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Local perceptions and adaptation to climate variability and change: In the Bilate watershed

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In this study, farmers' perceptions and adaptation options to climate variability and change were assessed in the Bilate watershed of south central Ethiopia. The determinant factors that influence the choice of farmers to climate change and variability adaptation were also investigated. Above 92% of the surveyed farm households perceived variability and change in climatic variables. Based on the data from 270 households, 59% of the households participated in one or the other way of the six major adaptation strategies which most prevailed inside farmers of the watershed. Changing the crop variety, using water harvesting scheme, intensifying irrigation, using cover crop or/and mulching, reducing the number of livestock owned and getting off-farm job are the main adaptation strategies used by the farming households. The results from the binary logistic model further showed that age and educational level of the household head, farm size and the income level of the household are household characteristics that significantly affect the choice of adaptation options, while access to climate information in the form of seasonal forecast and local agro ecology are other factors that determined the selection of adaptation methods by the farming households in the study area. The main constraints to adaptation to climate change in the study area are seen to be knowledge gap in the form of lack of information, shortage of labour and minimal land sizes which are the three most explained constraints to climate change as explained by responding household heads.

Key words: Climate variability and change, perception, binary logistic model.

INTRODUCTION

Climate change is defined statistically as significant variation in either mean state of the climate or its variability which persists for an extended period typically decades or longer. It is a global environmental threat to all economic sectors, particularly in the agricultural sector (Chandrasiri, 2013). Climate is a key factor influencing agricultural production. Agriculture also affects climate change, which means higher temperatures, reduced rainfall and increased rainfall variability reduce crop yield and threaten food security in low income and agriculture-

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based economies (Deressa et al., 2011).

Adaptation to climate change is getting global attention as the confidence in climate change projections is getting higher, because it can no longer be ignored (Wilbanks and Kates, 2010). Adaptation in the context of climate change refers to any adjustment that takes place in natural or human systems in response to actual or expected impacts of climate change, aimed at moderating harm or exploiting beneficial opportunities (Smit and Wandel, 2006; Picketts et al., 2012). Adapting to climate variability and change has been part of human practice for long period and the historical record includes many cases of successful adaptations (Wilbanks and Kates, 2010).

Impact of climate change is detrimental to countries that depend on agriculture as the main source of livelihood (Deressa et al., 2011) and Ethiopia is fundamentally an agrarian country, with its agriculture sector continuing to be the most dominant contributor to the national economy. It accounts for nearly 46% of GDP, 73% of employment, and nearly 80% of foreign export earnings (ATA, 2014). To guide future adaptation strategies, we have to understand how farmers perceive and adapt to climate change because adaptation to climate change is a two-step process; the first step requires the farmers to perceive a change in climate and the second step requires them to act through adaptation (Deressa et al., 2011). In order to understand what adaptation options are needed and how the perceptions of farmers are affected, it is important to identify the climatic and non-climatic factors that influence the sensitivity of rural livelihoods to climate change for example age or farming experience of farmers, exposure to mass media and income level of rural household may all affect perceptions of climate change (Ishaya and Abaje, 2008; Semenza et al., 2008; Akter and Bennett, 2009). Number of studies shows that in one way or the other farmers perceive that the climate is changing and also trying to adapt to reduce the negative impacts of climate change (Mertz et al., 2009; Deressa et al., 2011).

The impacts of climate change are typically discussed at the global, continental or national levels and developing countries are recognised as the most vulnerable to climate change impacts and have less capacity to adapt (Lindseth, 2005). But the impacts of climate change are most acutely felt at local level, so there are many advantages to pursuing adaptation planning at this level (Juholaa et al., 2012) and there are a lot of studies on farm-level adaptation to climate change across different disciplines in various countries which explored farmers' adaptive behaviour and its determinants (Deressa et al., 2009; Bryan et al., 2013; Abid et al., 2015).

System's ability to adjust to climate change in order to minimize potential damages, and take advantage of opportunities or cope with the consequences of climate change is its adaptive capacity (IPCC, 2007; Juholaa et al., 2012). Adaptive capacity is highly varied within a society or locality and often influenced by factors such as class, gender, health, social status and ethnicity (Nielsen and Reenberg, 2010). This study is meant to, first to look how farmers perceive long term changes to the local climatic variables and second to analyse how farmers adapt their farming in response to perceived changes in climate.

METHODOLOGY

Description of the study area

The Bilate River watershed (BRW) covers an area of about 5625 km^2 and is located in the southern Ethiopian Rift Valley and partly in the Western Ethiopian Highlands. The Bilate River watershed stretches across different topographical zones, sections of the watershed are located in the Ethiopian Highlands and display mountainous characteristics while other areas are part of the Rift Valley and thus, are almost flat or undulating. The altitude of the watershed ranges from 1300 at Lake Abaya to 3050 m above sea level at Mt. Ambaricho. Geographically, its absolute location, south-north extends from 6° 36'N 38°00'E at Lake Abaya Wolaita zone SNNPR to 8°05'N 38°12'E at Gurage and Silte zones border, SNNPR. On the other hand its west-east extension is from 7°18'N 46'E at Kambata zone to 7°12'N38°22'E Sidama zone (Figure 1).

The land cover in the BRW is predominated by different types of agricultural land (87%), grass and rangeland only 0.8% and the remaining mixed land cover including plantation forest, shrub land and wetland accounts for about 12.2%. These days the forests are transformed to croplands and/or grazing areas. The problem is directly attributed to increasing human population especially in the rural areas.

The mean annual rainfall in the BRW ranges between 721 and 1353 mm which shows large spatial variability with a maximum rainfall is as large as 1.87 times the minimum rainfall. Areas that belong to the part of the Western Ethiopian Highlands show higher rainfall on annual base while the part of the watershed that belongs to the Ethiopian rift valley shows lower rainfall. Based on the interpolation method used, the mean annual rainfall of the period 1984-2013 is estimated to be 1121 mm. The highest vales of the daily mean temperature is observed in February and March which are the dry period of the area. The lowest value of maximum temperature is recorded in the months of July and August.

The study kebeles (the lowest administrative unit in Ethiopia) come from three districts representing the upper, middle and lower parts of the Bilate River watershed and known to practice irrigation in the watershed. The first study site is Bilwanja kebele of Hulbareg Woreda in Silite zone near by the Hulbareg town with mean annual rainfall of 1131 mm from the upper part of the watershed. The second study site is Alemtena Kebele, in Halaba Zone near Alaba Kulito town with mean annual rainfall of 1025 mm representing the middle course of the watershed and the third study site is Bilate Charcho kebele in Duguna Fango Woreda of Wolaita zone near Bilate Tena with mean annual rainfall of 781 mm representing the lower course of the watershed Table 1.

Sampling and data collection

A multi stage sampling technique was used to select the study Kebeles and sample households in the watershed. First the Bilate River watershed was selected as the overall study area. In the second stage, three districts representing the upper, middle and lower course of the watershed and one kebele within each district were also purposely selected to include villages which practice

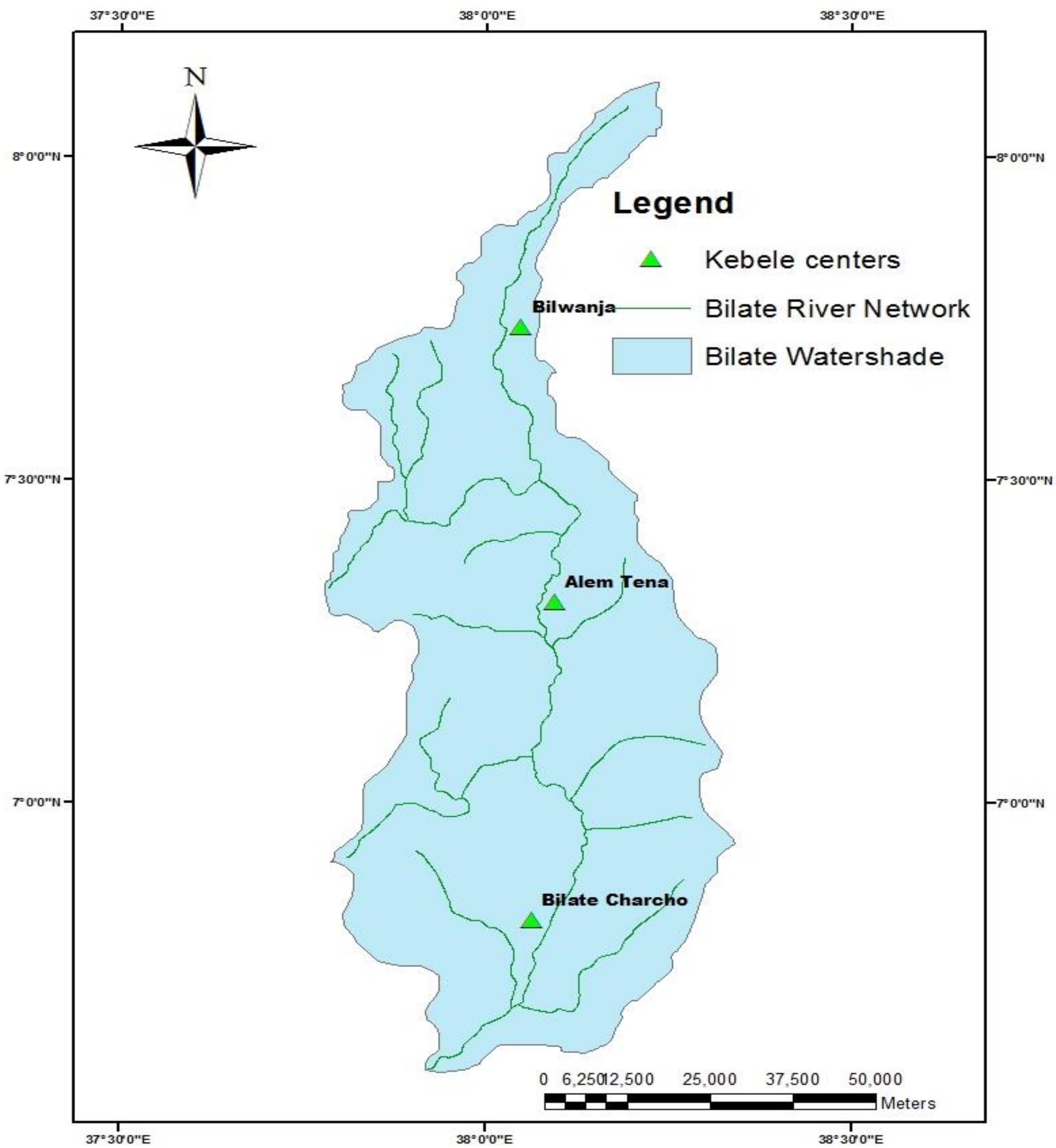

Figure 1. The Location map of the Bilate River watershed and selected kebeles.

Table 1. The study zone district (Woreda) and Kebele.

Zone/Woreda	Kebele	Total No. of HH	No. of HH Interviewed
Silite Zone/Hulbareg	Bilwanja	1030	95
Halaba Zone	AlemTena	506	86
Wolaita Zone/DugunaFango	BilateCharcho	735	89

irrigation and whose community are aware of the dynamics of the hydrology in the watershed. From these sampled kebeles, based on the methods by Israel (2009), 270 households were selected proportionally.

The survey was conducted between December 2013 and January 2014. Interview schedule was used to collect information from all sample farming households making use of structured and validated questionnaire to Understand Agricultural Household Adaptation to Climate Change prepared by Living Standards Measurement Study-Integrated Surveys on Agriculture (LSMS-ISA) project with slight modifications. Pretesting of the questionnaire was performed to avoid missing any important information.

Methods of analysis

The study examines, first whether smallholder farmers in the Bilate watershed perceived climate change and then whether, they have tried to adapt to the perceived climate change in their agricultural activities, finally to model the factors influencing their choice of adaptation methods.

To find out whether farmers in the watershed perceived climate change, a sample farm households were asked if they have observed variation in the climatic parameters and descriptive statistics were used to assess the perception of farmers on climate change and the different adaptation methods adopted by them.

Smallholder farmers are known to use adaptation methods when the perceived net benefit of their agricultural productivity is significantly greater than from the productivity without using it. That means the decision of whether or not to use any adaptation option could fall under the general framework of utility and profit maximization (Deressa et al., 2008, 2011; Gbetibouo, 2009).

At initial stage the multinomial logit (MNL) model was planned to be used to model climate change adaptation behaviour of farmers by making use of discrete dependent variables with multiple choices. Based on literatures multinomial estimation exhibits superior ability to predict discrete choices (Bezu et al., 2009); it is computationally simple (Hadgu et al., 2015) and the same model was used for similar studies in Ethiopia (Deressa et al., 2009; Tessema et al., 2013; Legese et al., 2014) for causes in which respondents are restricted to select only one adaptation option from different adaptation measures. During the survey, it was found out that several adaptation options were used simultaneously by a single respondent. This behaviour made the use of MNL modelling inappropriate by violating the assumption of mutually exclusiveness and failing to fit to the test for their independence of irrelevant alternatives (IIA).

Binary logit model specification is adopted to examine factors influencing the climate change adaptation behavior of farmers involving dummy dependent variables with binary choices. Consider (Y_{ij}^{*}) a latent variable equal to the benefit expected from the adoption of a given adaptation measure:

$$Y_{ij}^{*} = \alpha + \sum \beta_k X_k + \varepsilon_{Y_{ij}^{*}} \quad (1)$$

where Y_{ij}^{*} is a latent binary variable with subscripts i showing the household adapted to climate change and j showing six different adaptation measures, α stands for the model intercept, β_k is the vector of the binary regression coefficient, X_k is the vector of exogenous explanatory variable that influence the farmers choice particular adaptation option and k in the subscript shows specific explanatory variables and, $\varepsilon_{Y_{ij}^{*}} \cong \mathrm{N}(0, \alpha^2)$ is error term which is normally distributed.

One cannot directly observe the latent variable (Y_{ij}^{*}). All one can see is

$$Y_{ij} = \begin{cases} 1 & if\ Y_{ij}^{*} > 0 \\ 0 & if\ Y_{ij}^{*} \leq 0, \end{cases} \quad (2)$$

where $\mathrm{Y_{ij}}$ is observed variable showing the household i will use adaptation option j $(\mathrm{Y_{ij}} = 1)$ if the perceived benefit from option j is greater than zero $(\mathrm{Y_{ij}^{*}} > 0)$, otherwise household i will not use adaptation measure j if the perceived benefit from it is equal to or less than zero $(\mathrm{Y_{ij}^{*}} \leq 0)$ (Abid et al., 2015).

Therefore, we can interpret the Equation 2 in terms of the observed binary variable Y_{ij} as follows:

$$\Pr(Y_{ij} = 1) = Y_{ij} = G(X_k \beta_k) \quad (3)$$

where G(.) takes the specific binomial distribution (Fernihough, 2011; Abid et al., 2015).

The parameter estimates of the binary logit model provide only the direction of the effect of the independent variables on the dependent variable; it does not show the magnitude of change and probabilities. Therefore, to quantify the results, we need to find the marginal effects (Y_{ij}') by differentiating Equation 3 with respect to the explanatory variables provides marginal effects of the explanatory variables that describes the effect of a unit change in explanatory variables on the probability of dependent variable.

$$Y_{ij}' = \Pr(Y_{ij} = 1) * (1 - \Pr(Y_{ij} = 1))\beta_k \quad (4)$$

Model variables

Dependent variables (Adaptation options)

A wide variety of actions taken by an individual farmers, community level and organizations to prepare for, or respond to, climate change impacts have been identified as adaptation options by climate change research community. The adaptation options in Bilate watershed are identified by asking the farming households about their perception of the climate change and measures they take to offset the negative impacts of the changes (Figure 2). Some other adaptation options like planting shade trees, changing from crop to livestock, migrating to another area and renting out their land holding were assumed to be part of the adaptation options but ignored after interview schedule because they are not reported in the response of the farm households or are perceived as community level mitigation measures.

The used cover crop and mulching mainly to conserve moisture and intensification of irrigation are two main adaptation methods reported to be used by farmers of the Bilate watershed whereas changing crop varieties and building water harvesting schemes are the least used methods. About 41% of the farming household participants in the interview schedule reported that their family used none of the adaptation methods.

Independent variables

Farmers' choices of adaptation strategies are determined by a range of household socio-economic characteristics, institutional factors and agro-ecological setting. Hypothesized factors are discussed subsequently and the description with expected effect of each of these variables is presented in Table 2.

Age: In literatures, the age of farmers has been discussed to influence their decision to adopt to new technologies both positively and negatively (Gbegeh and Akubuilo, 2013). Some studies in Ethiopia showed the age of the household head as a measure of farming experience so that this experience affects positively the

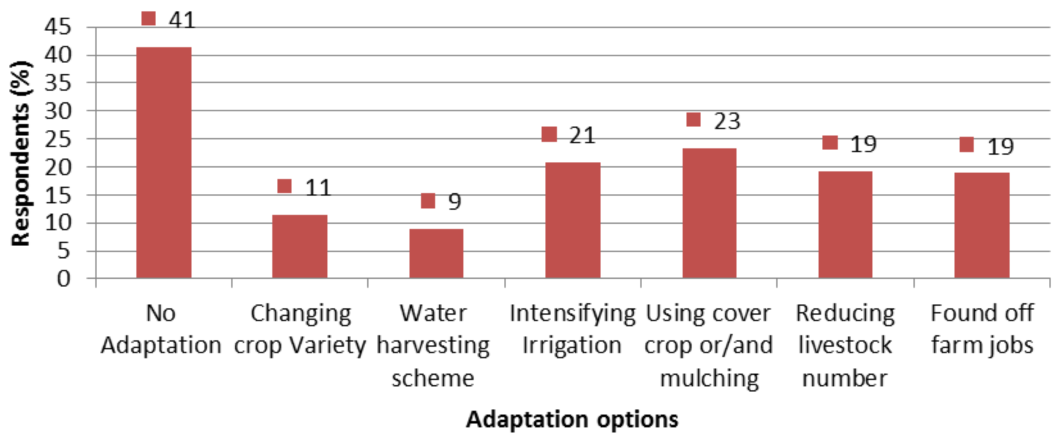

Figure 2. Farmer's adaptation options in Bilate watershed.

Table 2. Description of the independent variables.

Explanatory variable	Mean	S.D	Description
Age of the household head	39.49	8.55	Continuous
Gender of the household head	0.76	0.43	Dummy takes the value of 1 if male and zero otherwise
Educational level of household head	5.48	3.22	Continuous (number of formal schooling years)
Family size of household	6.33	1.95	Continuous
Average annual total income of the household	9728.63	4633.72	Continuous
Access to extension services	0.85	0.36	Dummy takes value of 1 if there is access and otherwise zero
Access to climate information	0.50	0.50	Dummy takes value of 1 if there is access and otherwise zero
Local agro-ecology (Mid-land)	0.67	0.47	Dummy takes value of 1 if kola and Zero otherwise
Farm size in hectare	1.30	0.84	Continuous
Livestock ownership	0.95	0.22	Dummy takes value of 1 if own cattle and otherwise zero

farmer's adaptation options (Deressa et al., 2009; Hadgu et al., 2015). While other researchers concluded that older farmers are less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting new technologies (Adesina and Baidu-Forson, 1995). The study of Shiferaw and Holden (1998) in Ethiopia shows that there is a negative relation between age and adoption of improved soil conservation practice. Here, it is expected that households with older head are more likely to adapt to climate change.

Gender: Gbetibouo (2009) argues the effect of gender on climate change adoption decisions to be location-specific. In many parts of Africa, women have fewer capabilities and resources than men, this in turn weaken their capacity to embrace labour-intensive agricultural innovations (Gbegeh and Akubuilo, 2013). In Ethiopia female-headed households are expected to be less likely to adapt due to their limited access to land, information, inputs and institutions as a result of traditional social barriers (Wilson and Getnet, 2011; Tessema et al., 2013). There are some other studies with results contrary to the aforementioned argument which shows that female-headed households are more likely to take up climate change adaptation methods (Nhemachena and Hassan, 2007). Thus, adaptation methods are assumed to be context specific.

Educational level: There is a positive relationship between the education level of the household head and the adoption of the household to new technology (Asfaw et al., 2015) and the years of formal education of the farmers were positively related to adaptation to climate change (Shongwe, 2014). This shows that farmers with higher levels of education are more likely to adapt better to climate change (Obayelu et al., 2014). Here also it is assumed that farmers with higher levels of education are more likely to adapt better to climate change.

Household size: There are two categories of views for the influence of household size to climate change adaptation (Deressa et al., 2008). The first category argues that households with a larger number are more likely to adopt an agricultural technology and use the execs labour more intensively because they have fewer labor shortages at peak times (Croppenstedt et al., 2003). While the second category argues that larger households were less likely to adapt to climate change than the smaller households (Ndambiri et al., 2012). Here it is expected that hypothesized households with larger family size have high probability of adapting to climate change.

Wealth: Owning Land and Livestock and Farm and nonfarm income are known to represent household wealth in rural areas and also influence adaptation options of households (Tessema et al., 2013). Shortage of land is seen to be a barrier in climate change adaptation (Bryan et al., 2009). Higher income and livestock ownership are seen as facilitators of climate change adaptations in literature (Tessema et al., 2013) because wealthier farmers are advantageous in adaptation (Foster and Rosenzweig, 2010). So all land size, income level and livestock ownership are hypothesized to have positive relation with adaptation to climate change.

Extension and Climate information: Many of the decisions made by farmers are affected by weather and climate but there is lack of reliable information that can help them consider these decisions (Clarkson et al., 2014). As discussed in Deressa et al. (2008) extension on crop and livestock production and information on climate are among these information's required to make decision on climate change adaptation. Extension services are claimed to encourage adaptation to climate change by raising farmer's awareness of the issue (Nhemachena and Hassan, 2007). Therefore, here also both the access to extension services and access to information on climate are expected to positively influence adaptation.

Agro-ecological zone: The agro-ecological setting of farmers is expected to influence their adaptation to climate change. In Ethiopia, there are three traditional agro-ecological zones, the *kolla* (lowland) characterized by hotter and drier climate, the *woinadega* (middle land) and *Dega* (highland) are wetter and cooler (Deressa et al., 2009; Tessema et al., 2013). Deressa et al. (2009) also explains that farmers in drier and hotter climate are more likely to respond to climate change. The study sites in this research are located in the *woinadega* and the *kola* areas and farmers residing in the *Kolla* area are hypothesized to adapt to climate change that the farmers of the *woinadega* area.

Hypothesis testing for model significance

A logistic regression model is very useful under two circumstances: first, given a set of values of the independent variables, we wish to estimate the probability that the event of interest will occur and second to evaluate the influence each independent variable has upon the response. There are various methods to measure the appropriateness of fit of logistic models under these circumstances. So, to test the overall significance of models, the global null hypothesis approach which tests the hypothesis that all the regression coefficient β's = 0 versus the alternative that at least one is not zero, was used.

In logistic regression, a likelihood ratio Chi-square test (Stata calls this LR Chi^2) is used and it is computed by contrasting a model which has no independent variables (that is, has the constant only) with a model that does (Williams, 2015). The test statistics is distributed $\chi 2$ with degrees of freedom equal to the difference between the number of variables in the model with predictors and intercept-only model (Abid et al., 2015).

In our case, it can be seen that $\chi 2$ (Table 3) for all adaptation values holds positive values between 58 and 118 with the p values associated to it are all less than 0.001. On the base of test statistics, the null hypothesis that states all the regression coefficient β's = 0 can be rejected and the alternative hypothesis that at least one is not zero can be accepted, so it can be concluded that our models with predictors fit significantly better than the intercept-only model.

The goodness of fit of all adaptation models is determined by the measure of pseudo-R^2. The results of pseudo-R^2 ranged from 0.26 to 0.56 showing the better fit of the models in adaptation to climate change. The classification matrices in logistic regression serve to evaluate the accuracy of the model. The overall percentage of accurate predictions for the models varies between 82 and 92% which shows only few cases are classified incorrectly and all the models selected for this study can fairly estimate the factors affecting the use of different adaptation methods in the study area.

RESULTS AND DISCUSSION

Farm level perception of climate change

In order to adapt to climate change, farmers must first perceive that changes are taking place (Bryan et al., 2009). Adger et al. (2009) discussed farmer's perception of long-term changes in climate to be crucial pre-indicator for the climate change adaptation. Therefore, sample farm households were asked if they perceived or not changes in long term climate indicators in their vicinity.

The results of the study shows that (Figure 3) the majority of farmers perceived decrease in the amount of annual rainfall (92%) while only 4% of the farmers felt an increase in annual rainfall while the remaining 4% said they did not notice any change in the amount of the rainfall in their area. 79% of the farmers felt an increase in the number of hot days while 11 and 10% of the remaining farmers are for the group of people who did not feel any change and those who felt decrease in the number of hot days, respectively. The sample households did not ask about their feelings in the change of mean temperature because the area under investigation is known to be with high range of daily temperature and it will not be easy to perceive the mean change in daily temperature for farmers.

The onset and end date of rainfall in a given year are determinants of the Length of Growing period for an area (Stern et al., 2006; Abiy et al., 2014). The farming household's perception on these climatic events is crucial to counteract the changes from the norm. 73% of the farmers perceived that the onset of rainfall in the area in the last 5 years is delayed, 27% said it is starting on time and no one has perceived it to begin earlier than the usual. 71% of the responding farmers also perceived that rainfall in the area ends sooner than the usual. So, most of the farmers perceived that in recent years, rainfall starts late and ends soon that leaves them with shorter length of growing period.

Farm level constraints to adaptation

Long term deviation of climatic variables from the norm was perceived by 92% of the sample farmers in one way or the other. Even though, the major sect of the community perceived that climate was changing, only 58% of the sample households actually made an adaptation at household level. The farmers who did not use any adaptation methods mentioned five main constraints (Figure 4) that hindered them from using adaptation options. These are knowledge gap in the form of lack of information (23%), financial constraints (16%), shortage of labour (21%), shortage of land size (21%) and water scarcity in the irrigation channels (19%).

The knowledge gap in the form of lack of information is mainly attributed to the educational level of the head of

Table 3. Model significance test and predictive power.

Model	χ2	df	p level	-2 Log likelihood	AIC	Model correctness (%)	Nagelkerke pseudo-R^2
Changing crop variety	58.35	10	0	134.14	154.14	86.9	0.38
Water harvesting scheme	69.50	10	0	121.12	141.11	92.2	0.31
Intensifying Irrigation	118.99	10	0	156.68	178.68	89.3	0.56
Using cover crop or/and mulching	81.15	10	0	212.22	234.22	85.6	0.39
Reducing livestock number	71.65	10	0	192.93	214.93	83.0	0.37
Found off farm jobs	74.21	10	0	214.17	236.17	82.2	0.26

df- Degrees of freedom, p-level shows the statistical significance to reject the null hypothesis (Ho), AIC (Akaike information criterion) measures relative quality of statistical model.

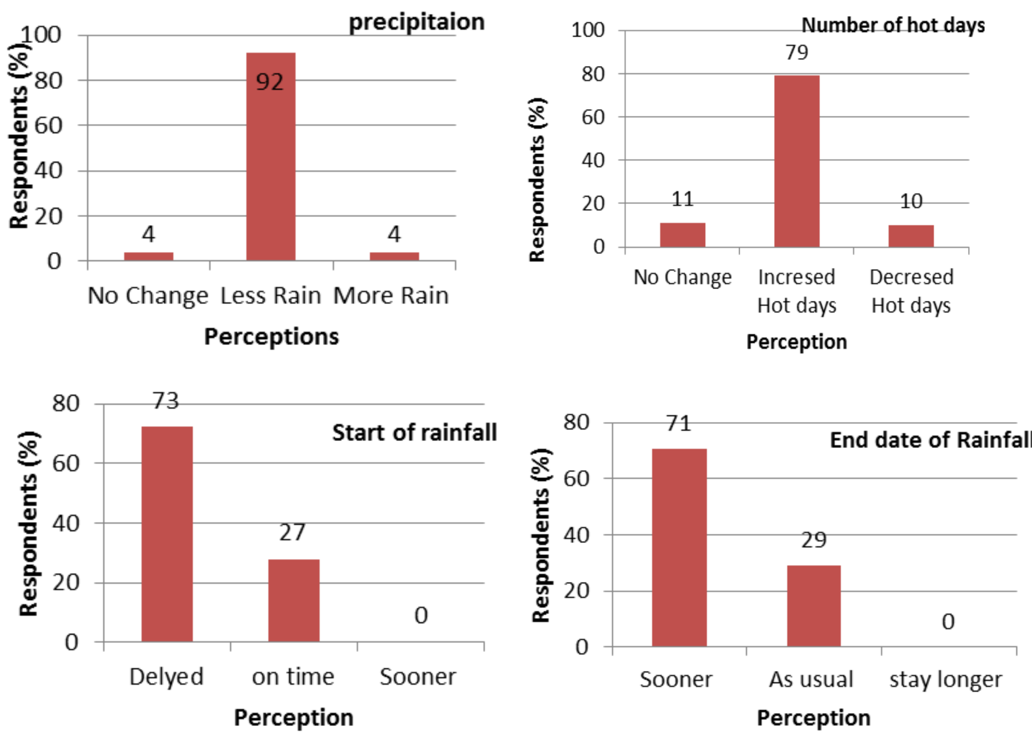

Figure 3. Farmers perceptions of climate change in Bilate watershed.

the household. The results of the cross tabulation of educational level of the household head with their response of adaptation for shift in temperature or rainfall show that 88.5% of the farmers who had 10 years and above formal schooling were made adaptable, while 85.2% of farmers who did not attended any level of formal education did not made adaptation.

Determinants of farmer's choice of adaptation methods

The logistic regression models for the adaptation strategies were used to quantify the impact of independent variables affecting the choice of adaptation methods by the sample farming households. The coefficients of the logistic regression (Table 4) provide only the direction of the effect of the independent variable on the response variables but do not show the actual magnitude of change and probability. Therefore, the marginal effect from the logistic regression model (Table 5) was computed and presented to show the expected change in the probability of a given choice in adaptation measure being made with respect to a unit change in an independent variable. The fitness of the model was earlier discussed.

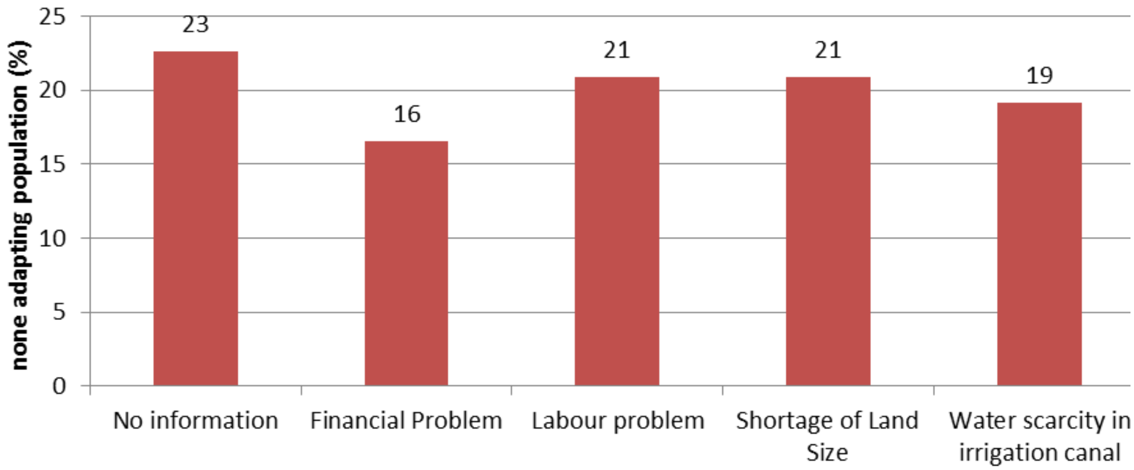

Figure 4. Constraints to adaptation to climate change in the study area.

Table 4. Parameter estimates of the logistic regression model for climate change adaptation at farm level.

Explanatory variable	Changing crop variety	Water harvesting scheme	Intensifying Irrigation	Using cover crop or/and mulching	Reducing livestock number	Found off farm jobs
Age of the household head	-0.0693**	-0.06974**	-0.24169*	-0.09026*	-0.1152137*	-0.014342
Gender of the household head	-0.0959	0.301735	0.17167	-0.78114	-0.4600129	0.3057538
Educational level of household Head	0.2476*	0.074736	0.33413*	-0.0451	0.1371988**	0.1354289**
Family size of household	-0.1634	-0.08552	0.23174**	0.0752	-0.0768305	-0.080697
Average annual total Income	0.0000	-0.000344*	0.00005	-0.0001278*	-0.0002944*	0.0000276
Access to Extension services	1.4226	0.514987	1.08566	-0.1902725	1.245076	0.6463725
Access to climate information	-1.4354*	0.788514	-0.96229**	1.651216*	-0.5327847	-0.3868611
Local agro-ecology *kolla*	-1.7476*	-0.417091	-0.58346	2.671329*	0.7797067**	-0.6721689
Farm size in hectare	0.6678**	-0.267969	1.30393*	-0.0564182	1.780417*	-1.698609*
Livestock ownership	0.4646	2.458837	1.07656	1.081059	1.708569**	0.6750463
const	-5.5165**	-18.2407	4.2613**	-3.8419**	3.145837	-2.5157

*,** show significance at 1and 5% probability levels, respectively.

Age of the household head

Contrary to the expectation and findings in other researches in Ethiopia the age of the household head is negatively associated to major adaptation strategies prevailed in the area at 5% level of significance. The average marginal effect computed shows that sample households with one more year older head would decrease the probability of the intensifying irrigation at 1% significance level by 1.26% and for other adaptation strategies the decrease in the probability at 5% significance level is extremely low with effects varying from 0.11 to 1.1%. The finding of this research is in agreement with arguments of Adesina and Baidu-Forson (1995) which states that older farmers are less likely to be flexible than younger farmers and thus have a lesser likelihood of adopting new technologies and in Ethiopia there is a negative relation between age and some adoption strategies to climate variability (Shiferaw and Holden, 1998).

Gender of the household head

A positive coefficient of the gender of the household head for building water harvesting scheme, intensifying irrigation and getting off-farm job indicates positive relationship between male headed household and probability of using these adaptation measures (Table 4) even if it is not significant at 1 and 5% significance level. But the negative coefficient of the gender for using mulching and reducing the number of livestock shows

Table 5. Marginal effects of the binary logistic models offarm level climate change adaptation.

Explanatory variable	Changing crop variety	Water harvesting scheme	Intensifying Irrigation	Using cover crop or/and mulching	Reducing livestock number	Found off farm jobs
Age of the household head	-0.00307	-0.00205	-0.01260	-0.0111942	-0.0099	-0.00155
Gender of the household head	-0.00434	0.008252	0.00860	-0.1118589	-0.0438	0.03517
Educational level of household head	0.01095	0.002196	0.01742	-0.0055962	0.0118	0.01466
Family size of household	-0.00723	-0.00251	0.01208	0.0093289	-0.0066	-0.0087
Average annual total income	-1.30E-06	-0.00001	2.73E-06	-0.0000158	-0.00003	2.98E-06
Access to extension services	0.04259	0.01289	0.041706	-0.024728	0.07737	0.0592
Access to climate information	-0.06718	0.02372	-0.05133	0.2108997	-0.0460	-0.0419
Local agro-ecology *kolla*	-0.10908	-0.01317	-0.03352	0.2628968	0.06096	-0.0796
Farm size in hectare	0.02955	-0.00787	0.06798	-0.0069969	0.15317	-0.18383
Livestock ownership	0.0249	0.03125	0.03755	0.0947675	0.08260	0.05817

these adaptation fevered by female household heads.

Educational level of household head

The years of formal education of the farmers were positively related to adaptation to climate change (Shongwe, 2014). According to results in Table 4, the highly significant coefficient of education of the household head to major adaptation strategies shows that the probability of adapting to climate change increases with the formal years of schooling. A unit increase in number of years of formal schooling would result 1 and 1.7% increase in the probability of changing crop verity and intensifying irrigation, respectively at 1% significance level (Table 5). Similarly, the marginal values of education are positive for reducing livestock number and getting off-farm jobs as adaptation to climate change.

Family size of household

Our results indicate that family size of the household is found to positively and at 5% significance level relate to intensifying irrigation. But this variable is not found to determine the other adaptation strategies at up to 10% significance. Even though it is less significant, the household size is negatively related to the rest of the adaptation measures and this is in agreement with the argument that larger households were less likely to adapt to climate change than the smaller households (Ndambiri et al., 2012).

Income

Regardless of the expectations, it is found that households with overall income is negatively and without fail associated to using water harvesting scheme, using cover crop or mulching and reducing number of livestock. The computed marginal effect for all strategies is almost zero. This finding is contrary to prior researches explaining that wealthier farmers are advantageous in adaptation (Foster and Rosenzweig, 2010).

Access to extension services

Extension services on crop and livestock production are known to be encouraging factor to adaptation to climate change (Nhemachena and Hassan, 2007). Also, in the current study, the direction of change is positively related to the adaptation methods explained except for mulching where it is negatively related (Table 4). But the relation was not significant at all level.

Access to climate information

Access to climate information mainly in the form of seasonal forecast has mixed direction of relation for the adaptation strategies mainly used in the study area. It has significant and positive impact on using cover plant and mulching as adaptation mechanism, thus households with access to climate information use this method (21%) more often than the households that are not using it at 1% significance level. But the result in Table 4 also shows that access to climate information is negatively and significantly related to changing crop varity and intensifying irrigation.

Local agro-ecology

According to Deressa et al. (2009) farmers in drier and hotter climate are more likely to respond to climate change. In this research, also farmers residing in the lowland (*Kolla*) area are hypothesized to adapt to climate change than the farmers of the midland (*woinadega)* by using all types of adaptation strategies. But the results are not consistent for all types of adaptation strategies. People living in *kolla* area use mulching and cover crop 26% more times people living in the *woinadega* and this is reliable at 1% level of significance. From Tables 4 and 5, we can see that people in *kolla* area are 10% less likely to opt for changing crop as mechanism to climate change adaptation.

Farm size

Owning land is known to represent household wealth in rural areas (Tessema et al., 2013). From the result in Table 4, we can see that land area has positive impacts on changing crop variety, intensifying irrigation and reducing livestock number. One unit change in the land area changes the probability of changing crop variety and intensifying irrigation by 2.9 and 6.7%, respectively at 5 and 1% significance level. This finding is in agreement with other research in Africa that states shortage of land is seen to be a barrier in climate change adaptation (Bryan et al., 2009).

Livestock ownership

Livestock ownership is not found to significantly determine any of the adaptation methods in the study area but the direction of relation is positive for all the adaptation option making the finding consistent with other researches that report livestock ownership as facilitator of climate change adaptations (Tessema et al., 2013).

Conclusion

The research was conducted in three *kebeles* in Bilate watershed (BRW) where 270 farm households were randomly selected for the study. Binary logit model specification is adopted to examine factors influencing the climate change adaptation behaviour of farmers involving dummy dependent variables with binary choices. Hypothesis testing for model significance was made to measure the appropriateness of fit of logistic models and all the models selected for the study was seen to fairly estimate the factors affecting the use of different adaptation methods in the study area. Even if, the majority of farmers (over 92%) perceived that climate was changing in one or the other form only 59% of the sample households were actually made an adaptation at household level by using different methods. Those who did not use any of the adaptation methods explained their real and perceived constraints for farm level adaptation to climate change. Knowledge gap in the form of lack of information, shortage of labour and minimal land size are the three most explained constraints to climate change as explained by responding household heads.

The results further showed that age and educational level of the household head, farm size and the income level of the household are household characteristics that significantly affect the choice of adaptation options, while access to climate information in the form of seasonal forecast and local agro ecology are other factors that determined the selection of adaptation methods by the farming households in the study area. Contrary to the expectation and findings of other research, explanatory variables like sex of the household head and access to extension services on crop and livestock production were not found to determine the adaptation methods in the study area significantly.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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