Determinants of Smallholder Farmers' Adaptation to Climate Change and Variability: The Case Study of Sire District, Arsi Zone, Oromia National Regional State, Ethiopia

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Abstract

Climate change is a worldwide issue that affects everyone livelihood. Ethiopian agriculture is heavily dependent on nature and the country's geographical location and topography in combination with low adaptive capacity entail a high vulnerability to adverse impacts of climate change and variability. The objectives in this study are to investigate smallholder farmers' perception of climate change and to assess determinants of adaptation strategies in Sire District. The study was followed a multi-stage stratified random sampling procedure, where a combination of purposive and random sampling technique were used to select respondents. A farm-level data were collected from 126 households for 2015/16 cropping season and 1983-2011 period climatic data were obtained from Ethiopian Meteorological Agency. The descriptive statistics results show that 90% of the interviewed farmer's perceived long-term change in temperature over 1983-2011. The rainfall distribution data imply that high monthly rainfall was recorded in July, August and September. The average annual minimum and maximum temperatures of the study area follow increasing trends while the rainfall data recorded from 1990 to 2011 show that the annual rainfall followed a decreasing trend over the period. For the perceived changes, about 32%-35% of respondents took remedial actions to counteract the impacts of climate change. The result of the logit model highlighted part of determinants (such as sex of household (at 5% level with adjustment to management option), education level, size of productive labor force, family size, socio-economic group, tenure security, off-farm income and agroecology) in line with the hypothesis, and other variables (such as age, soil fertility and market distance) opposing the hypothesis, as main factors that determines part of adaptations options. Then, based on the climate change perceptions and main determinant factors of this study, a corresponding government bodies and development practitioners should create awareness, develop and implement climate smart agriculture and strengthening farmers' adaptation and mitigation activities to survive the impact of climate change and variability.

Keywords: Sire District, Perception,Adaptation, Smallholder Farmers',Logit Model

1. Introduction

Climate change is a global phenomenon that has influence on everyone. It influences the most marginalized communities with limited access to resources and avenues to deal with changing weather patterns and the resulting environmental phenomena. Many studies scientifically proofed that the earth's climate is rapidly changing, due to increases in Greenhouse Gas (GHG) emissions (Belay *et al*., 2017). In developing countries climate change exacerbate food insecurity as it reduces yields (Joachin, 2008). Ethiopia's climate is influenced by general atmospheric and oceanic factors that affect the weather system (Bekele, 1997). The reported global cost of natural disasters has risen even more, with a 15-fold increase between the 1950s and 1990s (IFRC, 2001).

As climate varies, several direct influences alter precipitation amount, intensity, frequency and type (Mendelsohn *et al.*, 1999; Ravindranath *et al.*, 2002; Winkler, 2005; Aklilu *et al.*, 2009). One of the largest impacts of climate change is expected to be on agriculture (Nordhaus, 1991; Pearce *et al.*, 1996). The majority of the rural people in developing countries depend heavily on rain fed subsistence agriculture and exploitation of natural resources (Alebachew, 2011). Droughts and floods are very common occurrences with significant events every 3–5 years (World Bank, 2006). Because of changes in the patterns of the local climate, developing region is exposed to chronic food shortages, degradation of natural resources, unstable livelihoods and distress migration (Alebachew, 2000, 2011). Adaptation enhances the capacity of people and governments to reduce climate change impacts (Tompkins *et al.*, 2003). The core part of the adaptation options includes adoption of appropriate irrigation water management practices, efficient irrigation systems, awareness creation on efficient water utilization, implementation of water pricing and recycling, development of effective rain water harvesting technologies and construction of small to medium sized storage reservoirs with a minimum impact on the environment (Zeray *et al*, 2007).

Farmers who perceive the change in climate are hypothesised to make adjustments in their farms to reduce climate change born impacts unless they do face some barriers. However, identifying agricultural adaptation options to climate change is not an easy task as there is no adaptation started for climate change purpose alone. Most adaptation options have values of broad spectrum which can be undertaken as an adjustment to climate change, market, policy, demography, economic condition, resource availability and technology. Thus, it is important, if not sufficient, to have an insight of farmers' views on temperature and rainfall trends in advance to dig out genuine locally available climate change adaptation technologies on the ground.

Although there are well-established concerns about climate change effects worldwide, there is little quantitative information concerning farm level adaptations that farmers make to cope with the impacts of climate change are lacking. In spite of repeated drought experiences in Ethiopia, there is no properly documented information on past and current climate variability and its impact on the society, the environment, and the economy of the country. As Mahdi *et al.* (2000) states, development projects envisaging food security, resource management and rural development failed to consider climate variability and long-term climate change.

The research on smallholder farmers' vulnerability within the country is very less. Although Ethiopia contributes insignificant amount of GHGs to the world climate, the impacts of climate change is high as labelled by frequent drought, famine and spread of disease. Climate change is considered to be problematic issue for many countries impacting various sectors and areas. Widespread implications indicate that climate change is a complex and cross-cutting issue. There are rare studies on climate change perception and adaptation determinants in Ethiopian such as the impact of climate change and adaptation on food production in low income countries: evidence from the Nile Basin (Mahmud *et al*., 2008); analysing determinants of farmer's choice of adaptation methods and perception of climate change in Nile river basin (Temesgen *et al*., 2008b); adaptation to climate change in Ethiopia and South Africa: options and constraints (Bryan *et al*., 2009); analysis of farmers' perception and adaptation to climate change and variability: the case of Choke mountain, East Gojjam (Bewket, 2010); climate change adaptation strategies of smallholder farmers: the case of Babilie District, East Harerghe Zone of Oromia Regional State of Ethiopia (Aemro *et al*., 2012); smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia (Belay *et al*., 2017) and small holder farmers adaptation strategies to climate-related risk factors in wheat production in selected districts of central Oromia, Ethiopia (Zeray et al., 2017) are empirical studies worth to mention. Those studies are somehow aggregated and failed to exactly indicate farmers' precipitation towards climate change and adaptation determinants in Sire District.

Farmers' adoption behaviour, especially in low-income countries, is influenced by a complex set of socio-economic, demographic, technical, institutional and biophysical factors (Feder *et al.*, 1985). Hence, modelling farmers' response to agricultural adaptations has become important in identifying major determinants of adoption of the various adaptation measures. Then, this study had acknowledged the need of further studies at local levels to assist policy formulation and decision making in terms of adaptation determinants and climate change perceptions. Have a clear information on the climate change at district level can provide a basis for a detailed exploration and recommendation of climate change influences on smallholder farmers'. Hence, the objectives of this study are to investigate smallholder farmers' perception towards climate change and to assess determinants of climate-adaptation strategies in Sire District.

Results from this research have great significance for policy design and adoption of indigenous knowledge with scientific approach on present day's challenging issue of climate change, particularly on smallholder farmers. It is useful for academic institutions, regional government, and rural development actors, which aim at changing the perception of local communities towards climate change perception and determinants of adaptation. The local leaders strengthen their decision-making by relying on the findings of this study. It provides directions for further research, extension and development schemes that would benefit the farming population.

2. Material and Methods

2.1. Description of the Study Area

This study was undertaken in Sire, one of the 26 districts in the Arsi zone, Oromia National Regional State of Ethiopia. It is part of former Dodota and Sire District. Figure 1 shows that Sire district is one of the Administrative Units of Arsi zone located in the north eastern part of the zone. Sire town is the capital of the district, located at 125 km from Finfinne and 70 km from zonal capital, Asella town. The 2007 national census reported a total population of the district was 73,970, of which 37,812 were men and 36,158 were women; 8,376 or 11.32% of its population were urban dwellers. (FDRE population census commission, 2008; SDARDO, 2014).

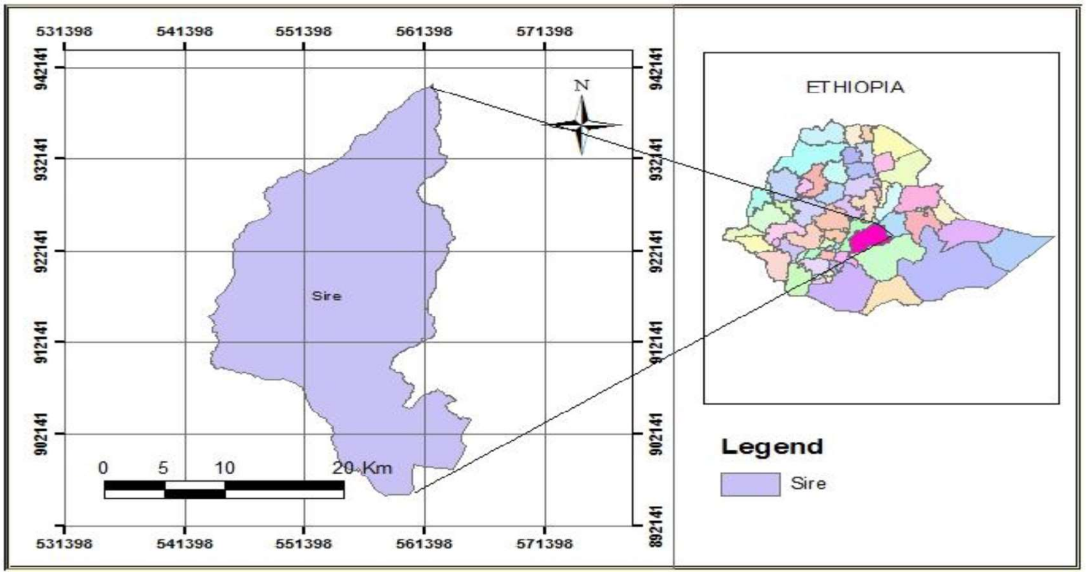

Figure 1: Map of the Study Area

2.2. Sources of Data and Sampling Design

In this study, both primary and secondary data were collected. The primary data includes reconnaissance and Household (HH) survey, focus group discussion, key informants' interview and field observation. The secondary sources of data include climatic and socioeconomic data and ancillary.

A multi-stage stratified random sampling procedure, which combines purposive and random sampling procedures, was used to select sample Kebeles[1] and HHs. The population was divided into three strata considering the agroecological variation that created heterogeneity in the livelihoods of the local people, especially on the factors related to climatic variation (Weiss *et al.*, 1982). The strata are 14.5% Temperate ('Dega'), 24.5% Sub-tropical ('Woyenadega') and 61% Tropical ('Kola') (SDARDO, 2014). At the first stage, out of 23 Districts in Arsi zone, Sire District was purposively selected due to the fact that the District is frequently susceptible to climate related problems. In the second stage, 9 Kebeles (Koloba Bale, Lode Banban, Gasala Amuta, Alelu Gasala, Ibsata, Gasala Shashe, Borera Chira'o, Gasala Chacha and Hogis Borera) were selected from the 3 agroecologies, using probability proportional to size. At the third stage, in order to know impact of climate variability and change sample HH were selected using a simple random sampling lottery system with probability proportional to size technique.

The simplified formula provided by Yamane (1967) to determine the required sample size at 95% confidence level, 0.05 degree of variability and 9% level of precision was applied. In equation 1, 'n' is the sample size, 'N' is the population size, and 'e' is the level of precision. The formula required a minimum of 122 responses but this study was carried out on a sample size of 126 HHs for 2015/16 cropping season.

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[1] Kebele refers to the lower administrative unit in a district.

$$n = \frac{N}{[1+N(e)^2]} \quad (1)$$

Climatic records were intended to collect station data from selected Kebeles. Regrettably, active weather station is not available in selected Kebeles. As alternative, grid data of temperature and rainfall for the period 1983 to 2014 that acquired from Ethiopian Meteorological Agency was used for analysis (EMA, 2016). The rainfall and temperature data acquired are not equally available. Therefore, a common period from 1983-2011 were used for analysis. The climatic grid data acquired for Dega and Woyenadega are structurally similar while the data obtained for Kola are independent. Hence, the agroecology of the district is categorized as upper (Dega and Woyenadega) and lower (Kola).

2.3. Method of Data Analysis

2.3.1. Descriptive Analysis

Descriptive statistics used for the study include ratios, percentages, means, frequency, range, variances, ranking, standard deviation, chi-square and t-test.

2.3.2. Econometric Analysis

Econometric model plays a great role in research works for identifying the relation between different factors, and forecasting the future event. For this study major factors that determine Smallholder Farmers' Adaptation to Climate Change and Variability (Y_i) analysed using econometric models. Thus, a binary logistic regression model was employed to understand which factors are influential to Smallholder Farmers' Adaptation to Climate Change and Variability (Y_i) in the study area.

For this particular study logistic econometric regression method has been employed to analyse the relationship between Smallholder Farmers' Adaptation to Climate Change and Variability (Y_i) and factors affecting for adaptation of climate change and variability. The model has been assumed to predict a binary response in relation to Determinants of Smallholder Farmers' Adaptation to Climate Change and Variability (Y_i).

Logistic regression has been used extensively in the health sciences since the late 1960s to predict a binary response from explanatory variables (Lemeshow *et al*., 1988). The response is binary variable taking two values, i.e. 0 if the Smallholder Farmers' Adapt to Climate Change and Variability and 1 if it does not (non-adaptor). Estimation of this type of relationship requires the use of qualitative response models. This means that the dependent, regress and is qualitative in nature unlike regression models that their dependent variable is quantitative.

Although logit and probit yield similar parameter estimates, a cumulative logistic regression model is preferred because of its comparative mathematical simplicity (Gujarati, 1995 and Greene, 2000). Logit exhibits superior ability to predict discrete choices (Mohammed, 2007; Sosina *et al*., 2009). The two functions are quite comparable or are very close in the mid-range, except in the tails that probit function has slightly flatter tails while the logistic distribution has thicker-tailed or slightly heavier tails more closely resembles at distribution with seven degrees of freedom (Johnston, 1984; Greene, 2000 and Gujarati, 2003). The logistic distribution tends to give larger probabilities to Y = 0 where ß'X is extremely small and smaller probabilistic to Y = 0 where ß'X is very large than the normal distribution (Gujarati, 1995 and Greene, 2000). Thus, for this study the logit model was selected to answer the question which factors are influential to Smallholder Farmers' Adaptation to Climate Change and Variability (Y_i).

The dependent variable i.e., Determinants of Smallholder Farmers' Adaptation to Climate Change and Variability (Y_i): is dichotomous in nature and can be represented by dummy variables. When dealing with a dichotomous dependent variable our main interest is to assess the probability that one or other characteristics is present (Mukherjee *et al.*, 1998). In this study a dichotomous dependent variable Determinants of Smallholder Farmers' Adaptation to Climate Change and Variability: be taken as dependent variable and has been represented in the model by dummy variable taking the value of 0 if a HH adapt climate change variability and 1 otherwise.

The main assumption of logistic regression is that the natural logarithm of the odds ratio or probability of being in a response category is linearly related to the explanatory variables. Regression coefficients are estimated using the method of maximum likelihood. The log of the odds ratio, the logit, transforms a variable constrained between 0 and 1 into a continuous unbounded variable. The cumulative logistic probability function is specified as:

$$P_i = F(Z_i) = F\,[\alpha + \textstyle\sum_{i=1}^{n} \beta_i X_i] = \left[\frac{1}{1+e^{-(\alpha+\sum \beta_i X_i}}\right]$$

(2)

Where, P_i is that the probability that i^{th} farmer is being adopted climate change variability given X_i variable, X_i is the i^{th} farmer explanatory variables, Z_i is a linear function of n explanatory variables, e: is the base of natural logarithms, α and β_i are regression parameters to be estimated.

The model can also be written in terms of the log of the odds ratio (Gujrati, 1998). The odds ratio in favor of Smallholder Farmers' Adaptation to Climate Change and Variability (P_i) to the probability that he/she is non adaptor ($1 - P_i$). The probability that he/she is non adapter (1-Pi) is defined by:

$$(1 - P_i) = \frac{1}{1+e^{Z_i}} \qquad (3)$$

Using equation (2) and (3), the odds ratio becomes:

$$\left(\frac{P_i}{1-P_i}\right)=\left[\frac{1+e^{Z_i}}{1+e^{-Z_i}}\right]=e^{Z_i} \qquad (4)$$

Alternatively:

$$\left(\frac{P_i}{1-P_i}\right)=\left[\frac{1+e^{Z_i}}{1+e^{-Z_i}}\right]=e^{(\alpha+\sum\beta_i X_i)} \qquad (5)$$

Thus the ratio $\frac{P_i}{1-P_i}=Z_i$ is simply the odds ratio in favor of Smallholder Farmers' Adaptation to Climate Change and Variability or the ratio of the probability that a Smallholder Farmers' Adaptation to Climate Change and Variability to the probability that he is non-adapter. Taking the natural logarithms of odds ratio of equation (5) results in the logit model as indicated in equation (6).

$$Z_i=\ln\left[\frac{P_i}{1-P_i}\right]=\ln e^{[\alpha+\sum_{i=1}^{n}\beta_i X_i]}=\alpha+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n \qquad (6)$$

If the disturbance term (U_i) is introduced to the model, the logit model becomes:

$$Z_i=\alpha+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n+U_i \quad \text{or} \quad Z_i=\alpha+\sum_{i=1}^{n}\beta_iX_i+U_i$$

(7)

Therefore, for this study Determinants of Smallholder Farmers' Adaptation to Climate Change and Variability (Y_i) depend on the various explanatory variables (X_i) which can be modeled as:

$$Y_i=\alpha+\beta_1X_1+\beta_2X_2+\cdots+\beta_nX_n+U_i \qquad (8)$$

Where; Y_i is Determinants of Smallholder Farmers' Adaptation to Climate Change and Variability, X_i is explanatory variables which have associations with small holder Farmers' Adaptation to climate change and variability, U_i is the error term.

Key test statistics which include Wald test statistic, Score (or Lagrange Multiplier) test statistic and Likelihood Ratio (LR) test statistic were used in this study as set by Wooldridge (2002), Train (2003) and Maddala *et al.* (2009). Econometric analysis with cross-sectional data is usually associated with problems of multicollinearity, heteroscedasticity and the effect of outliers in the variables. For those diagnostics tests, the study used procedures set by Gujarati (2003) and Hayes *et al*. (2007). After the analytical framework is established it is important to define the measurements of the variables as well as the symbols representing them. The variables included in the analysis are presented in Table 1.

Table 1: Description of Variables

Variable	**Description**	**Type**	**Expected Sign**
(Y_i) = Determinants of Smallholder Farmers' Adaptation to Climate Change and Variability (adaptor and non-adaptor)			
Agroecology of the HH	Agro-ecology of the HH. 1, if location is *Woyenadega,* 0 otherwise, etc..	dummy	Positive (+)
Education level of the HH heads	Number of years of formal schooling attained by the head of the HH. 1= illiterate,2=ReadandWrite,3=complete 1st cycle.	dummy	Positive (+)
Sex of the HH head	Gender of the head of the farm HH. 1= male, 0=Female.	dummy	Cannot be signed (±)
Family size	Number of family members of a HH.	continuous	Cannot be signed (±)
Productive labor force	Number of family members whose age falls between 35 and 65. Number.	continuous	Positive (+)

Wealth Status/ Socio-economic group[2]	Socio-economic group of the HH according to local wealth ranking criteria. 1=Rich, 2= Medium, 3=Poor.	dummy	Positive (+)
Farming experience	Number of years of farming experience for the HH head. Years.	continuous	Positive (+)
Farm size	Size of farm in owned by the HH. Temad[3].	continuous	Positive (+)
Soil fertility	Farmer's own perception of the fertility level of his land. 1= infertile, 2= less fertile, 3= fertile, 4=highly fertile.	dummy	Negative (-)
Contact with extension agents	Frequency of visit of the HH by extension agents. 1= no visit, 2= occasionally, 3=mostly, 4= regularly. 1=yes, 0= No.	dummy	Positive (+)
Access to climate information	If HH gets information aboutweather, climate from any source. 1=yes, 0= No	dummy	Positive (+)
Credit service usage	If a HH is a costumer to credit service from any source. 1=yes, 0= No.	dummy	Positive (+)
Market distance	Distance between a farmer's house and the nearest market. Kilometres.	continuous	Negative (-)
Non/Off-farm	Income from off-farm activities	dummy	Cannot be

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[2] For the classification of the socio-economic group, the criteria used by the Kebeles' (i.e. farmers' land possession, number of livestock, ownership of resident building in near city, bank saving and ability to supply crops and livestock to the market) were employed.

[3] One temad is half (0.5) hectare

income	during the survey year. 1=yes, 0=no.		signed (±)
Tenure security	If a farmer feels secure in his land holding. 1=yes, 0=no	dummy	Positive (+)
Perception to climate change	If a HH head perceived the change in climate over the last couple of decades. 1=yes, 0=no.	dummy	Positive (+)

3. Results and Discussion

Socio-Economic Profile of Sampled Household

The survey data indicated the family size of the sampled HHs have an average HH size of 6.44, which is slightly beyond the national average family size of five. HHs who have large family size has an opportunity to develop a better climate change resilient capacity. On the other hand, as indicated in Table 2, the number of productive labor forces (35 to 65 ages) with in a family range from 0 to 6 with an average productive labor force of 2.06. This implies that within a family member, less than half is productive force and that makes it difficult to adopt various strategies that help the HH to combat climate change and variability. Statistically significant variation was observed in family size and productive labour force at 5% significant level among the three agroecological Zones. Among the interviewed HH heads 23 were females and 103 were males. All male HH heads except 2 were married, the 2 were widowed. On the other hand, from the females 19 were married, 2 were divorced and 2 were widows. Though the number of female headed HHs are not many in number adoption tendencies they made based on their experience and proximity to the farmland might be far better than their counterparts. At 10% level there is statistically significant variation in sex composition across the zones.

Table 2: Family Size and Productive Labor Force by Agroecologies

Description	**Family Size**				**Productive Labor Force**			
	Woyenadega	***Dega***	***Kola***	***Average***	***Woyenadega***	***Dega***	***Kola***	***Average***
Mean	6.24	7.43	5.64	6.44	2.21	2.14	1.83	2.06
Std. Deviation	2.721	2.989	2.229	2.747	1.071	1.260	1.124	1.158
Minimum	2	2	2	2	1	0	1	0
Maximum	13	20	11	20	5	6	5	6
F-Value	4.89**				2.40**			

**, significant at 5% level.

Source: Own Computation

Crop production and subsistence mixed farming are the types of farming system practiced by the sampled HHs. Teff, maize, wheat, barley, haricot bean, sorghum, Faba Bean and Onion are commonly cultivated crops. Farmers in the area also rear sheep, goats, cattle, poultry, and equine. The size of land owned by a HH lies between 0.5 and 7 hectares with an average farm size of 1.89 hectare, which is above the average national arable land holding size per HH of 0.97 ha (MOA, 1989). Table 3 exhibits there is no statistically significant variation in size of land holding per HH across the zones, however, there is across socio-economic groups. Survey data revealed that large farms are owned by resource-rich farmers followed by medium endowed farmers. This could confirm Desalegn's (1994) conclusion stating that '*the common notion among state officials that land policy should equalize everyone and discourage all forms of social differentiation simply does not work in practice*'. Land ownership certificate is possessed by 95% of the respondents' and they feel secured in their possession. 84.1% of the respondents perceive that their soil is less fertile and 9.5% of the respondents perceive that their soil is not fertile at all. This could be explained by the fact that the area has been supporting high population pressure, and massive degradation due to its erosion-vulnerable topography confounded with its prevailing high rainfall amount it receives It is found that 13%, 75% and 12% of the informants perceived the slop gradient of their farm to be plain, gentle and very steep respectively. The analysis of variance showed significant variation (at 1% level) in the slope gradient of farms across the zones. The farming power they have been using is family labor, shared labor (debo), animal traction, or any combination of these.

Table 3: Size of Land Holding Per HH

Agroecological Zone of the HH	**Mean**	**Std. Deviation**	**Minimum**	**Maximum**	**F-Value**
Woyenadega	1.9976	1.53611	.50	7.00	0.22
Dega	1.8238	1.30320	.50	7.00	
Kola	1.8548	.95343	.50	4.00	
Total	1.8921	1.27865	.50	7.00	

Source: Own Computation

Farmers exercise farming as a major means of livelihood. Other farmers also engaged in off-farm activities such as petty trading to compromise losses in agricultural production. Survey result reveals that 82% of the respondents do farming alone whereas 18% of the respondents engaged in off-farm activities besides farming. Farmers in the kola and woynadega seem to be engaged in off-farm activities than farmers in the highland. It is indicated in the study that a statically significant variation in off-farm employment across the zones. This could be explained by location advantage for market and farmers took positional advantage to be engaged in off-farm activities such as trade.

Regarding education, more than half of the interviewed farmers (16.7%) can read and write, 42% are illiterate, and 33.3% completed first cycle education. There is statistically significant variation in educational level across the agroecology zones. Even though most of the HH heads in the study site have poor performance in education, they do have wealth of indigenous knowledge and skills accumulated over generations through trial and error and lessons learned over many centuries of successes and failures. This is true especially in the sector of agriculture. 71.4% of the respondents falls in the age bracket of 35 -65 years, 24.6% of respondents fall below 35 years of age, and 4% of the respondents' falls beyond 65 years of age. Farmers belonging to different age category have different farming experience. Accordingly, 43%, 52%, 5% of respondents claimed to have medium, high, and short experience, respectively. At 5% significant level, there is variation in experience across the three study areas. The number of respondents within each socio-economic stratum in the midland is less or balanced with their counterparts in the highland. However, the statistical test shows trivial difference in wealth status across the zones.

3.1. Farmers' Perception of Climate Change and Variability in Sire District

3.1.1. Farmers' Perception of Temperature Changes

Among the interviewed farmers, 98% perceived long-term[4] change in temperature in Sire District. Figure 2 presents that 75% perceived increase in temperature, 20% climatic variability, 3% decreasing temperature, 1% claimed no change in temperate, and 1% did not pay enough attention to say anything about the temperature trend of the study area over the last three decades.

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[4] The benchmark category between short-term and long-term in this study is set to $\cong$ 20-30 year.

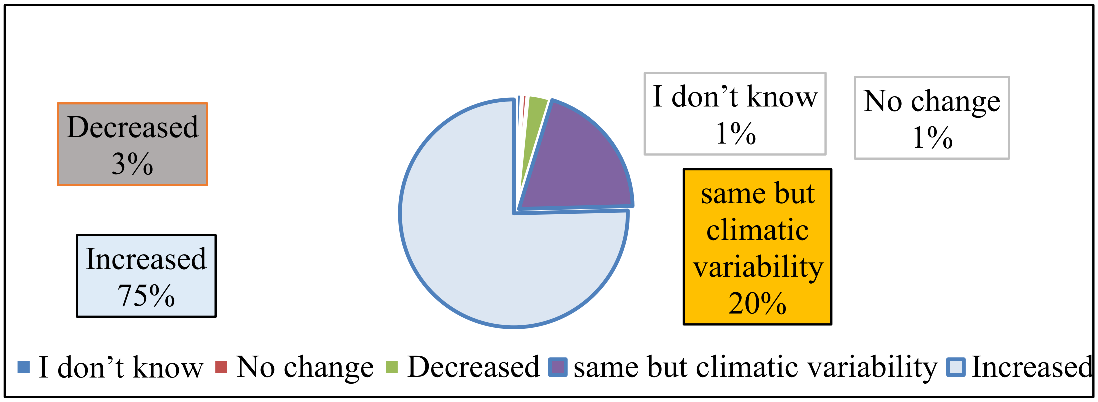

Figure 2: Farmers' Perceptions of Changes in Temperature in Sire District.

Source: Own Computation

Figure 3 demonstrates the monthly temperature analysis at the lower parts and upper parts of Sire district. Mean monthly maximum temperature reaches the highest value in May (29.9^{0}C) and lowest value in August (26.2^{0}C) at the lower parts of Sire District. Mean monthly minimum temperature reaches the highest value in June (16.82^{0}C) and lowest value in December (12.16^{0}C) at the lower parts of Sire District. Whereas mean monthly minimum temperature reaches the highest value in May (27.6^{0}C) and lowest value in August (23.8^{0}C) at the upper parts of Sire District. Mean monthly minimum temperature reaches the highest value in Jun (14.3^{0}C) and lowest value in December (9.6^{0}C) at the Upper parts of Sire District.

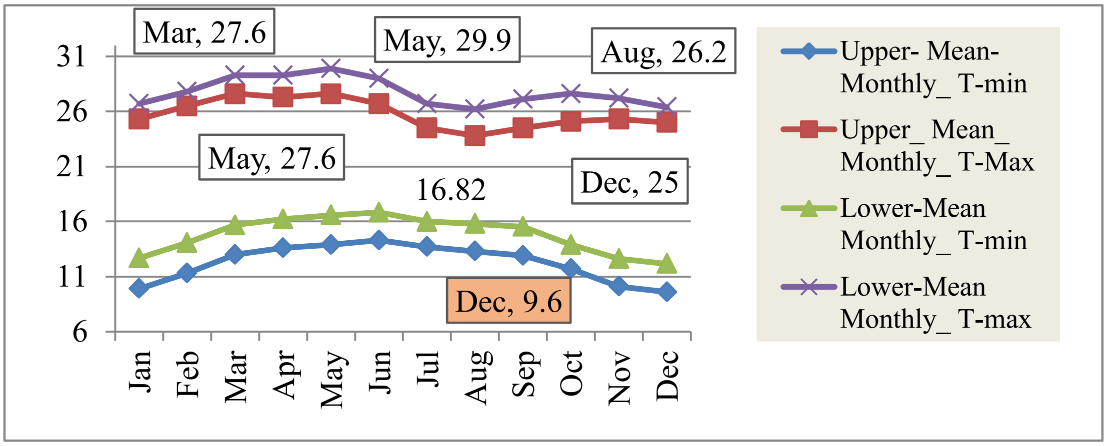

Figure 3: Mean Monthly Temperature Distribution at The Lower and Upper Parts

Source: Own Computation

The average annual minimum temperature over Ethiopia has been increasing by about 0.25^{0}C every 10 years, while average annual maximum temperature has been increasing by about 0.1^{0}C every decade (NMSA, 2001). As explained in IPCC Fourth Assessment Report (2007c), global warming is obvious and the linear warming trend over the last 50 years is 0.13°C per decade. Warming is also observed in Ethiopia. The temperature data analysis shows that both average maximum and minimum temperatures are increasing sharply at both lower and upper parts of Sire district. The maximum temperature increases by 0.67°C and 0.74°C per decade at the lower and upper parts of sire district, respectively, whereas average minimum temperatures trend analysis shows increment by 0.32 °C and 0.51°C in both lower and upper parts of Sire District, respectively. It is greater than the national average. This might be due to the study carried out over a specified location; however, agrees with Sharma (2009) findings.

Figure 4 indicated that the trend analysis of both annual mean temperatures over whole parts, as well as at upper and lower parts of sire District shows sharp increment, which is 0.56^{0}C, 0.63^{0}C and 0.50^{0}C, respectively. This is in agreement with the perception of most farmers i.e. 75.4% towards increasing temperature trends. This indicates series action have to be taken in adapting the temperature changes. Almaz (2009) and Bewket (2010) had observed similar patterns of increasing trends.

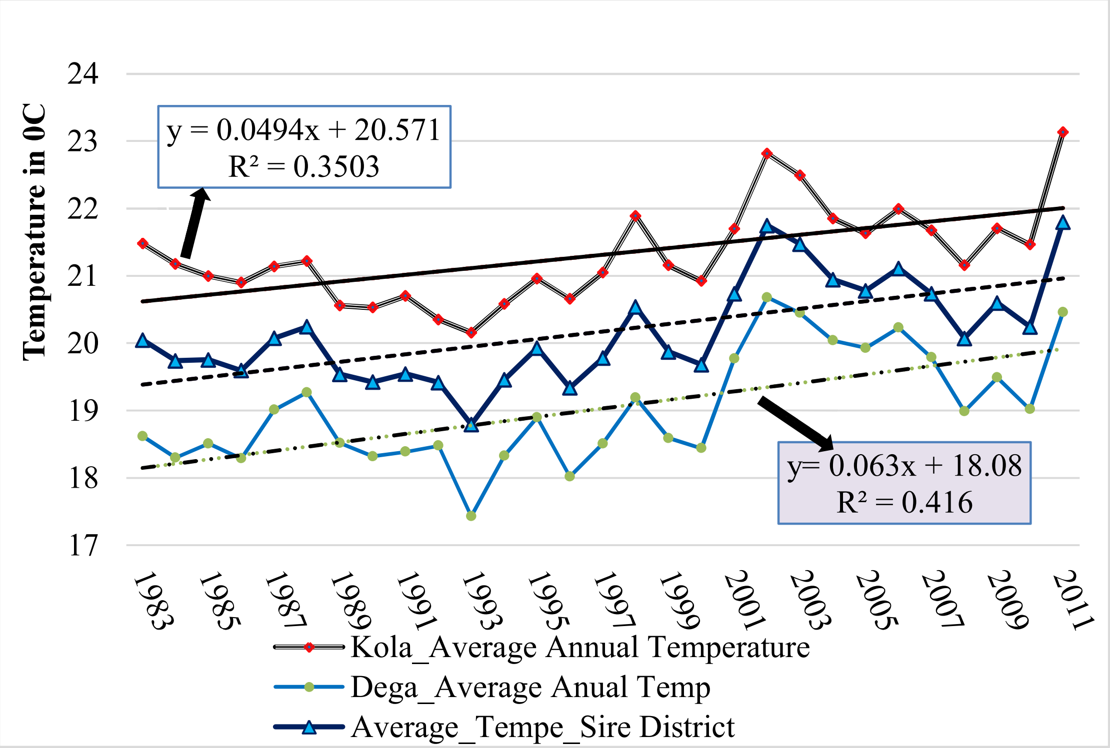

Figure 4: Average Temperature Trends of Sire district (1983-2011)

Source: Own Computation

3.1.2. Farmers' Perception of Precipitation changes

As depicted in Figure 5, 63% of respondents noticed a change not in the total amount of rainfall but variability of rains, 15% observed increasing precipitation and 22% replied as decrement in rainfall. Although, literature reviews and recorded station data indicated that climate extremes, especially drought and flood, are not a new phenomenon to Ethiopian farmers, only 34% of respondents reported this.

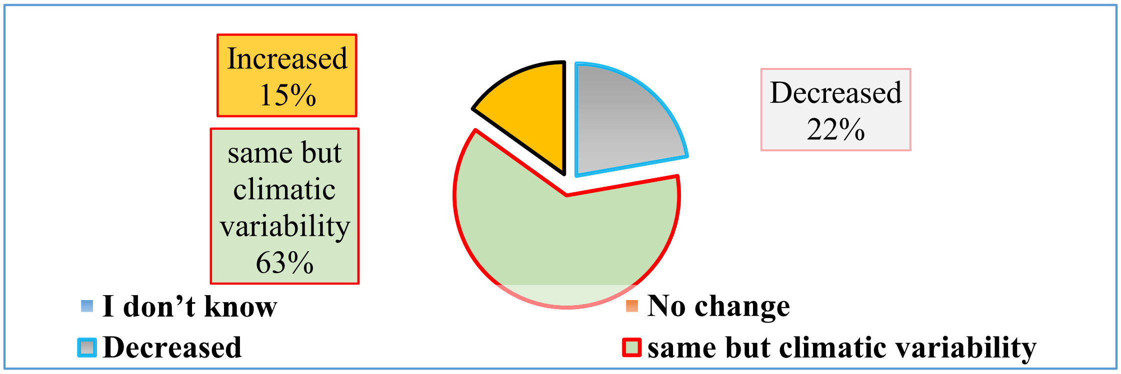

Figure 5: Farmers' Perceptions of Changes in Precipitation in Sire District

Source: Own Computation

The mean (1983-2011) reconstructed annual rainfall of the Sire district is 28065.65mm. Recorded data of Average annual total rainfall trends of Sire district for the period of (1983-2011) shows increasing trends as indicated on Figure 6. The trend analysis is in agreement with change in timing of rains. Climatic data proofs farmer's perception. The study agreed with Gashaw (2009), which found out increasing trends of rainfall volume. Similarly, on rainfall volume trend of the central highlands of Ethiopia, Mahdi (2001) produced the same results.

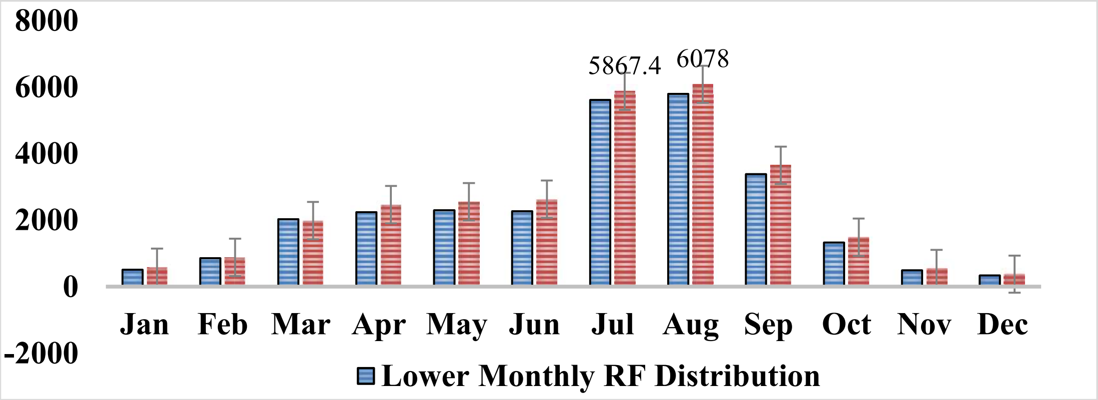

Figure 6: Yearly Rainfall Distribution Over Months (1983-2011)

Source: Own Computation

Recent analysis of reconstructed grid climatic data indicate that rainfall trends are associated with the observed warming. Similar studies have been done by Williams *et al.* (2011) and Paulo *et al*. (2012). Therefore, a determination of the observed trends might be assumed as the most likely case, against which climate adaptation efforts should be oriented. Trend analysis of precipitation in Birnin Kebbi, Nigeria by Ismail *et al.* (2012) was in agreement with results of the study.

The recorded data on rainfall from 1983 to 2011 shows that the annual rainfall total followed an increased trend in both lower and upper parts of Sire District. The annual total rainfall is heavily dependent on seasonal rainfall volume. Although the trend analysis is in agreement with only 15% of the respondents who replied an increased rainfall amount, it does not contradict perceptions of respondents who observed climatic variability. The result of the study indicated that farmers' perception was in accordance with the meteorological record. Similar finding was done by Mahdi (2001), Hageback *et al*. (2005) , Gashaw (2009) and Gbetibouo (2009).

Climate change is dynamic which changes over various areas based on characteristics such as resource, education, experience, age, etc. For instance, rich farmers are supposed to have better access to climate change information sources that potentially enhance their perception. Conceptually, farming experience, age, and educational level are believed to play important role in climate change perception. Climate change is not an outcome of a single time phenomenon; it has taken thousands of years for its genesis. The impact of a change in average climate parameters is likely to be felt over longer time scales. Hence, farmers with more experience are more likely to notice the changes in climatic conditions. Educational level is also tending to increase perception because it increases one's ability to receive, decode and understand information related with climate.

Pearson chi-square test was applied in order to see any existing association between climate change perception, agroecology, and HH head characteristics. The result in the Table 4 shows that there is statistically significant variation on temperature perception across agroecological zones at 5% probability level. Despite people living in all agroecologies seemed to feel the change in precipitation in more or less similar way, the statistical test indicated a not significant difference. The number of farmers who perceived increased flood and drought frequency in the kola are twice the number of farmers who have similar perception in the midlands. This could be explained by the fact that most farms in the kola are located on dry lands, and erratic rains with strong volumes increased the frequency of floods and erosion on such kinds of farms. Farmers in the kola paid more attention to floods than erratic rainfall, as it is the major means by which the ever-left precious soils are taken away from their farms, plus the impacts of the phenomenon are also not season bounded.

Table 4: Perceptions of Farmers Towards Temperature and Precipitation Changes Based on Agro ecological Zones

Agro ecological Zone of the HH	**Trend of hot days (temperature) over the last 30 yrs.**								
	Increased		**no change**		**same but change climatic range**		**I don't know**		X^2
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	
Woyenadega	34	27.9%	0	0.0%	8	6.6%	0	0.0%	
Dega	25	20.5%	0	0.0%	13	10.7%	1	0.8%	11.11**
Kola	36	29.5%	1	0.8%	4	3.3%	0	0.0%	

Agroecological Zone of the HH	**Trend of precipitation over the last 30 yrs**						
	Increased		**Change in times of raining**		**Increase in frequency of drought and Flood**		X^2
	N	**%**	**N**	**%**	**N**	**%**	0.62

Woyenadega	3	4.3%	5	7.1%	10	14.3%
Dega	3	4.3%	5	7.1%	14	20.0%
Kola	4	5.7%	6	8.6%	20	28.6%

**, significant at 5% level

Source: Own Computation

The same statistical analysis was run to explore the nexus between climate change perception and socio-economic groups. None of the calculated chi-square figures indicated a statistically significant relationship between the twin perceptions and wealth status at 5% probability level. The possible reason for this is that farmers use local indicators, which merely need natural sense organs, to perceive the changes in climate.

The results displayed in Table 5 showed that a higher proportion of farmers with more than 30 years' experience claimed that temperature and rainfall are increasing, and noted change in the frequency of droughts and floods. On the other hand, farmers with less than 30 years' experience confirmed same but change climatic range in temperature and observed erratic rainfall. Statistical tests indicated not significant difference between the views of experienced and inexperienced farmers existed in temperature and rainfall change perceptions.

Table 5: Perceptions of Farmers Towards Temperature Change and Precipitation Changes Based on Experience

Trend of hot days over the last 30 yrs									
Farming Experience	**Increased**		**No change**		**Same but change climatic range**		**I don't know**		**X^2**
	N	**%**	**N**	**%**	**N**	**%**	**N**	**%**	**3.95**
Short (0-10 yrs)	6	4.9%	0	0.0%	0	0.0%	0	0.0%	

medium (10-30 yrs)	40	32.8%	1	0.8%	11	9.0%	0	0.0%
long (30+ yrs)	49	40.2%	0	0.0%	14	11.5%	1	0.8%

Trend of precipitation over the last 30 yrs

	Increased		Change in times of raining		increase in frequency of drought and Flood		X^2
	N	%	N	%	N	%	
Short (0-10 yrs)	0	0.0%	0	0.0%	0	0.0%	
medium (10-30 yrs)	3	4.3%	3	4.3%	19	27.1%	3.22
long (30+ yrs)	7	10.0%	13	18.6%	25	35.7%	

Source: Own Computation

3.2. Determinants of Farmers' Adaptation

The coefficients of the binary logit model analysis represent the effect of each explanatory variable on the ratio of the probability of the HH to adopt an adaptation option, relative to the probability of not adopting the option. In general terms the results suggest that adaptation options are associated with differences in HH characters, farming characters and institutional factors that jointly determine the way in which an individual HH decides to adopt an adaptation option or not.

To ease interpretation of the model result, the marginal effects (discrete change) of the explanatory variables on the probability of each adaption option is reported in Table 6. The problem of multicollinearity among the independent variables was accounted before running the model. The collinearity statistics for continues variables and contingency coefficient for discrete variables were less than 10 (1.1–2.47) and less than 0.75, respectively. It points out that as we include all hypothesized explanatory variables, multicollinearity is not a problem in model estimation.

As reported on Table 6, out of the sixteen explanatory variables hypothesized to affect farmers' adaptation, eleven have been flagged to be statistically significant. These factors include sex, age, size of productive labor, socio-economic group, farming experience, soil fertility status, and market distance, access to media information, off-farm income, credit usage and agroecology. Eight of the significant variables, namely, sex of HH, education level, family size, size of productive labor force, socio-economic group, tenure security, off-farm income, and agroecology, were found to be statistically significant with expected signs. Accordingly, sex of HH, education level, family size, size of productive labor force, socio-economic group, tenure security, off-farm income, and agroecology were positively and significantly related with farmers' adaptation. By contrast, age of HH, fertility of soil and market distance were significantly related to farmer's adaptation but as opposed to the set hypothesis. Studies by Bryan *et al.* (2009), Temesgen *et al.* (2008b) and Nhemachena *et al.* (2007) identified wealth, access to extension, credit, and climate information as factors influencing farmers' decisions to adapt in Ethiopia. Their findings on wealth is in agreement with this study. The section ahead describes the interpretation of the key findings of the model.

Gender of HH head: Female headed HHs are more likely to take up adjustment to management adaptation option. For instance, being female, as head of HH, increases the probability of adjustment to management by 87%. The possible reason for this observation is that in the farming community women do many agricultural activities particularly in processing stage; hence, women have more farming experience and information on various management practices (Bewket, 2010). On the contrary, male-headed HH are more likely to take portfolio diversification and changing planting dates adaptation options. Which agrees with Buyinza *et al.*, 2008 result that male-headed HHs often have high likelihood of adopting agricultural technologies, at least in some parts of Africa. Male-headed = HH highly adaptive of portfolio diversification and in changing planting dates.

Educational level of HH head: It presented a positive and significant relationship with water additions[5] and adjustment to management adaptation options. It is probably that as HHs assume higher education, they respond to climate change by making best adaptation option based on his preference and influences individual decision making as it tends to reduce farmers' risk aversion. This finding is in line with the investigation of Temesgen *et al*. (2008b) and Aemro *et al*. (2012).

Age of HH head: age was hypothesized to affect adaption positively. However, against the hypothesis age affects change use of chemicals (or fertilizer) adaptation option to climate change negatively and significantly. Because as the age of the HH head increases, the person is exposed for various health issues and that prevent the likelihood of using chemicals (or fertilizer) adaptation strategy for climate change.

Productive labor force: it significantly increases the probability to change planting dates as a viable option to minimize the risk of climate change and variability. As the number of productive labour force within a family increases by one individual, the probability of diversifying crops increases by 196.5%.

Family size: As the size of family increases by one person, the probability of adjusting oneself to management adaptation option increases by 57%. This is possibly because HH**s** have developed a capacity of working in group as

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[5] Any kind and form of ground and surface water that is conceivably available for farmers.

family labour which in turn contribute for the adoption of adjustment to management option.

Medium income (wealth) HHs: are less capable of adapting to climate change and variability using various adaptation options. The probability of resource-medium farmers adopting water additions, is lower by 97% than resource-rich farmers. Adaptation of water addition is a costly activity and medium income farmers have the lowest adaptive capacity which agrees with Bewket, 2010 findings. On the contrary, the likelihood of poor wealth HHs for changing planting dates is higher than the resource rich HHs. This is perhaps changing planting date is the cheapest adaptation option and more likely used by poor wealth farmers.

Tenure security: has an increasing impact on the adoption. The more the farmer has security on his land the better he is ready to adopt changing planting dates adaptation option.

Fertility of soil: have unpredictable impact of various adaptation options. Surprisingly, the probability farmers who possess fertile land in changing planting dates and diversify crops in response to changing climate is greater by more than 100% than farmers who possess infertile land. Farmers who possess less fertile soil are less likely to adopt changed use of chemicals (or fertilizer) as an adaptation option than farmers with infertile land. Farmers with less fertile soil are 90% less likely to adopt chemical and fertilizer adaptation option than those with fertile soil. Targeting and modelling such farmers is important in promoting adaptation management to other farmers who do not have fertile land and are not yet adapting to changing climatic conditions.

Market distance: the distance of market centre is negatively related with adaptation measures. So distant market decreases the probability of farmers using changing planting dates and adjustment to management. An additional kilometre of the road decreases the probability of adopting changing planting dates and adjustment to management by 16% and 17%, respectively. It is because HHs low access to agricultural inputs and technologies in the nearby market affects their adaptation to climate change. Proximity to market is an important determinant of adaptation, presumably because the market serves as a means of exchanging information with other farmers (Maddison, 2006). However, market distance shows a positive correlation with changed use of chemical and fertilizer.

Off/non-farm income: it has positively influence on adaptation; so, increases the probability that farmers implement changing planting dates and use of chemical and fertilizer as an adaptation options than farmers who have no off-farm income. This is perhaps due to that additional income help the farm to acquire flexible and costly adaptation strategies.

Agroecology: HH**s** who live in various agroecological zones possibly will make use of different adaptation methods. HH in *Dega* and *Kola* are more likely adjust planting trees than *Woyenadega* HH**s** do. This is perhaps because farmers dwell in *Dega* and *Kola* are exposed more for many extreme effects of climate change and variability that those who dwell in *Woyenadega.*

Table 6: Econometric Results of the logit model for Rainfall Variability

Dependent Variables	**Portfolio diversification**	**Water Additions**	**Changing Planting Dates**	**Adjustment to Management**	**Implement soil Conservation** [a]	**Changed use of chemicals (or fertilizer)**	**Other Options** [a6]
Female Headed HH	233.14 (2.95)*	11.0316(0.01)	333.3 (3.20 374)*	-86.6 (4.72)**	656.6 (2.07) 435	240.2 (1.63 120)	55.51 (0.41 38)
HH in age range of 35-65	-56.56(1.31)	-81.1922(2.40)	273.7 (2.6 183 0)	3.000 (0.00 0)	3.62E (3.7 +03 3)*	- (4.21 89.35)** 95	- (2.39 63.15) 05
HH above 65 years of age	-82.56(1.53)	2.59E+03(3.19)*	141.6 (0.3 614 3)	- (0.00 100.0) 000	8.62E (3.9 +03 7)**	- (1.92 97.43) 66	- (1.05 77.69) 71
read and write	1.37(0.00)	64.9997(0.18)	53.31 (0.2 02 4)	685.2 (4.13 000)**	- (0.07) 25.95 02	- (1.13 73.13) 45	- (1.20 58.39) 08
primary school education	15.34(0.05)	106.9941(0.63)	- (0.4 35.61 4) 24	112.7 (0.88 000)	147.1 (1.16) 232	- (0.70 48.63) 43	- (0.71 38.98) 14

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[6] This option contains move to a different site, change in quantity of land under cultivation, buy insurance, put trees for shading, migration, off-farm job, lease land, change use of capital and labour, etc.

secondary school education	-75.56(1.75)	4.77E+03(5.38)**	-78.3616 (1.73)	-68.3000 (0.58)	55.3957 (0.10)	181.5887 (0.80)	-51.3221 (0.55)
Graduate level education	-67.38(0.42)	-100.0000(0.00)	201.6933 (0.44)	1.30E+03 (1.96)	-100.0000 (0.00)	-78.4512 (0.33)	-51.0071 (0.21)
Family size	-3.49(0.06)	10.5635(0.16)	-18.3790 (1.33)	56.8000 (4.87)**	-19.1328 (1.27)	-14.8920 (0.62)	-3.9603 (0.07)
Productive labor force	18.10(0.19)	-6.8712(0.01)	196.5047 (6.38)**	-25.9000 (0.51)	2.2462 (0.00)	-43.9515 (1.52)	10.6177 (0.10)
Medium wealth	266.76(1.09)	-97.6639(6.03)**	226.5434 (1.04)	64.8000 (0.17)	-82.9119 (1.66)	1.19E+10 (0.00)	37.2128 (0.09)
Poor wealth	98.92(0.26)	-86.6671(1.70)	976.8478 (3.32) *	-37.3000 (0.12)	-50.4788 (0.20)	7.44E+09 (0.00)	46.3237 (0.11)
Farm size	44.29(1.34)	-18.9353(0.35)	23.3485 (0.55)	14.4000 (0.18)	2.9120 (0.01)	-33.3840 (0.84)	19.5765 (0.54)
Tenure Security	-68.59(0.99)	642.1734(1.60)	2.33E+03 (4.06) **	1.24E+11 (0.00)	-79.8568 (0.93)	2.19E+11 (0.00)	884.1339 (3.25)*
Medium experience (10-30 yrs)	114.94(0.26)	1.18E+10(0.00)	-21.4625 (0.03)	61.7000 (0.07)	1.75E+10 (0.00)	-80.0746 (0.65)	-86.1146 (1.80)

Long experience (30+ yrs)	470.17(1.53)	3.51E+09(0.00)	-80.7667 (1.20)	-59.1000 (0.30)	3.75E+10 (0.00)	179.3460 (0.32)	-92.3771 (3.25)*
Less Fertile soil	298.23(2.50)	429.7804(1.60)	138.1369 (1.04)	-33.5000 (0.19)	-77.3252 (1.35)	-89.8805 (5.18) **	482.4533 (3.68)
Fertile soil	1644.67(5.25) **	-100.0000(0.00)	2424.7282 (6.03) **	-90.8000 (2.99)*	-39.6235 (0.09)	-96.6226 (4.00) **	1.48E+03 (4.98)
No visit by extension agents	-100.00(0.59)	-100.0000(3.94)	-100.0000 (1.09)	-100.0000 (9.84)	-100.0000 (6.46)	-100.0000 (6.96)	-100.0000 (0.17)
Occasionally visit by agents	138.77(0.24)	4.34E+11(0.00)	-100.0000 (0.00)	1.14E+13 (0.00)	-99.5048 (5.43)**	-97.1321 (1.24)	2.54E+11 (0.00)
Mostly visit by extension agents	44.53(0.04)	1.23E+10(0.00)	-100.0000 (0.00)	1.22E+13 (0.00)	-99.6669 (5.72) **	-89.7719 (0.51)	1.94E+11 (0.00)
Regularly visit by extension agents	71.93(0.09)	4.73E+11(0.00)	-100.0000 (0.00)	1.24E+14 (0.00)	-99.7993 (6.20) **	-99.4737 (2.53)	2.11E+11 (0.00)

Access to climate information	-85.23(1.08)	-100.0000(0.00)	1.07E+10 (0.00)	-100.0000 (0.00)	1.24E+04 (4.22)**	7.57E+03 (1.73)	-100.0000 (0.00)
Credit service usage	-37.84(0.40)	20.9627(0.04)	-61.1916 (1.45)	287.4000 (2.27)	43.4232 (0.14)*	203.1306 (0.78)	96.8847 (1.08)
Market distance	11.11(2.21)	-4.2630(0.12)	-16.2785 (5.24) *	-17.0000 (4.90)**	8.9802 (0.70)	17.6481 (3.10)***	-.5877 (0.01)
Non/Off-farm income	-21.91(0.11)	-72.2132(0.83)	1.03E+03 (7.00)***	-67.0000 (1.26)	-26.6815 (0.09)	1.74E+03 (6.10)**	-63.2507 (1.79)
Agroecology Dega	73.55(0.50)	-56.3873(0.53)	8.60E+03 (15.12)***	-57.7000 (0.80)	-37.7589 (0.15)	89.9985 (0.35)	14.9563 (0.04)
Agroecology Kola	149.57(0.97)	-88.4596(2.16)	1.11E+04 (14.22)***	-49.1000 (0.40)	42.0850 (0.08)	16.7738 (0.02)	-31.8413 (0.21)

***, ** and * significant at 1%, 5% and 10% probability levels, respectively; values in bracket = Z values

a – ominibus method of model coefficients tests show insignificance of the model[7].

Source: Own Compu

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[7] The omnibus method of model coefficients tests for implementing soil conservation and other adaptation options show insignificant results. Which implies there is no improvement in the overall model from Block 0. Therefore, the study was not considering the unfitted model of 'other and 'implementing soil conservation' adaptation' options in the discussion.

4. Conclusion and Recommendation

Farmers in Sire District perceive changes in temperature and rainfall. Farmers' perception is reflected in the changes of the agricultural calendar, increment of hotter and drier area and adaptations of different farming strategies across time. The present agricultural calendar is shorter than it was before 1990. Farmers have shortened the cropping calendar and the majority of the respondents have adjusted their farming practices to counteract the impacts of changes in temperature and rainfall patterns. The descriptive statistics results show that 90% of farmers perceived long-term change in temperature over 1983-2011. Rainfall distribution implies that highest monthly rainfall was recorded in July, August and September. These months are locally called Meher season having long rain shower. Temperature trends of both average annual minimum and maximum temperature values follow increasing trends while rainfall data recorded from 1990 to 2014 shows that the annual rainfall values followed decreasing trend over the period. For the perceived changes, about 32-35% of respondents took remedial actions (such as diversification, changing planting dates, soil conservation measures, chemical uses, etc.) to counteract the impacts of climate change. As the logit model result produced sex of household (e.g. at 5% level with adjustment to management option), education level, family size, size of productive labor force (e.g. at 5% level with changed use of chemicals option), socio-economic group, tenure security, soil fertility, market distance, off-farm income (e.g. at 1% level with changing planting dates option), and agro ecology were found positively and significantly related with farmers' adaptation. As opposed to the set hypothesis, age of HH (e.g. it affects change use of chemicals adaptation option to climate change negatively), fertility of soil and market distance (e.g. market distance shows a positive correlation with changed use of chemical and fertilizer option), were in reverse and significantly related to part of farmer's adaptation options. The implications of these findings are that adaptation measures significantly increase for HHs with more productive labor, better educational level, farming experience, wealth status and off-farm income. Hence, designing policies with the aim of improving these factors will improve farm-level adaptations such as the educational level has a positive relation with farmers adaptation strategies but it could be considerably improved if the educational policies rearticulated by emphasizing on quality of education. Furthermore, responsible agents could contribute to mitigating climate change effects on agriculture by investing in research, soil conservation measures, technology dissemination, by expanding agricultural input and markets and strengthen non-agriculture sector.

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