-farmer extension increases the likelihood of using different adaptation methods. It appears to increase the probability of use of adjusting planting date and crop diversification adaptation methods as compared to irrigation method (the base category) to climate change, although the results are not statistically significant.

Generally, the result of this study indicates that adaptation of climate change is a result of an interplay of several factors, which need due attention.

4. CONCLUSIONS

A combination of strategies is used to adapt climate change in La'ilay Maichew woreda. changing planting dates (adjusting timing of agricultural operations), crop diversification, use of different improved crop varieties, increased use of water and soil conservation techniques, use of irrigation, destocking (decrease number of livestock) and introducing improved livestock breed are the main climatic change adaptation strategies used by farmers in the study area.

The multinomial logit model results highlighted that sex, age or farming experience, education, family size, farm income, farm size, TLU, extension visit, credit use, and access to climate Information are the factors that influence farmers' choice of adaptation option to climate change in the study area. The variable including nonfarm activities (income), distance to nearest or woreda market as well as farmer to farmer extension, however, had not significant in influencing climate change adaptation option choice of farmers in the study area.

The result from the multinomial logit analysis also shows that age, number of livestock owned, and use of credit have a significant positive impact on changing/adjusting planting date while family size, farm income extension visit and climate information have a significant negative effect as compared to the reference state (use of irrigation). From the observed result one may conclude that when farmers get climate information, agricultural extension service and have higher farm income they tend to invest in irrigation agriculture which is more effective to cope with adverse impacts from climate change rather than using changing planting date as adaptation method. The result also shows age, education and number of livestock owned have a significant positive effect on crop diversification adaptation option, whereas sex of the household head, family size and farm income of the household have significant negative effect on crop diversification adaptation option as compared to use of irrigation. Use of improved crop variety adaptation option is also positively affected by frequency of extension visit and access to climate information, but income of the household has negative and significant effect on the improved crop variety adaptation option as compared to use of irrigation. Thus, when farmers get climate information and agricultural extension service they tend to use improved crop variety as adaptation option to cope with adverse impacts from climate change.

Use of soil and water conservation adaptation option is positively affected by family size and access land size, but age, income of the household and frequency of extension visit have negative and significant influences on soil and water conservation adaptation option as compared to use of irrigation. From this result, in relation to soil and water conservation, the influence of extension agent is clearly seen in influencing decision of farmers to use other adaptation option more than Soil and water conservation adaptation option to cope with adverse impacts from climate change. Use of irrigation which is capital intensive, but most effective adaptation option, is positively affected by farm income of the household, but farm size of the household has negative and significant effect on use of irrigation adaptation option. This is may be due to lack availability and accessibility of irrigation water around their farm; those who have large farms are away from source of irrigation water.

In addition, the result from the model shows that male headed household is more likely preferred to adapt irrigation to crop diversification adaptation method to cope with adverse impacts from climate change than female headed household. The age of the household head increase the probability of preferring adjusting planting date crop diversification and soil and water conservation adaptation method to use of irrigation adaptation method. The level of education of the household head increases the probability of preferring crop diversification adaptation method than use of irrigation adaptation method by 2%. Large family size increases the probability of preferring soil and water conservation adaptation method to use of irrigation adaptation method by 7.7 %. The result also shows that having large family size increase the probability of preferring use of irrigation adaptation method than adjusting planting date and crop diversification and soil adaptation methods by 0.01%. and 3.3% respectively.

Larger land size owned increase the probability of preferring soil and water conservation adaptation method to use of irrigation adaptation method by 30.8%. The number of livestock owned increase the probability of preferring soil and water conservation adaptation method to use of irrigation adaptation method. The result also shows that having large total tropical livestock unit increase the probability of preferring adjusting planting and crop diversification adaptation methods by less than 1% and 3.3% respectively as compared to use of irrigation adaptation option. The result also shows that having better farm income promotes switching to use irrigation adaptation method than adjusting planting date and crop diversification, improved crop variety and soil and water conservation adaptation methods by less than 1%. These results clearly shows that when farm income of the household increase they tend to invest more to irrigation water, which is considered the most effective method, rather than any other adaptation option to cope with adverse impacts from climate change.

Utilization of formal credit increase the probability of preferring adjusting planting date adaptation method to use of irrigation adaptation method by less than 1%. Better visited farmers tend to use irrigation adaptation option than adjusting planting date and soil adaptation methods. The result also shows having more extension visit increase the probability of preferring improved crop variety adaptation method than use of irrigation adaptation method. More access to reliable seasonal forecast and climate information tend to increase the use of irrigation option than adjusting planting date adaptation option. The result also shows having more access to reliable seasonal forecast and climate information tend to increase the use of improved crop variety adaptation option than to use of irrigation adaptation option.

5. Recommendations

Farmers in La'ilay Maichew woreda in general are very poor and cannot afford to invest on irrigation technology (which are usually capital intensive) not only to adapt to climate change but also to sustain their livelihood during harsh climatic extremes such as drought. As a result most farmers of the woreda are involving in inexpensive, but less effective adaption options, such as crop diversification and changing planting date, to cope with the adverse effect from climate change. Government policies should therefore ensure that farmers have access to affordable credit to increase their ability and flexibility to change production strategies in response to the forecasted climate conditions. In addition, farmers' choices of climate change adaptation options in the study community are relatively low. Hence, researchers, extension agents, policy makers and farmers should interact to develop multiple of climate change adaption options appropriate to the farmers' situations.

With the ever increasing weather unreliability, strong dependence on climate sensitive sector and continued water deficit, the involvement of institution on early warning and robust contingency planning is crucial. Therefore, improving farmers' farm and off/non-farm income-earning opportunities is of great need in La'ilay Maichew woreda. Thus, investment in education systems, sufficient input supply which increases farm income and creation of off/non-farm employment opportunities in the rural areas can be underlined as a policy option in the reduction of the negative impacts of climate change. Furthermore, government should increase access and amount of credit given to farmers.

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7. APPENDICES

Appendix I. Conversion factors used to calculate Tropical Livestock Units (TLU)

Animals	TLU-equivalent
Calf	0.25
Heifer and Bull	0.75
Cows and Oxen	1.00
Horse	1.10
Donkey	0.70
Sheep and Goat	0.13
Chicken/poultry	0.013

Source: Strock *et al*., (1991)

Appendix II. Variance Inflation Factor (VIF) for continuous and discrete explanatory variables

Variables	Co linearity Variables Diagnoses	
	Tolerance(1/VIF)	Variance Inflation Factor (VIF)
Farm income	0.424547	2.36
Farm size	0.494693	2.02
Family size	0.549061	1.82
TTLU	0.555222	1.80
Age	0.599034	1.67
Education	0.689761	1.45
Climate information	0.690683	1.45
Distance from market	0.733741	1.36
Frequency of extension visit	0.752868	1.33
Use credit	0.860418	1.16
Non/off income	0.866147	1.15
Farmer to Farmer	0.959429	1.04
Mean VIF		1.55

Source: Model out put

Appendix III. Contingency Coefficients for the qualitative explanatory variables

	A	B	C	D	E
A	1	0.234	0.301	0.129	0.094
B		1	0.082	-0.080	0.153
C			1	0.286	-0.087
D				1	0.085
E					1

Source: Model out put

A = Sex of the household head
B = Extension service
C = Information on climate change
D = Farmer-to-farmer extension
E = Credit

Appendix IV. Monthly average temperature of Axum area

	National Meteorological Agency											
	Station:-Axum Element :- Average Temp.(0C)											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1992	#DIV/0!	#DIV/0!	22.29375	21.78086	21.95	22.11333	18.65323	17.62097	17.735	17.78387	17.15333	17.24839
1993	17.33065	17.38393	19.68548	19.78	20.73387	20.35833	18.46774	#DIV/0!	18.99167	18.75806	18.475	17.9
1994	18.27903	19.22857	20.56613	21.46167	22.20323	20.49167	18.12258	18.0129	17.49	18.30774	18.77833	18.39032
1995	19.09355	20.07857	20.96452	22.33667	21.85161	22.39333	20.37581	19.82742	19.2895	18.05323	18.59667	18.78871
1996	18.43065	19.31724	20.90968	19.25	19.81774	19.375	18.65645	18.94839	18.435	#DIV/0!	19.06	16.92419
1997	17.01452	17.35179	19.53226	18.59	19.82581	18.75667	16.41667	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
1998	#DIV/0!	18.38727	18.64677	20.805	21.67742	22.005	20.16613	18.95323	20.015	18.77903	18.01167	16.88548
1999	16.85806	17.86071	19.02903	21.42167	21.96935	21.88333	18.09333	19.57258	19.04183	19.21452	16.375	16.96129
2000	17.40161	18.78103	19.99032	19.42833	19.43871	20.96	19.08548	18.46129	18.62	18.7629	18.56333	17.21774
2001	17.85645	18.78036	20.49194	21.75	22.2129	20.66167	20.21935	19.84516	19.625	19.75645	19.325	18.05645
2002	18.56774	20.64464	21.58548	21.99333	22.61613	22.20333	20.45806	19.22581	19.58	19.75645	20.46	19.24516
2003	18.25161	20.7375	22.27097	21.82	21.18387	21.41661	19.96935	21.16774	21.31667	20.44194	19.185	18.71774
2004	19.24677	19.3069	19.5375	22.075	22.80645	21.11	12.25495	20.65161	19.80333	19.99516	19.10333	21.69032
2005	17.52258	19.54821	20.4629	21.16333	21.26935	20.58667	20.08065	20.57742	20.235	19.69194	18.86167	18.57258
2006	18.87419	19.82679	20.19194	20.61667	20.34032	20.24333	19.37903	18.79355	18.63833	19.15645	18.52667	18.20161
2007	18.68065	19.2375	20.05	20.05167	20.85323	21.05667	19.15968	20.31935	19.26833	18.10161	18.15333	16.66774
2008	18.18387	18.33966	18.92419	19.83333	20.57419	19.72333	18.94516	18.63871	17.43	17.50484	16.37667	16.45806
2009	17.13387	18.8375	21.40484	20.09333	21.89516	21.825	19.02903	18.69516	18.59833	18.40968	18.80466	18.32581
2010	17.49194	18.88571	19.87742	19.96	20.31129	19.58	19.80484	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

Appendix V. Monthly average rainfall amount of Axum area

	National Meteorological Agency												
	Station:-Axum												
	Element:-Average Rainfall												
Year	*Jan*	*Feb*	*Mar*	*Apr*	*May*	*Jun*	*Jul*	*Aug*	*Sep*	*Oct*	*Nov*	*Dec*	*Average RF(mm)*
1992	*0.0*	*0.0*	*0.0*	*14.9*	*19.5*	*57.4*	*176.5*	*427.4*	*77.6*	*23.7*	*57.3*	*3.9*	*858.2*
1993	*4.9*	*4.6*	*42.2*	*83.1*	*42.8*	*74.6*	*122.3*	*0.0*	*36.8*	*39.9*	*0.0*	*0.0*	*451.2*
1994	*0.0*	*3.2*	*0.0*	*8.4*	*23.3*	*166.6*	*215.6*	*284.7*	*46.6*	*2.4*	*0.0*	*0.0*	*750.8*
1995	*0.0*	*0.0*	*29.2*	*33.9*	*67.5*	*33.8*	*328.0*	*130.8*	*87.7*	*2.6*	*0.0*	*0.0*	*713.5*
1996	*0.0*	*0.0*	*73.7*	*56.5*	*146.1*	*56.4*	*168.5*	*219.9*	*30.5*	*0.0*	*72.6*	*0.0*	*824.2*
1997	*0.0*	*0.0*	*21.8*	*8.9*	*122.2*	*111.0*	*90.8*	*103.7*	*42.8*	*147.1*	*26.9*	*0.0*	*675.2*
1998	*0.0*	*0.0*	*6.7*	*33.2*	*85.0*	*76.6*	*372.1*	*356.1*	*83.6*	*23.7*	*0.0*	*0.0*	*1037.0*
1999	*40.3*	*0.0*	*0.0*	*20.7*	*10.2*	*42.1*	*278.4*	*219.5*	*52.3*	*92.0*	*0.0*	*2.0*	*757.5*
2000	*0.0*	*0.0*	*2.0*	*66.5*	*11.4*	*13.6*	*162.8*	*139.1*	*100.4*	*160.5*	*16.8*	*0.0*	*673.1*
2001	*0.0*	*0.0*	*1.5*	*6.4*	*15.9*	*74.0*	*212.1*	*355.6*	*25.8*	*14.5*	*0.0*	*0.0*	*705.8*
2002	*0.0*	*8.8*	*10.0*	*15.3*	*9.2*	*31.1*	*102.3*	*96.5*	*50.6*	*1.3*	*1.8*	*27.7*	*354.6*
2003	*2.5*	*8.5*	*2.4*	*8.3*	*12.2*	*126.1*	*322.7*	*209.1*	*89.6*	*1.4*	*3.7*	*0.0*	*786.5*
2004	*18.2*	*3.8*	*3.9*	*41.0*	*0.0*	*132.4*	*269.9*	*173.6*	*16.8*	*24.4*	*34.8*	*0.0*	*718.8*
2005	*0.0*	*0.0*	*129.7*	*86.0*	*5.1*	*85.4*	*176.6*	*226.0*	*67.2*	*0.0*	*0.0*	*0.0*	*776.0*
2006	*0.0*	*0.0*	*0.0*	*31.1*	*61.0*	*86.5*	*230.7*	*240.6*	*123.9*	*9.5*	*0.0*	*30.5*	*813.8*
2007	*0.0*	*0.0*	*7.0*	*10.9*	*35.5*	*112.6*	*428.1*	*272.8*	*154.3*	*0.0*	*6.1*	*0.0*	*1027.3*
2008	*38.5*	*0.0*	*0.0*	*85.2*	*41.3*	*102.3*	*161.8*	*174.7*	*49.9*	*1.5*	*6.8*	*0.0*	*662.0*
2009	*0.0*	*0.0*	*0.9*	*6.0*	*8.6*	*35.6*	*231.9*	*288.6*	*1.8*	*0.0*	*2.9*	*0.0*	*576.3*
2010	*1.2*	*0.0*	*54.2*	*36.3*	*17.3*	*109.4*	*209.4*	*0.0*	*0.0*	*0.0*	*0.0*	*0.0*	*427.8*