

# Socio-economic determinants of smallholder mixed crop-livestock farmers' choice of climate change adaptation in the drylands of Northern Ethiopia

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## Abstract

**Purpose** – This paper aims to understand the perception of smallholder farmers on climate change, identify major livestock related climate change adaptation (CCA) strategies and their determinants in selected neighboring districts of Tigray and Amhara regions of Ethiopia.

**Design/methodology/approach** – A total of 416 household heads were involved in a questionnaire survey using a multistage sampling approach. To understand the socio-economic factors that influence



farmers' perception on climate change (CC) and/or variability, a binary logit model was used. Multinomial logit model was used to identify the determinants of smallholder farmers' choices of adaptation strategies.

**Findings** – Milk reduction, weight loss, feed shortage and frequent animal disease outbreak were indicated as major impacts of CC on livestock production. About 86.2% of the farmers' exercise CCA measures where livestock health care and management (25%), followed by livelihood diversification (21.5%) and shifting and diversification of livestock species (20.9%) were the top three adaptation measures implemented. Education, knowledge on CCA strategies, access to veterinary service and extension, market access, annual income, non-farm income, total livestock unit, sex of household head and household size were the major determinant factors to farmers' choice of CCA.

**Research limitations/implications** – Concerned authorities working in CC related sectors should give due attention to improve smallholder farmers' access to extension and veterinary services, market access and climate information to enhance their adaptive capacity to CC impacts. In addition, incorporating climate change awareness trainings into the existing extension packages is crucial to enhance the awareness of farmers on climate change and implement appropriate adaptation strategies. Moreover, it is very essential to provide appropriate herd management and marketing strategy based on the production system to avoid the significant price reduction during drought periods.

**Practical implications** – Concerned authorities working in CC related sectors should give due attention to improve smallholder farmers' access to extension and veterinary services, market access and climate information to enhance their adaptive capacity to CC impacts. In addition, incorporating climate change awareness trainings into the existing extension packages is crucial to implement appropriate adaptation strategies. Moreover, it is very essential to provide appropriate herd management and marketing strategy based on the production system to avoid the significant price reduction during drought periods.

**Originality/value** – This research is focused on smallholder crop-livestock farmers, livestock-based CCAs and presents the determinant factors to their choice of adaptation.

**Keywords** Determinants, Adaptation, Climate change, Multinomial logit model, Agro-pastoralists, Smallholder farmers

**Paper type** Research paper

## 1. Introduction

In Ethiopia, the livestock sector significantly contributes to sustainable agricultural development where it accounts approximately 17% of total gross domestic product (GDP) and 39% of agricultural GDP (Shapiro *et al.*, 2017). The livestock sector is increasingly organized in long market chains that employ at least 1.3 billion people globally and directly supports the livelihoods of 600 million poor smallholder farmers in developing countries (Thornton *et al.*, 2007). Smallholder production remains the predominant enterprise model in global agriculture, largely because of the large number of household farms in low income countries (FAO, 2014). Climate change (CC) and/or climate variability (CV) have substantial effects on the global livestock sector. Increasing CV will undoubtedly increase livestock production risks as well as reduce the ability of farmers to manage these risks (Claire, 2013).

The impacts of CC and/or CV are severe in farming communities within developing low-income countries like Ethiopia and low-middle income countries owing to lack of resources, knowledge, veterinary and extension services and research in technology development (Thornton *et al.*, 2009; Bryan *et al.*, 2013). Ethiopia is among the most vulnerable countries in Africa to the impacts of CC. Analysis of observed temperature data indicates that there has been an increase in seasonal mean temperature in many areas of the country over the past decades (Funk *et al.*, 2008), and there is also a change in the rainfall trend.

Climate change adaptation is very crucial response strategy to cope up with the changing climate (Alam *et al.*, 2017; Amamou *et al.*, 2018). Adaptation to CC includes adjustments in socio-economic systems to reduce their vulnerability both to long-term shifts in average climate and to changes in the frequency and magnitude of climatic extremes. Climate change

adaptation strategies (CCASs) could be implemented both at individual or group level, where the community-based adaptation can reduce the vulnerability as well as improving the resilience of local communities to CC. Understanding CCASs exercised by mixed crop-livestock farmers plays a paramount role in designing locally customized adaptation strategies. Besides, CCA is location specific, and its effectiveness depends on local institutions and socio-economic setting which mediate and translate the impact of external interventions (Gebreyes, 2018; Gedefaw *et al.*, 2018). Furthermore, understanding the perception of mixed crop-livestock farmers on CC and its impacts could help to determine their level of adaptation.

Demographic, socio-economic and institutional factors are considered as determinants to farmers' CCA. Literature to date indicate that household income/capital, sex, age and farming experience of decision-maker, household size, information on CC, land/livestock ownership, farm size, access to extension service and market access as the most important determinant factors among others in agro-pastoral/smallholder farming communities (Ajao *et al.*, 2011; Yila and Resurreccion, 2013; Misganaw *et al.*, 2014; Serkalem *et al.*, 2014; Kima *et al.*, 2015; Mengistu and Haji, 2015; Alemayehu and Bewket, 2017; Belay *et al.*, 2017; Kgosikoma *et al.*, 2018). However, most of these studies are focused on crop production-based CCA and the focus to livestock-based adaptation strategies were limited.

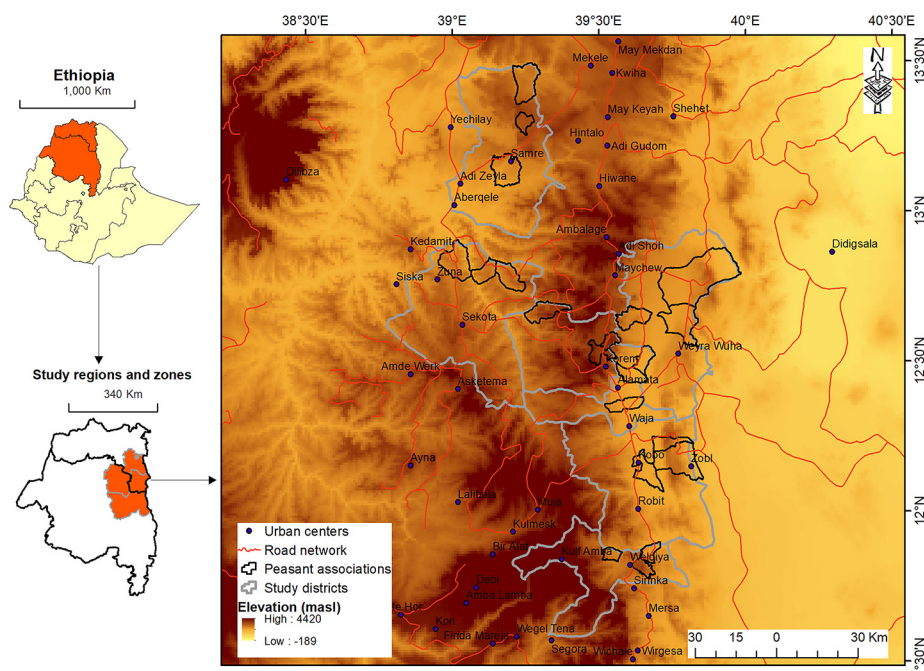
Majority of the areas in the northern parts of Ethiopia are characterized by an arid and semi-arid climate with low and erratic rainfall. Smallholder mixed crop-livestock farmers in these regions of the country suffer from the impacts of CC and extreme weather conditions. Therefore, understanding their perception and identifying and analyzing the underlying factors that affect adaptation choices is key to adopt locally suitable measures. Thus, in the present study the perception of smallholder crop-livestock farmers on CC and/or CV, livestock-based adaptation measures and the major determinants to farmers' choices of CCA were assessed in selected neighboring districts of Tigray and Amhara regions.

## 2. Materials and methods

### 2.1 Study area and target groups

The study was conducted in selected bordering districts of Tigray and Amhara regions of Ethiopia from November 2017 to February 2018. Smallholder mixed crop-livestock farmers who live in the selected sites and their livestock population were the targets in this study. Bordering districts within the two regions were selected purposively based on the existence of integrated crop-livestock production systems, transboundary animal movement and sharing resources, proximity and previous history of adaptation practices. In Tigray region, three districts in the Southern zone (Raya Azebo, Raya Alamata and Ofla) and one district in southeastern zone (Saharti Samre) were selected, whereas in Amhara region two districts from North Wollo zone (Guba Lafto and Raya Kobo) and one district (Sekota) from Waghemra zone were considered as study areas (Figure 1). Raya Azebo, Raya Alamata, Saharti Samre, Raya kobo and Sekota represent lowland (<1,500 m.a.s.l.) to midland (1,500–2,300 m. a.s.l.) agro-ecology, whereas Ofla and Guba Lafto districts represent highland (>2,300 m.a.s. l.) agro-ecology.

The districts in Southern zone of Tigray and North Wollo zone of Amhara region are characterized by having a bimodal type of rainfall pattern with light rains during February to April and heavy rains between July and September, whereas Saharti Samre and Sekota districts are characterized by a unimodal rainfall pattern. Being found in the arid and semiarid regions of the country with an erratic and unpredictable rainfall, the study districts are highly susceptible to the impacts of CC and/or CV. For this reason, the study districts are highly vulnerable to climate extremes like drought which could result in reduced crop and



**Figure 1.**  
Map of the study areas

livestock productivity or complete crop failure/death of livestock that could jeopardize rural livelihoods and food security (Abrha and Simhadri, 2015). The southern and southeastern zones of Tigray region are characterized by huge livestock population, which accounts for 16%, 29.3% and 10% of the cattle, sheep and goat population of the region, respectively. The livestock population in North Wollo and Wag-hemra zones accounts for 7.6%, 9.4% and 13.9% of the region's cattle, sheep and goat population, respectively (CSA, 2018).

## 2.2 Study design and sample size

A cross-sectional study design with a multistage sampling approach, which uses a combination of sampling techniques, was used to select the study peasant associations (PAs) (lowest administrative units in Ethiopia) and collect the necessary data. In the first stage, four districts in Tigray region and three districts in Amhara region were selected purposely to represent different agro-ecological zones.

In the second stage, three PAs from each study district were selected purposely considering their livestock potential, living style, proximity and exposure to extreme climate events like drought/flood. In the third stage, smallholder mixed crop-livestock farmers living in the identified PAs were selected randomly with the assumption that smallholder farmers within each site may have differences in their traditional knowledge and skills, socio-economic variations, perception of climate change and access to services, which may in turn influence their adaptation choices. As the impacts of CC and/or CV vary between different agro-ecological zones, farmers in the respective districts may practice different CCAS. The choice to adaptation is also influenced by biophysical, socio-economic and socio-cultural context of the areas (Yila and Resurreccion, 2013; Alemayehu and Bewket, 2017; Belay *et al.*,

2017; Kgosikoma *et al.*, 2018). Sample size determination was done using (Yemane, 1967) formula:

$$n = N/(1 + Ne^2)$$

where  $n$  = total sample size,  $N$  = total number of households (HHs) in the study sites and  $e$  = 5% precision level. Thus, a total of 416 respondents selected randomly considering 10% non-response rate were involved from the seven districts in the two regions. Proportional sampling approach was used based on the number of households in the study sites (Table S1).

### 2.3 Data sources and data collection methods

Both primary and secondary data sources were used in the present study. The primary data was collected through administration of structured questionnaire. A quantitative data collection approach was used to collect the required data through face-to-face administration of structured questionnaire with the household heads. A questionnaire data about the perception of farmers on CC and/or CV, the perceived impacts on the livelihood of smallholder farmers, community-based adaptation strategies and major determinant factors were assessed. Participation to the survey was on voluntary basis, and the purpose of the study was explained to participants before administration of the questionnaire. The questionnaire was divided into three sections: Part I: household demographic and socio-economic characteristics; Part II: farmers' perception of CC and its impacts in their livelihood; Part III: adaptation strategies exercised by farmers and their determinants (File S1).

Enumerators were trained for one day to familiarize them with the issues of CC, farmer level adaptation to CC, the significance of research on CCA and the basic concepts in sampling, interviewing and processing data (Tessema *et al.*, 2013). A pre-testing was conducted on five randomly selected households from non-sampled PAs in each district to validate the prepared questionnaire.

In addition, temperature and rainfall data of the study districts were collected from the monthly/annually meteorological weather-related data recorded by the National Meteorological Agency of Ethiopia. Depending on the availability and launching of stations, a trend analysis of temperature and rainfall data from 2000 to 2017/18 was performed. This was used as a secondary data to validate the responses of farmers. Considering the maximum flexible thresholds of 10% for missing values adopted by Ngongondo *et al.* (2011), the data for meteorological stations were used for trend analysis once missing values were filled by averaging neighboring records.

### 2.4 Description of the explanatory variables

As the present study used a two-stage analysis, two dependent variables were considered. In the first and second stages "perception of farmers on CC and/or CV" and "choices of CCA," respectively, were the dependent variables. The explanatory variables were selected considering the characteristics of the surveyed respondents and previous research works, and their hypothesized effects on the dependent variables (Table S2).

### 2.5 Methods of data analysis

**2.5.1 Descriptive data analysis.** In this study, demographic and socio-economic data were summarized and presented using descriptive statistics such as frequency, percentage, graphs, figures and tables. In addition,  $t$  test and Chi-square tests were used to compare the

difference among groups for different socio-economic and demographic variables. For this analysis, both Microsoft Excel and STATA version 12 were used (StataCorp, 2011).

The livestock numbers owned by the smallholder farmers were converted into tropical livestock units (TLU) for better comparison and the following conversion factors were used: cattle = 0.7, sheep = 0.1, goats = 0.1, camel = 0.75, chicken = 0.01 (Chilonda and Otte, 2006). The household income was also converted to USD using the existing currency exchange rate.

*2.5.2 Econometric data analysis.* Adaptation to CC is a two-stage process involving perception and adaptation stages. In the first stage whether the respondents perceive that there is CC or not was assessed, and the second stage assessed the respondents' choice of CCASs. To choose to adapt to climate change, households must first acknowledge that the climate is changing and perceive that this change poses a risk to their well-being that warrants a response, whether it be proactive or reactive (Bryan *et al.*, 2013). As the second stage of adaptation is a sub-sample of the first stage, it is likely that the second stage subsample is non-random and different from those who did not perceive CC creating sample selection bias. This study, therefore, used a combination of the binary logistic regression and multinomial logistic regression models.

The binary logistic regression model was used to examine the characteristics that best explain variation in the measures of attitudes of the indigent perception of households to CC and/or CV. This model is an appropriate model where the dependent variable is dummy (whether the respondent is aware or not, specified as Yes = 1, 0 = otherwise) (Alemayehu and Bewket, 2017). This regression analysis is useful for predicting discrete outcome of dichotomous dependent variable from independent variables that may be continuous, discrete and/or dichotomous (Tefahunegn *et al.*, 2016; Gedefaw *et al.*, 2018). First, a univariable logistic regression analysis was performed and those variables that showed significant difference at  $p = 0.01$ ,  $p = 0.05$  and  $p = 0.1$  levels were considered for the multivariable logistic regression analysis.

The analytical approaches that are commonly used in an adoption decision study involving multiple choices are the multinomial logit (MNL) and multinomial probit (MNP) models. Both the MNL and MNP are important for analyzing farmer adaptation decisions as these are usually made jointly. These approaches are also appropriate for evaluating alternative combinations of adaptation strategies, including individual strategies (Ajao *et al.*, 2011; Belay *et al.*, 2017). This study used a MNL model to analyze the determinants of farmers' choices of CCA because it is widely used in adoption decision studies involving multiple choices and is easier to compute than its alternative, the MNP (Ajao *et al.*, 2011; Belay *et al.*, 2017).

The advantage of using MNL model is its computational simplicity in calculating the choice probabilities that are expressible in analytical form (Ajao *et al.*, 2011). This model permits the analysis of multiple responses over a chosen base category (in this case, no adaptation measure as base outcome). This model also provides a convenient closed form for underlying choice probabilities, with no need of multivariate integration, making it simple to compute choice situations characterized by many alternatives. In addition, the computational burden of the MNL specification is made easier by its likelihood function, which is globally concave (Ajao *et al.*, 2011). Though, MNL has several advantages, it has also limitations where it restricts the farmers' choice of adaptation to only a single option (most preferred option). In situations where households report choosing several adaptation options simultaneously, it is important to group similar responses before performing a MNL model (Bryan *et al.*, 2013). Moreover, unbiased and consistent parameter estimates using this model need to assume independence of irrelevant alternatives that requires the probability

of using a certain adaptation method by a given household is independent from the probability of choosing another adaptation method (Belay *et al.*, 2017). To avoid such challenges, households were asked to prioritize their most preferred adaptation option and similar adaptation options were categorized into a collective group to reduce the choices of adaptation to be fitted to the model (Table S3). The model was specified as described previously (Greene, 2003; Ajao *et al.*, 2011; Belay *et al.*, 2017).

The parameter estimates of the MNL model only provide the direction of the effect of the independent variables on the dependent (response) variable; estimates represent neither the actual magnitude of change nor the probabilities (Belay *et al.*, 2017). This makes MNL coefficients difficult to interpret. Thus, to interpret the effects of explanatory variables on the probabilities, marginal effects are usually used as described previously (Greene, 2003; Ajao *et al.*, 2011).

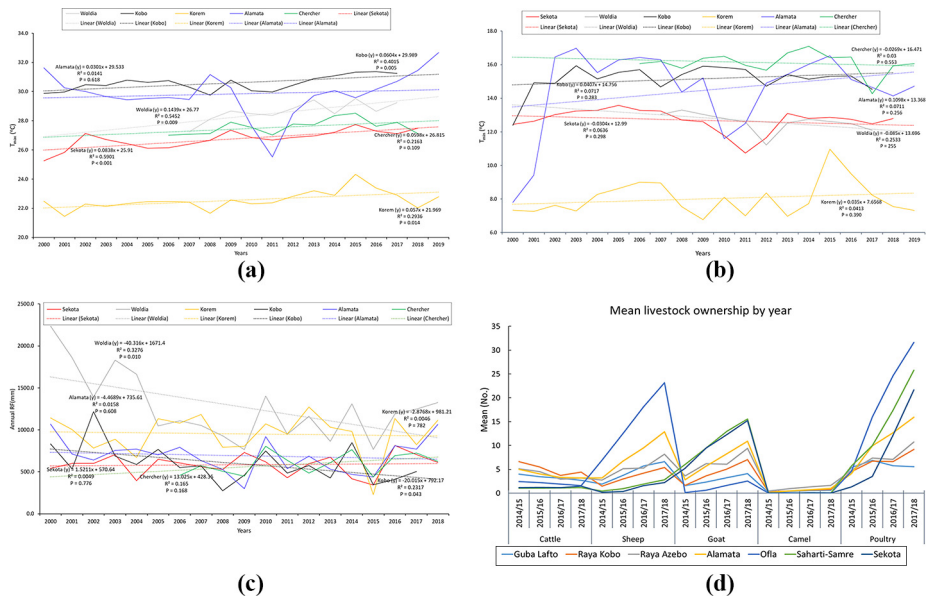
The marginal effects measure the expected change in probability of an adaptation choice being made with respect to a unit change in an explanatory/independent variable from the mean (Ajao *et al.*, 2011; Belay *et al.*, 2017). The signs of the marginal effects and respective coefficients may be different, as the former depend on the sign and magnitude of all other coefficients (Ajao *et al.*, 2011). In all the analysis a *p*-value at significance level of *p* = 0.01, *p* = 0.05 and *p* = 0.1 was maintained. The problem of multicollinearity among the explanatory variables was tested using variation inflation factor and contingency coefficient for continuous and dummy explanatory variables, respectively.

### 3. Results

#### 3.1 Temperature and rainfall trend analysis

The maximum temperature in all the study districts showed an increasing trend over the past 17–18 years where a maximum annual increase was observed in Woldiya station by 0.14°C (Figure 2a). The minimum temperature showed an increasing trend in Alamata,

**Figure 2.** Trend analysis of maximum (a) and minimum (b) temperature, annual rainfall (c) for the study districts (2000–2019) and five-year mean livestock ownership of smallholder farmers by species and district (d)



Kobo, and Korem/Ofla stations, where the maximum increase was recorded in Alamata station (0.11°C). On the other hand, a decreasing trend was observed in Woldiya, Chercher and Sekota stations, where the highest decrease was in Woldiya (−0.09°C) (Figure 2b).

Except Alamata station, the change in  $T_{\max}$  was statistically significant ( $p < 0.05$ ) (Figure 2a). However, the change in  $T_{\min}$  was not significant in all stations ( $p > 0.05$ ) (Figure 2b). The coefficient of variation (CoV) for  $T_{\max}$  ranged between 1.66% (Kobo) and 5.02% (Alamata), which shows that the variability in maximum temperature was minimum. However, the variability for minimum temperature in Alamata and Korem was very significant where the CoV for the two stations was 16.78% and 12.72%, respectively. The  $T_{\min}$  in Sekota (CoV = 5.34) and Kobo (CoV = 5.36%) was slightly variable. The rainfall trend showed variability between stations and within stations across the years where the CoV was more than 20%. Maximum variability was observed in Kobo (CoV = 36.88%) and Woldiya (CoV = 31.25%). A decreasing trend was observed in Woldiya, Kobo, Alamata and Korem stations while an increasing trend was seen in Chercher and Sekota stations. The decrease in Woldiya and Kobo stations was statistically significant ( $p < 0.05$ ). In all the stations, annual rainfall was low in 2015, which was a drought year in the country (Figure 2c).

### 3.2 Socio-economic characteristics of respondents and descriptive statistics

The main source of livelihood in the study areas was crop-livestock production (68.3%) and a significant proportion of farmers (42.8%) have non-farm income source either in addition to their farm income or as sole source of income. The mean annual HH income was US \$1,158.24 where the minimum and maximum income were US\$223.74 and US\$4,250.98, respectively. The highest mean annual income was in Raya-Alamata (US\$1,363.09) and the lowest was in Sekota (US\$898.83). The annual non-farm income of respondents ranged from US\$178.99 to US\$1,252.92 with the mean of US\$628.21. The average age of respondents was 44.6 years. The lowest mean death of animals was reported in camels (0.03) followed by goat (0.72). Total livestock unit ranged between 0.1 and 14.7 where the mean TLU was 3.71 (Table S4).

The highest and lowest mean TLU were recorded in Raya Kobo (4.66) and Sekota (2.12), respectively. In general, the average livestock ownership for cattle reduced over the years for all the study districts except Saharti-Samre and Sekota. On the other side, the population of sheep, goat, camel and poultry showed a relative increase over the years (Figure 2d).

### 3.3 Smallholder farmers' perceptions of climate change

In the present study, 81.7% of the respondents perceived CC and/or CV. In a univariable binary logistic regression, explanatory variables such as district, sex of household head, major source of livelihood, non-farm income, land ownership, landholding size, frequency of contact with extension and/or veterinarians, HH income, TLU, age and HH size showed statistically significant variation in the perception of farmers on CC and/or CV ( $p < 0.05$ ). However, in the reduced multivariable logistic regression analysis only variables such as household size, HH income and frequency of contact with extension agents and/or veterinarians showed statistically significant variation regarding the perception of farmers. Frequent contact with extension agents and/or veterinarians increases the awareness of farmers on CC by 4.7 times. Though HH income showed a statistically significant variation in the perception of farmers, the likelihood difference for each unit increase in HH income was very small. For every unit increase in HH size, the awareness of farmers increased by 68% (Table S5). The mean predicted probability of the model was 0.194, and percent correctly predicted by the model was 91.1%.



3.4 Livestock related impacts of climate change

Of the farmers, who were aware of CC and/or CV, 87.6% of them indicated the direct impacts of CC and/or CV on livestock production and productivity. The impact of CC and/or CV on milk reduction and weight loss were ranked top by 98.7 and 80.9% of the farmers, respectively, as very high and high (Figure 3). In addition, 91.4%, 90.8% and 86.9% of the farmers, respectively, indicated high temperature, irregularity and shortage in rainfall pattern and animal feed shortage as major indicators for the impacts of CC and/or CV. Moreover, frequent animal disease outbreak was also indicated by 78.2% of the respondents as the major impact of CC and/or CV. According to the respondents, the species of animals highly affected because of CC and/or CV were cattle (59.1%) followed by sheep (28.5%). The least species affected were camel (0 %) and goats (3.36%).

3.5 Livestock-based climate change adaptation strategies

Out of the 340 respondents who were aware of CC and/or CV, 86.2% (293/340) of them implement CCASs. Livestock health care and management (25%), followed by livelihood diversification (21.5%), and shifting and diversification of livestock species (20.9%) were indicated as the most frequently exercised livestock-based CCASs by smallholder mixed crop-livestock farmers in the study areas (Table S6).

3.6 Determinants of farmers' choices of adaptation strategies to climate change

Of the demographic, socio-economic and institutional variables tested, education status and knowledge on CCASs were found to have influence on the choice of farmers' decision to take all livestock-based adaptation options studied. Access to veterinary service and extension was found to be a determinant factor on farmers' decision to implement animal destocking, shifting and diversification of livestock spp., animal feed development related strategies and animal health care and management. In addition, to education status and knowledge of

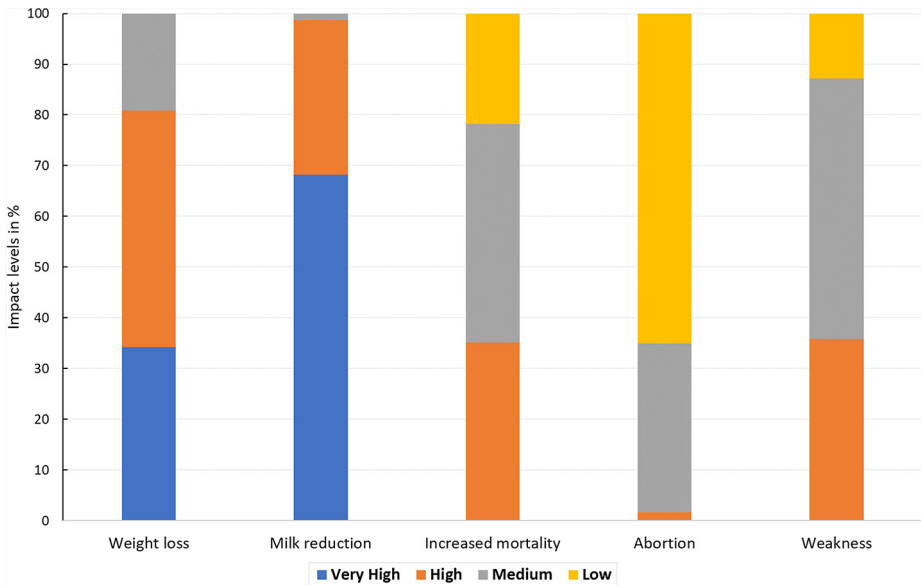


Figure 3. Direct impacts of climate change on livestock production and productivity

farmer on CCASs, livelihood diversification strategy was influenced by the household annual income and presence of non-farming income. Unlike other strategies, animal destocking was influenced by access to market (Table 1).

The marginal effects of the logit model on determinant factors are described in Table 2. Considering the decision-maker's characteristics, farmers with better education levels were 7.5%, 4.9%, 2.8%, 2.1% and 1.7% more likely to take animal health care and management, livelihood diversification, animal destocking, shifting and diversification of livestock spp. and animal feed development strategies, respectively, compared to illiterate farmers. Female headed households are 7.3% more likely to take the livelihood diversification adaptation strategy compared to male headed households. Besides, the likelihood of taking livelihood diversification, animal health care and management, animal feed development, animal destocking and shifting and diversification of livestock spp. options increased by 16.4%, 15.7%, 5.6%, 3.0% and 2.3%, respectively, for farmers who are aware of the different CCASs.

The household level factors and household size had a positive effect on animal feed development related adaptation strategy where for every unit increase in household size the likelihood of taking this adaption measure has increased by 2%. Besides, for every unit increase in TLU of the household, the likelihood of taking shifting and diversification of livestock species, and animal feed development related strategies have increased by 4.8% and 3.3%, respectively. Household income has positive effect on farmers' decision to take animal health care and management and livelihood diversification strategies. Farmers who

Explanatory variables	Animal destocking	Shifting and diversification of livestock spp.	Animal feed development	Animal Health and Mgt	Livelihood diversification
Sex	1.191 (0.542)	-0.133 (0.937)	1.470 (0.447)	0.389 (0.818)	-0.661 (0.694)
Age	-0.182 (0.127)	-0.157 (0.180)	-0.183 (0.122)	-0.152 (0.192)	-0.139 (0.236)
Education	4.172** (0.033)	3.773** (0.050)	3.891** (0.045)	3.298* (0.086)	4.252** (0.032)
Household size	0.206 (0.642)	0.179 (0.673)	0.363 (0.402)	0.080 (0.850)	0.032 (0.940)
Household annual income	0.003 (0.367)	0.003 (0.313)	0.003 (0.313)	0.005 (0.147)	0.006* (0.094)
Non-farm income	-0.157 (0.933)	-1.069 (0.557)	-0.945 (0.607)	-1.560 (0.393)	3.525* (0.055)
Livestock size (TLU)	0.580 (0.306)	0.594 (0.274)	0.724 (0.190)	0.228 (0.674)	-0.439 (0.439)
Land ownership	15.286 (0.982)	0.952 (0.531)	1.099 (0.490)	0.223 (0.875)	-0.742 (0.621)
Market access	4.186** (0.020)	1.532 (0.353)	2.070 (0.216)	1.690 (0.305)	1.212 (0.469)
Access to vet service and extension	4.017** (0.015)	3.999** (0.010)	3.121** (0.046)	5.631*** (0.001)	1.925 (0.219)
Knowledge on CCA	10.211*** (0.001)	9.795*** (0.001)	9.135*** (0.002)	9.348*** (0.001)	11.654*** (0.000)
Constant	-24.271 (0.971)	-6.460 (0.221)	-8.280 (0.128)	-6.974 (0.185)	-6.819 (0.208)
Base category	No adaptation option				
No. of observations	340				
Prob > $\chi^2$	0.000				
Log likelihood	-326.896				
Pseudo R square	0.441				

Notes: \*\*\*, \*\* and \* significant at 1%, 5% and 10% probability level, respectively

**Table 1.** Parameter estimates of multinomial logit model for climate change adaptation decision

**Table 2.**  
Marginal effects of independent variables on livestock-based climate change adaptation strategies

Explanatory variables	Animal destocking	Shifting and diversification of livestock spp.	Animal feed development	Animal Health and Mgt	Livelihood diversification
Sex	0.050 (0.444)	-0.097 (0.149)	0.104 (0.242)	0.017 (0.814)	-0.073* (0.088)
Age	-0.001 (0.426)	0.001 (0.964)	-0.002 (0.284)	0.001 (0.758)	0.001 (0.623)
Education	0.028* (0.033)	0.021* (0.066)	0.017** (0.048)	0.075 (0.165)	0.049** (0.020)
Household size	0.002 (0.846)	0.005 (0.729)	0.020* (0.059)	-0.016 (0.273)	-0.009 (0.347)
Household annual income	-0.000 (0.158)	-0.0001* (0.070)	-0.0001 (0.308)	0.002** (0.030)	0.0001** (0.033)
Non-farm income	0.024 (0.326)	-0.092 (0.021)	-0.039 (0.208)	-0.192 (0.000)	0.300*** (0.000)
Livestock size (TLU)	0.012 (0.259)	0.048** (0.015)	0.033** (0.027)	-0.031* (0.106)	-0.059*** (0.000)
Land ownership	0.884 (0.982)	-0.182 (0.988)	-0.171 (0.987)	-0.316 (0.978)	-0.209 (0.969)
Market access	0.151*** (0.002)	-0.066 (0.201)	0.005 (0.908)	-0.026 (0.608)	-0.047 (0.160)
Access to vet service and extension	0.140*** (0.009)	0.036** (0.063)	0.093** (0.021)	0.315*** (0.003)	-0.150*** (0.000)
Knowledge on CCA	0.030*** (0.064)	0.023 (0.038)	0.056** (0.011)	0.157 (0.059)	0.164* (0.053)

**Notes:** \*\*\*, \*\* and \* significant at 1%, 5% and 10% probability level, respectively

have non-farm income sources are 30% more likely to implement livelihood diversification strategy. The likelihood of taking animal health care and management and shifting and diversification of livestock species strategies had reduced by 19.2% and 9.2%, respectively, for farmers who have non-farm income.

Access to veterinary services and market are statistically significant determinants where farmers who have better access to veterinary service facilities such as clinics and extension service are 31.5%, 14.0%, 9.3% and 3.6% more likely to take animal health care and management, animal destocking, animal feed development and shifting and diversification of livestock spp. strategies, respectively. However, access to veterinary service and extension has a negative effect on farmers' choice of taking livelihood diversification strategy, where there was a 15% reduction. The likelihood of implementing animal destocking adaptation measure has increased by 15.1% for farmers who have a better access to market.

#### 4. Discussion

##### 4.1 Smallholder and livestock farmers' perceptions of climate change

To understand the responsiveness of farmers in taking CCASs, it is important first to understand their level of perception about CC and/or CV. In the present study, 81.7% of the respondents perceived that there is CC and/or CV, which shows a relatively good level of awareness. The increased trend in temperature, and variation/decreased pattern in rainfall in the study areas can also justify the change. In line with this, several studies conducted in the country showed that the awareness of smallholder farmers and agro-pastoralists is higher than 80% (Legesse *et al.*, 2013; Misganaw *et al.*, 2014; Feleke *et al.*, 2016; Belay *et al.*, 2017; Ayal *et al.*, 2018; Gedefaw *et al.*, 2018). This shows that the perception of farmers on CC and/or CV is increasing over time. Smallholder farmers who have frequent contact with extension agents and/or veterinarians have better source of information about the changing climate than their counter parts (Ajao *et al.*, 2011; Belay *et al.*, 2017). Similarly, for each unit of HH size increase, the perception of farmers increased by 68% which could be associated with diversified source of information from the household members.

Moreover, farmers with higher HH income have better perception on CC and/or CV (Ajao *et al.*, 2011; Gedefaw *et al.*, 2018).

#### 4.2 Perceived impacts of climate change on livestock production

In the study areas, in addition to perceiving CC and/or CV, smallholder mixed crop-livestock farmers also perceived its impacts related to livestock production. The direct effects of CC on livestock are associated with higher temperature and changing rainfall patterns which could translate into increased spread of animal diseases, increased mortality and reduced productivity. Whereas the indirect effects of CC are associated with changes in feed resources (Ifejika, 2010; Ajao *et al.*, 2011; Kima *et al.*, 2015; Ayal *et al.*, 2018). This has also been evidenced in the present study where weight loss, milk reduction, increased mortality and weakness could be affected by the increase in temperature, and the feed shortage could be associated with the decrease and variation in rainfall. The increased incidence of animal disease outbreaks could be the result of increased temperature and decrease/variation in rainfall pattern which creates suitable condition for the vector/pathogen and increases the susceptibility of animals (Rojas-Downing *et al.*, 2017). This has also been justified from the data obtained from the national meteorological agency of Ethiopia. The increased weight loss and weakness of animals reported by the smallholder farmers could also be associated with tick infestations that are predominant in the study areas (Hadgu *et al.*, 2018). The higher mean mortality in sheep and cattle could be because of the grazing nature of these animals which could facilitate transmission of soilborne diseases and shortage of grazing land (Thornton *et al.*, 2009).

#### 4.3 Livestock-based climate change adaptation strategies

Majority of the CCASs exercised by smallholder farmers and agro-pastoralists reported in previous studies in Ethiopia were crop related with few livestock-based adaptation strategies (Legesse *et al.*, 2013; Misganaw *et al.*, 2014; Alemayehu and Bewket, 2017; Belay *et al.*, 2017; Gedefaw *et al.*, 2018). However, the present study focused specifically on livestock-based adaptation strategies. The animal health care and management strategy was the majorly practiced adaptation measure. Previous studies (Ifejika, 2010; Kgosikoma *et al.*, 2018) also identified this adaptation measure as being commonly practiced by smallholder and agro-pastoral farmers.

Livelihood diversification was the second most commonly practiced CCAS in the study areas where farmers are trying to increase their income sources either by getting involved in non-farming activities such as labor work, firewood selling, petty trade or shifting to commercial farming (Thornton *et al.*, 2009; Zampaligré *et al.*, 2014; Kima *et al.*, 2015; Mengistu and Haji, 2015). As crop and livestock farming are becoming highly sensitive to impacts of climate change, farmers are trying to diversify their livelihood options. Shifting from cattle to small ruminant and/or camel production (Serkalem *et al.*, 2014; Zampaligré *et al.*, 2014) and diversification of livestock species composition (Legesse *et al.*, 2013; Serkalem *et al.*, 2014; Mengistu and Haji, 2015) are the other common livestock-based CCASs exercised by smallholder and agro-pastoral farmers. As the recurrent drought is causing depletion of pasture and water resources, owing to the high feed demanding nature of cattle and fast turn-over in small ruminant production, farmers are shifting to small ruminant and/or camel production. Furthermore, farmers consider diversification of their livestock species as a risk aversion mechanism (Serkalem *et al.*, 2014). Moreover, the declining trend in cattle ownership through time and increasing small ruminant ownership is a good justification for shifting from cattle to small ruminant production as an adaptation measure.

Natural resource conservation and improvement (Legesse *et al.*, 2013; Alemayehu and Bewket, 2017; Belay *et al.*, 2017; Gedefaw *et al.*, 2018), developing and conserving livestock

forage (Kima *et al.*, 2015; Feleke *et al.*, 2016), herd mobility in search of animal feed and water (Thornton *et al.*, 2009; Kima *et al.*, 2015; Syomiti *et al.*, 2015) and growing cactus for own and animal feed consumption were considered as animal feed development related adaptation strategies. Though farmers do not practice programmed destocking of animals, selling animals at the time of drought (Legesse *et al.*, 2013; Misganaw *et al.*, 2014; Kima *et al.*, 2015; Mengistu and Haji, 2015; Alemayehu and Bewket, 2017; Gedefaw *et al.*, 2018) was among CCASs exercised by farmers.

#### *4.4 Determinants to climate change adaptation by smallholder farmers*

Farmer's level of education has showed a positive and significant effect on the likelihood of implementing livestock-based adaptation measures. This is associated with the fact that literate farmers consider the potential benefits of implementing CCA measures (Serkalem *et al.*, 2014; Zampaligré *et al.*, 2014; Mengistu and Haji, 2015; Belay *et al.*, 2017). Besides, education is expected to enhance the household's ability to receive, decipher and comprehend information relevant to implement appropriate CCASs (Serkalem *et al.*, 2014). Farmers who are knowledgeable about CCASs are more likely to take adaptation measures than their counter parts (Yila and Resurreccion, 2013; Serkalem *et al.*, 2014; Alemayehu and Bewket, 2017; Belay *et al.*, 2017; Gedefaw *et al.*, 2018; Kgosikoma *et al.*, 2018).

The existing veterinary clinics and extension packages in a form of loan and distribution of livestock (chicken, dairy cows and goats/sheep) could have motivated farmers to take CCASs except livelihood diversification. Proper animal health care and management is also considered as both adaptation and mitigation strategy to CC; however, access to veterinary clinics and extension is a major factor to take this measure. It is strongly believed that improved extension services that provide technical support on agriculture and livestock production will significantly reduce vulnerability to climate risk (Ajao *et al.*, 2011; Yila and Resurreccion, 2013; Serkalem *et al.*, 2014; Alemayehu and Bewket, 2017). Access to livestock market increases the likelihood of taking animal destocking as an adaptation measure because farmers can sell their animals before the onset of drought periods and buy animals during the time of pasture availability.

When household income increases the financial resource of farmers and their capacity to take care of their animals also increases. In addition, farmers whose annual income is higher are more likely to diversify their livelihood by getting involved in commercial farming, small-scale business or other livelihood means (Belay *et al.*, 2017). Farmers who have additional source of income are more likely to implement the livelihood diversification strategy. The opportunity of having non-farm income sources strengthens the financial stability of the household, thereby enabling them to take this adaptation measure (Ifejika, 2010; Serkalem *et al.*, 2014). However, the presence of non-farm income sources has negatively influenced shifting and diversification of livestock species and animal health care and management strategies. This could be because of the fact that majority of the farmers who have non-farm income either have small plot of land or a smaller number of livestock.

As the total livestock unit increases, farmers are more likely to shift from cattle to small ruminant production, diversify their livestock species and implement animal feed development related strategies. This is because livestock diversification and developing and conserving forage is the foremost concern of household with larger livestock numbers (Mengistu and Haji, 2015). On the other hand, the increase in livestock number discourages farmers to take proper health care and management as the cost of treatment increases with the increase in TLU, which was in contrary with the findings of Mengistu and Haji (2015). Farmers who have higher TLU are less likely to get involved in other livelihood diversification measures as they are more engaged in livestock husbandry and management practices.

In line with [Serkalem et al. \(2014\)](#), sex of household is found to have influence on the choice of CCAS. Female headed households are more likely to implement livelihood diversification strategies such as petty trade, which could be because of the less labor-intensive nature of the work compared to livestock-based management strategies. Household size had a positive and significant effect on animal feed development related adaptation strategy, which could be associated with the large household members who can contribute for feed development and management. It has been indicated that larger family size and productive household members increase agricultural production as it is labor-intensive practice ([Belay et al., 2017](#)).

## 5. Conclusion

Though livestock-based climate change adaptation measures are instrumental to build the resilience of mixed crop-livestock farmers to climate change, their implementation has been influenced by inadequate information and resources in the study regions. Hence, this research has contributed to fill the scientific knowledge gap on the livestock-based climate change adaptation strategies and determinants to farmers' adaptation choices. Animal destocking is a preferred adaptation strategy in areas where there is a better access to market. Planting permanent and indigenous fodder trees that vegetate during the dry season, when most trees shed their leaves, could be considered as an option for mitigation of feed shortage. Awareness creation trainings, provision of appropriate herd management and marketing strategies, institutional, political and economic support systems should be taken into account to ensure the sustainability of climate change adaptation by local communities and enhance their adaptive capacity. The evidence generated in this research supports federal and local governments in designing context-specific policy frameworks to enhance the adaptive capacity of mixed crop-livestock farming communities and similarly guide other stakeholders working to improve the livelihoods of crop-livestock farmers.

## 6. Limitation of the study

Though the present study had tried to address major research challenges in building the adaptive capacity of mixed crop-livestock farmers in Tigray and Amhara regions of Ethiopia, it is limited in scope and time. The impacts of climate change on livestock production systems were assessed in the present study using farmers' response. Therefore, impact of the adaptation options on livestock productivity, livelihoods of agro-pastoral and smallholder mixed crop-livestock farmers and climate change should be considered for future research using appropriate models.

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### Supplementary materials

Supplementary files are to be made available online for this article.

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