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CLIMATE VARIABILITY AND AGRO-PASTORALS' ADAPTATION STRATEGIES TO CLIMATE CHANGE IN SOMALI REGION OF ETHIOPIA, THE CASE OF KEBRIBAYAH DISTRICT

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Abstract
The study examined climate variability; identified types of adjustments agro-pastoral households are making in their crop and livestock production practices in response to climate changes; and assessed factors influencing agro-pastoral households' decision to practice adaptation mechanism. Thirty years of meteorological station data beginning from the year 1987 to 2016 and primary data collected from randomly selected 156 agro-pastoral households were used in this study. The data were analyzed using descriptive statistics and multinomial econometric model. The result revealed that the temporal variation of total amount of annual rainfall was recognized as moderate and there was an increase of maximum temperature throughout the study period. There were also five highest drought and four highest flood years. Agro-pastorals practice multiple strategies to adapt to the changing climate. The empirical model also confirmed multiple factors including formal education, access to extension service, and market access influenced households' decision to adopt climate change adaptation options. Therefore, policies and intervention programs aimed at promoting household level climate change adaptation need to invest more on providing reliable meteorological information, formal education, extension services, and better infrastructure.

Key Words: *Agro-pastoral, Climate variability, Climate change, Adaptation strategies, Somali Region, MNL model*

Introduction

People in developing world face multiple stressors such as droughts, plant diseases, policy changes and market fluctuations (Misselhorn, 2005; O'Brien *et al.,* 2004). In East Africa, droughts and climate variability in general are among the most important stressors (Misselhorn, 2005). Climate change has become priority concern of mankind and is considered as one of the main environmental problems of the 21st century. Climate impacts are being felt today and greater impacts are expected in

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the future. In Ethiopia, the temperature has been increasing annually at the rate of 0.2°C over the past five decades. This has already led to a decline in agricultural production. Needless to mention that the consequences of climate change and the emphasis to be placed on it depends, among others, upon the significance of the agricultural sector in the national economy. The economy of many developing countries, including Ethiopia, is heavily dependent on agriculture. The livelihoods of the vast majority of their populations depend directly and indirectly on this sector. This dependence on agriculture increases the vulnerability of the economy of these countries and the rural smallholders' to problems related to climate change.

Concerns over population growth, climate change, conflict and declining productivity of the natural resource base also present very real challenges for pastoralists and agro-pastoralists in the Horn of Africa. Without significant support, levels of poverty, vulnerability and destitution will rise due to the effects of marginalization, recurrent drought and floods, conflict and livestock epidemics (Magda, *et al.,* 2009). The frequency of drought, flood, outbreaks of livestock and human diseases, crop pests and other associated emergencies have dramatically intensified in the pastoral and agro-pastoral areas of Ethiopian Somali Region. Further, the economic and social impacts of these calamities are very vast as reflected by the past and recent experiences in the Region. According to the regional Disaster Prevention and Preparedness Bureau (DPPB) estimates, there were about 200,000 - 300,000 pastoralists and agro-pastoralists that had dropped off their livelihoods and substantially reduced and depleted their assets due to drought induced emergencies in the region during the past 15 years (DPPB, 2008). The effect of climate variability coupled with the increase in human population exacerbated the impacts of climate changes on crop and livestock production which further complicates the problem of rural households' food insecurity and poverty in the region. These calamities also have political consequences and serious development implications that no one in region and beyond could ignore.

The fact that climate has been changing and will continue to change in foreseeable future implies the need to understand how farmers practice different strategies for adaptation to climate change in the future. Adaptation to climate change is an essential strategy to reduce the harshness and cost of climate change impacts. Adaptation measures help farmers guard against losses due to increasing temperatures and decreasing precipitation (IPCC, 2007). Adaptation to current or expected climate variability and changing climate conditions involves adjustment in natural or human systems in response to actual or expected climate stimuli or their effects, which moderates harm or exploits beneficial opportunities (IPCC 2001).

Hence, developing a better understanding of the adaptation strategies and factors influencing the agro-pastorals' choice of the strategies provide the ground for wiser agricultural and environmental policies, and identify entry points to mitigate the impacts of climate change. In the face of this different studies regarding farmers' choices of adaptation options and their determinants were carried out in different countries including Ethiopia (Deressa *et al.,* 2008; Hassan and Nhemachena, 2008; Deressa *et al.,* 2009;

Aemro and Jemma, 2012; Regmi *et al.,* 2017). However, most of the studies were undertaken at a macro level; and those studies conducted at micro-level also gave significant emphasis to the people residing in the highlands and pursuing sedentary way of life, which might make the results unclear to generalize about specific households located in other agro-ecological areas. The main objectives of the study therefore, were to examine the climate variability in the district, to identify the adaptation options practiced and the factors influencing the choice of adaptation strategies by agro-pastoral households in Kebribayah district of Ethiopia Somali Region.

Study Area

The study was conducted in Kebribayah district which is found in Faafan Zone of the Ethiopia Somali Regional State (ESRS). The Region which forms part of the Federal Democratic Republic of Ethiopia is situated in the eastern part of the country. Kebribayah district is one of the six districts of Faafan Zone of ESRS. It is located 50km east from regional capital, Jigjiga, and it is an agro-pastoral livelihood district. The district has 29 kebeles and its total area is 162,474km^2.

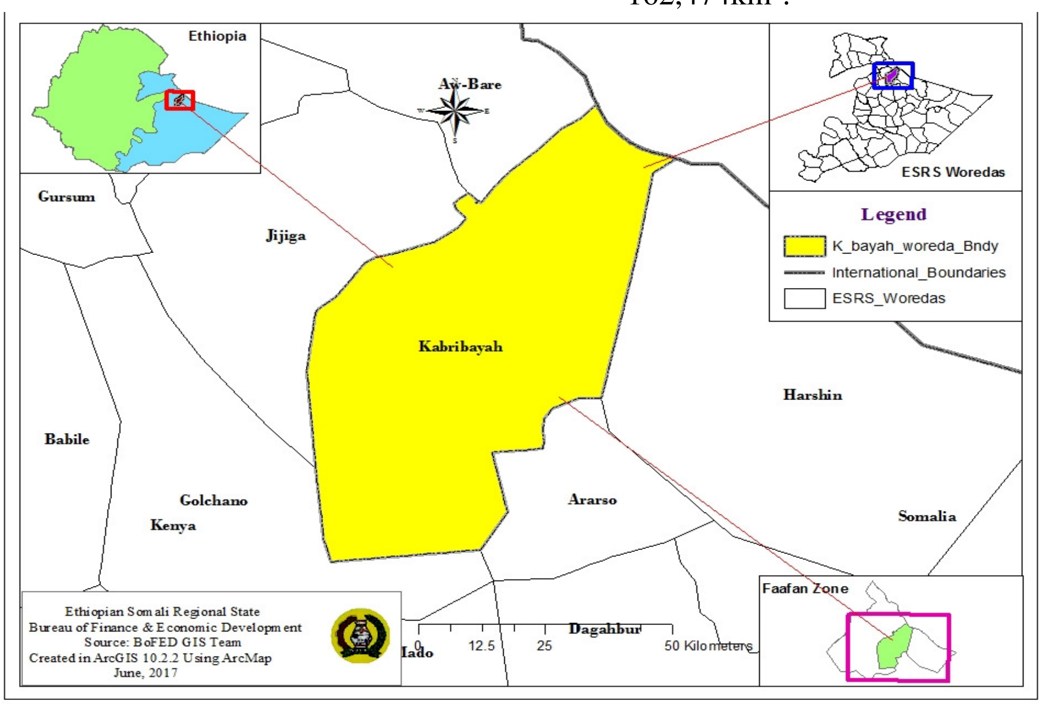

Fig. 1: Map of Ethiopia showing the location of the study region, zone and district

Research Methods

The study followed multistage sampling procedures with the rural households as the ultimate sampling unit to acquire primary data. Purposive sampling procedure was applied in the first stage to identify the study zone and district, Faafan and Kebribayah respectively where agro-pastoral population is dominating. In the second stage simple random sampling was used to select three agro-pastoral kebeles from the 29. Then the complete list of households of each sampled kebeles was secured from the kebeles. Finally, using simple random and probability proportionate to size sampling procedures the ultimate sample households were selected from the three sampled kebeles.

Both primary and secondary data were collected for this study. The household survey was conducted in the production year of 2018/19. Primary data at the household level were collected through a household survey using structured questionnaire. Five enumerators who know the local language and the culture of the community were trained and undertook the survey. The questionnaire helped to capture data on demographic, social, economic and institutional factors, and information on climate variability and trends of such variations in the district, adaptation strategies practiced, etc. Monthly temperature and precipitation data from 1987 to 2016 were also obtained from the Ethiopian Ministry of Metrology to the study area.

The sample size for the households' survey was determined using Yamane (1967) simplified formula to calculate sample size, $\boldsymbol{n = N/1 + N(e)^2}$, where *n* = sample size, N is the population size, e is the level of precision. Consequently, a total of 156 sample households were selected (Table 1).

Table 1: Distribution of sampled households by kebeles

Name of Kebeles	Total number of households	Sampled households
Guyow	1450	66
Danaba	801	37
Garbi	1155	53
Total	3406	156

In this study both descriptive and econometric data analysis methods were employed. Demographic and socioeconomic data were summarized and presented using descriptive statistics.

Co-efficient of Variability (CV) and Anomalies were the methods used to know the long-term variability and anomalies in rainfall and temperature for the study district. Rainfall variability is determined by the statistical test coefficient of variation. A higher value of Co-efficient of Variation is the indicator of larger variability and is calculated with the following equation (1).

$$CV = \frac{\sigma}{\mu} \times 100 \qquad (1)$$

Where,
CV - co-efficient of variation; σ - standard deviation and -µ mean precipitation. Based on the results, degree of variability of the rainfall events will be classified as, less (CV<20), moderate (20<CV<30) and high (CV>30) (Asfaw *et al.,* 2018).

Similarly, anomalies in rainfall have been done to determine the dry and wet years to severity of droughts and to identify the nature of trends (Asfaw *et al.,* 2018). as eq. (2):

$$z = \frac{(b_i - \tilde{b_i})}{s} \qquad (2)$$

Where, 'Z'- rainfall anomaly; 'b_i'- annual rainfall of particular year; '$\bar{b}_i$' – long term annual mean rainfall over a period of observation and 's' – is a standard deviation of annual rainfall over the period of observation. Drought severity classes are extreme drought (Z < -1.65), severe drought (-1.28 > Z > -1.65), moderate drought (-0.84 > Z > -1.28) and no drought (Z > -0.84).

The determinants of agro-pastorals' adaptation decisions to climate change were analyzed using a multinomial logit

(MNL) model. The MNL model was used based on the previous literature on determinants of farmers' adaptation to climate change (Sanga *et al*., 2013). The model is appropriate for this type of study because it allows the analysis of decisions involving more than two categories (Greene, 2003). Nevertheless, the model requires that households are associated with only their most preferred option from a given set of adaptation strategies. In other words, it requires that the probability of using a certain adaptation method by a given household is independent from the probability of choosing another adaptation method. Meaning the parameter estimates of this model have to satisfy the assumption of independence of irrelevant alternatives (IIA). Specifically, IIA states that the ratio of the probabilities of choosing any of the two alternatives is independent of the attributes of any other alternative in the choice set (Long, 1997; Tse, 1987).

The model is specified as follows:

Let A_i be a random variable representing the adaptation measure chosen by any agro-pastoral household. It is assumed that each agro-pastoral faces a set of discrete, mutually exclusive choices of adaptation measures. These measures are assumed to depend on a number of socioeconomic characteristics and other factors X. The MNL model for adaptation choice specifies the following relationship between the probability of choosing option A_i and the set of explanatory variables X as (Greene, 2003):

$$Prob(A = j) = \frac{e^{\beta_j x_i}}{\sum_{k=0}^{j} e^{\beta_k x_i}} \text{ , j=0,1,…,J} \quad (3)$$

Where β_j is a vector of coefficients on each of the independent variables X. Equation (3) can be normalized to remove indeterminacy in the model by assuming that $\beta_0 = 0$ and the probabilities can be estimated as:

$$Prob(A_i = j) = \frac{e^{\beta_j x_i}}{1+\sum_{k=1}^{j} e^{\beta_k x_i}} \text{ , j=0,1,…,J, } \beta_0 = 0 \quad (4)$$

Estimating equation (4) yields the J log-odds ratios

$$ln\frac{p_{ij}}{p_{ik}} = x_i'(\beta_j - \beta_k) = x_i'\beta_j, if\ k = 0 \quad (5)$$

The dependent variable is therefore the log of one alternative relative to the base alternative. The MNL coefficients are difficult to interpret, and associating the β_j with the *jth* outcome is tempting and misleading. To interpret the effects of explanatory variables on the probabilities, marginal effects are usually derived as (Greene, 2008):

$$\delta_j = \frac{\partial p_j}{\partial x_i} = p_j\left[\beta_j - \sum_{k=0}^{J} p_k\beta_k\right] = p_j(\beta_j - \bar{\beta})$$

Therefore, the full model is specified as follows:

$$y = \beta_i x_i + \varepsilon_{ij} \quad (6)$$

Where:

$\beta_i's$ are parameters to be estimated; y_i are adaptation options (or alternatives); x_i is a set of independent variables; and ε_i are the error terms.

Results

Climate Variability Analysis

The annual rainfall ranges from 286.0 mm (in 2015) to 617.0 mm (in 2010) for the study period of 1987 to 2016. The trends of rainfall was neither increasing nor decreasing but for the period of 1990 to 1997 there was an increase of the amount of rainfall from year to year. The temporal variation of total amount of annual rainfall was recognized as moderate on Kebribayah with the coefficient of variation (CV= 17.99 %) based on the data. The variation was high after 2007 relative to the previous period.

Similarly, anomalies in rainfall have been done, and from figure 3, we can understand that 1990, 2004, 2008, 2009 and 2015 were the highest drought years where as 1996, 1997, 2007 and 2010 were flood years. These patterns of climate change affected the agricultural and pastoral productivities of the district.

The temporal variations for maximum and minimum temperature on kebribayah were low with coefficient of variation 2.36 % and 1.98 % respectively. But there was an increase of maximum temperature throughout the study period with (R^2 = 0.4374). With this trend it is likely that the maximum temperature for the next years will increase. Climatological mean of temperature were 27.38°C and 14.76°C for maximum and minimum temperature respectively. The trends of minimum temperature was neither increasing nor decreasing within the study period.

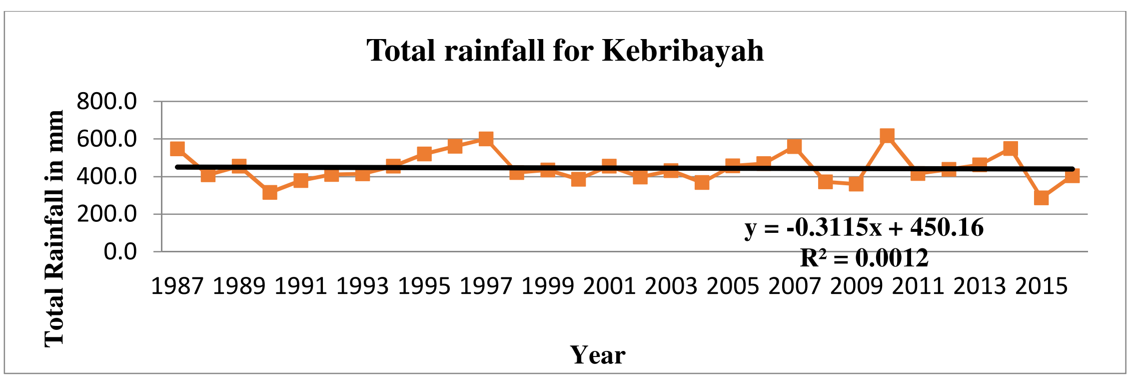

Fig. 2: Total amount of Annual rainfall for Kebribayah district from 1987 to 2016

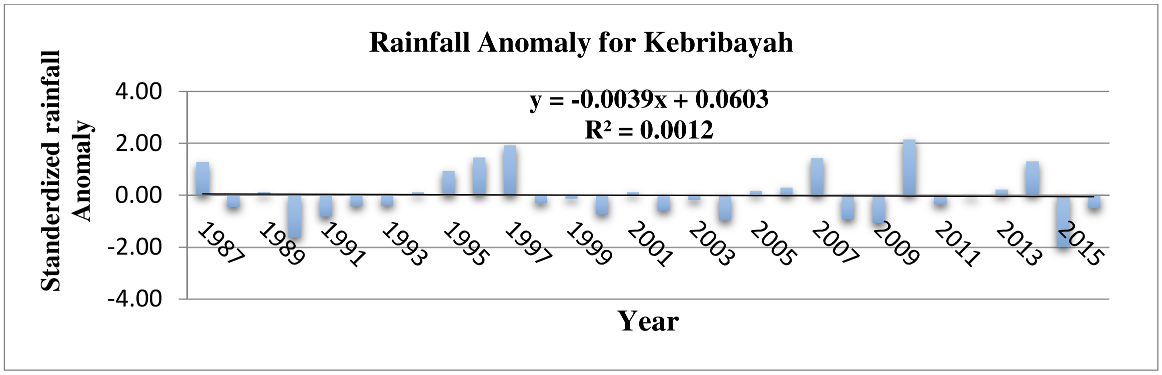

Fig. 3: Standardized rainfalls Anomaly for Kebribayah from 1987 to 2016

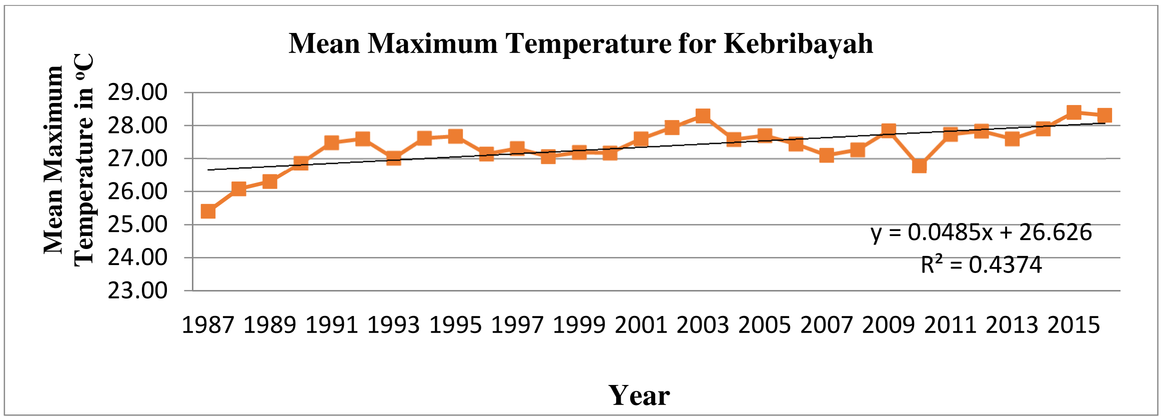

Fig. 4: Annual Average Maximum Temperature for Kebribayah district from 1987 to 2016

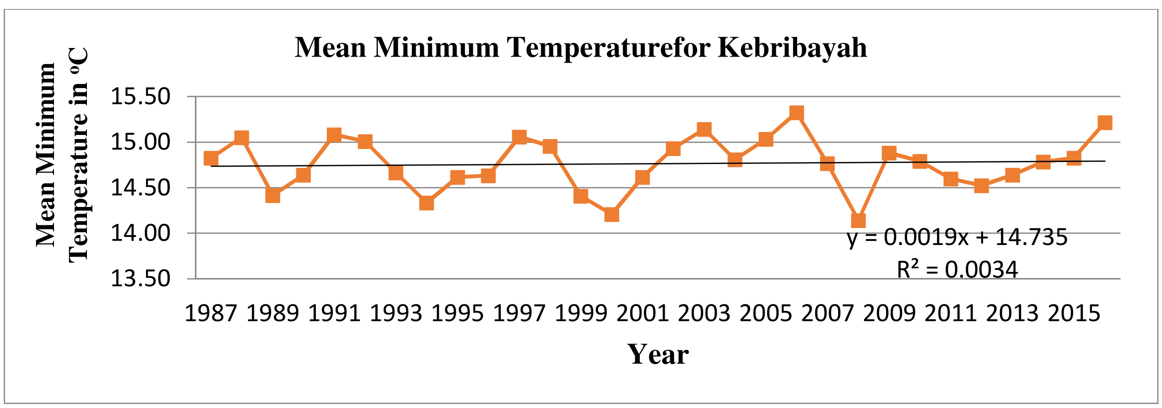

Fig. 5: Annual Average Minimum Temperature for Kebribayah district from 1987 to 2016

Climate Change Adaptation Options

Table 2 shows the adaptation strategies employed by the sampled agro-pastorals. It reveals that most agro-pastorals practiced adjusting planting date and adopting early maturing drought tolerant crop varieties strategy (25%). The result also shows that 20% and 14% of the respondents adopted herd diversification and herd mobility strategies, respectively. However, about 41% of the sampled agro-pastorals did not pursue any adaptation measure to cope with climate change.

Table 2: Sampled agro-pastorals' adaptation strategies to climate change

Adaptation Strategy	Sampled agro-pastorals (%)	Number of sampled agro-pastorals (156)
Herd mobility	0.14	22
Herd diversification	0.20	31
Adjusting planting date and adopting early maturing drought tolerant crop varieties	0.25	39
No adaptation	0.41	64

Factors Affecting Agro-pastorals' Adaptation Choices

To capture the effect of various factors on the probability of adopting various climate change adaptation strategies at the agro-pastorals' disposal "***no adaptation"*** option was used as the base category or reference strategy and other choices were evaluated as alternatives to this option. The parameter estimates of the MNL model provide only the direction of the effect of the independent variables on the dependent variable; they do not represent the actual magnitude of change of probability. Thus, the marginal effects of the MNL, which measure the expected change in the probability of a particular choice being made with respect to a unit change in an independent variable, were calculated. Consequently, the estimated coefficients were compared with the base category of no adaptation option.

Table 3 presents the parameter estimates of the MNL model and the marginal effects along with the levels of statistical significance. The likelihood ratio statistics from the MNL model indicated that Chi-square statistics (159.72) was highly significant ($P<0.001$), suggesting the model has a strong explanatory power. The result showed that educational status of household head, land holding, access to extension service, marital status, livestock holding, and household size positively and significantly influenced using one or a combination of climate change adaptation strategies identified by sampled agro-pastorals. In contrast income from crop production negatively and significantly influenced herd mobility adaptation strategy. The under mentioned section discuss on variables that significantly influenced climate change adaptation options.

Table 3: Parameter estimates of multinomial logistic regression model

Variable	Adjusting planting date and adopt early maturing drought tolerant crop varieties		Herd diversification		Herd Mobility	
	Co-eff.	Marginal effect	Co-eff.	Marginal effect	Co-eff.	Marginal effect
Age	.019	.009	-.015	.985	-.024	.976
Sex	-.139	.870	.061	.063	.456	.577
Education	.953**	.595	.425*	.530	-.094	.910
Marital status	1.311**	.709	.396***	.485	-.637	.529
Access to credit	-.013	.987	.213	.434	-.734	.480
Access to extension	.090***	.094	.360**	.434	.737	.089
Remittance	-.632	.531	-35.315	3.4e-15	-.720	.487
Market distance	-.192**	.825	.021	.022	.027	.027
Household size	-.111	.895	.062**	.063	.177***	.194
Livestock holding	.060*	.062	.119	.126	.072***	.075
Income from crop production	.008	.992	-.023	.977	-.075**	.928
Land holding in hectare	.113**	.120	.079**	.083	.029	.029
Access to a. of climate	.404	.498	.258	.295	.107	.113
Dependent variable	Adaptation strategy					
Reference category	No adaptation strategy					
Number of observation	156					
LR chi^2	159.72					
Log likelihood	-174.415					
Prob > chi2	0 . 0 0 1 2					

Note:*, ** and *** significant at 10%, 5% and 1% probability level of significance, respectively

Discussion

Education of the household head increases the probability of adapting to climate change. It significantly increases the use of adjusting planting date and adopting early maturing drought tolerant crop varieties as well as herd diversification as climate change adaptation methods. One year increase in the number of years of schooling was associated with a 59.5% and 53% increase in adjusting planting date and adopting early maturing drought tolerant crop varieties, and herd diversification, respectively. Moreover, all adaptation methods have a positive relationship with education. Agro-pastorals' with better education are likely to have more information on climate change, which in turn might promote the probability of adopting climate change adaptation strategies. This result was similar to that of Deressa *et al.* (2009).

Household size has a significant and positive effect on climate change adaptation. It significantly increases the use of herd diversification and herd mobility as climate adaptation strategies at 5 and 1 % level of significance, respectively (Table 3). The marginal effect result also shows that a unit increase in household size increases the likelihood of adopting the aforementioned adaptation strategies by 6.3 and 19.4%, respectively. According to Anbes (2003), the larger household size is associated with increased labor availability. Livestock production in pastoral and agro-pastoral system is highly labor intensive. Thus, household size has a significant association with herd diversification and herd mobility.

In line with Abreham *et al.* (2017) the size of land holding has a positive and significant association with adaptation strategies to climate change. That is, as the size of land holding increases by a unit the probability of adjusting planting date and adopting early maturing drought tolerant crop varieties as well as diversifying livestock production increase by 12 and 8.3%, respectively (Table 3). Large land holding provide opportunities for adoption of different crop varieties and diversification of livestock enterprises, and it can also help to distribute risks associated with unpredictable weather.

According to Sanga *et al*. (2013) better access to crop and livestock extension services has a strong and positive impact on climate adaptation strategies. The present study result also indicates that access to extension is positively and significantly related with adjusting planting date and adopting early maturing drought tolerant crop varieties as well as herd diversification adaptation options at 1 and 5% respectively. Having access to extension service increased the likelihood of the stated adaptation strategies by 9.4% and 5% respectively (Table 3). Extension services improve awareness of potential benefits and willingness to adopt climate change adaptation options and enables agro-pastorals to make use the information to change their management practices in response to changing climatic and other conditions. This result is in conformity with Dolisca *et al*. (2006).

In agro-pastoral households of Kebribayah district livestock and crop production are the main economic activities. The result in Table 3 indicated that livestock production has a positive association with the adoption of climate change adaptation strategies such as adjusting planting date and adopting early maturing drought tolerant crop varieties, as well as herd mobility. A unit increase in livestock holding increases the likelihood of adjusting planting date and adopting early maturing drought tolerant crop varieties and herd mobility by 6.2% and 7.5% respectively (Table 3). Increases in livestock holding builds confidence and widen the chance to test better opportunities and crop technologies available at the agro-pastorals disposal. The income derived from livestock production hence could help the household to cope and adapt to the changing climate if the adjusted planting date did not work. Further, increases in livestock production in agro-pastoral areas directly related with availability of feed and moisture which implies households respond to climate variability and changing climatic situations through herd mobility.

Being married significantly increases the use of adjusting planting date and adopting early maturing drought tolerant crop varieties and herd diversification as climate adaptation options at 5 and 1 % level of significance (Table 3). Being married increases the probabilities of the mentioned adaptation strategies by 70.9% and 48.5% respectively (Table 3). The likely reason is that crop and livestock production is labor intensive. On top of this men and women in agro-pastoral households take different responsibilities in crop and livestock production in a way to favor integration of crop production with herd diversification.

As expected on average a kilometer increase in the market distance required to arrive at input and output market decreases the probability of adapting to climate change. The study result confirmed the prior expectation that a km increase to the market distance from the households' residence negatively and significantly related to practice adjusting planting date and adopting early maturing drought tolerant crop varieties as climate change adaptation strategy at 5% significance level. The likelihood of practicing the mentioned adaptation strategy decreases by 82.5% for a km increase in market distance. This finding is in agreement with many studies (Solomon *et al.,* 2014).

Crop income negatively and significantly decreases practicing herd mobility as adaptation option at 5% level of significance (Table 3). This implies when the dominant source of income is crop production, increase in crop income encourage agro-pastoral households to lead sedentary life. On the contrary decreases in the level of crop income could be regarded as an incentive to increase their herd size which could urge the holder to be mobile in response to the changing climate.

Conclusions and Recommendations

There is noticeable climate variability that has influenced crop and livestock productivity in the district. Agro-pastoral households heavily depend on primary economic activities. These activities are highly vulnerable to variations in temperature and precipitation and climate change impacts. Hence this study based on the analysis of household level identified types of adjustments agro-pastorals are making in their crop and livestock production practices in response to the climate changes, and factors influencing the probability of choosing adaptation mechanism.

The study has revealed a number of adaptation options being used by agro-pastoral households. Agro-pastorals practice adjusting planting date and adopting early maturing drought tolerant crop varieties, herd diversification and herd mobility. Empirical results from multinomial discrete choice model confirmed the role of knowledge acquired through formal education and extension services, in improving agro-pastorals' awareness and adopting climate change adaptation measures. Moreover, increased market distance became a disincentive for the agro-pastorals to adopt adjusting planting date and early maturing crop varieties. This is obviously associated with costly transportation service. Therefore, intervention programs aimed at promoting household level climate change adaptation need to invest more on providing reliable meteorological information, formal education, extension services and better infrastructure.

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