

Smallholder farmers' perception of climate change and adaptation strategy choices in Central Ethiopia

Yonnas Addis and Solomon Abirdew
Wolkite University, Welkite, Ethiopia

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climate change

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Abstract

Purpose – Smallholder farmers have always been profoundly the first to be impacted by climate change, and therefore, farmers understanding of climate change and accessibility to alternative adaptation strategies are crucial for reducing the effect of climate change. The purpose of this study is to assess the perception of farmers to climate change, adaptation strategies and determinants of adaptation choice in central Ethiopia.

Design/methodology/approach – The study used data from randomly selected 240 farm households. Descriptive statistics were used to describe farmers' perceptions of climate change and adaptation strategies. Also, a multivariate probit model was used to identify the major factors affecting farmers' choice of adaptation strategies to climate change in central Ethiopia.

Findings – Smallholder farmers perceive climate change in the past two decades in response; the majority (91.47%) of farmers used adaptation options. Improved crop varieties and input intensity, crop diversification, planting date adjustment, soil and water conservation activities and changing of the crop type were used as adaptation options in the study area. A few of these strategies were significantly confirmed a complementary and supplementary relationship. The study identified sex, family size, agroecology, climate information, crop-fail history and formal extension service as significant determinants for farmers' adaptation choices as these variables significantly affected more than two farmers' adaptation strategies simultaneously.

Research limitations/implications – Farmers' choice of adaptation was highly constrained by institutional factors and all these identified factors can be possibly addressed through a better institutional service provision system. It is, therefore, recommended that local administrators should explore the institutional service provision system for a better farm-level adaptation while considering demographic characteristics as well.

Originality/value – This study identified factors affecting farmers' several adaptation strategies at a time and provides information for the policymaker to make cost-effective interventions for better farm-level adaptation practices.

Keywords Climate change, Multivariate probit model, Climate Adaptation, Farmers' 2019 perception

Paper type Research paper

Abbreviations

ADS = Adaptation strategies;
GZoLR = Gurage Zone office of Agriculture Livelihood Report;

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HHs = households;
HHHs = household heads;
NAP-ETH = National Adaptation Plan of Ethiopia; and
SARI = South Ethiopia Agricultural and Research Institute.

Background

Climate change affects the economic growth of developing countries due to its multiple interdependent effects on different sectors including, agriculture, health, forestry, fisheries and tourism (Kahsay *et al.*, 2019; Lawson *et al.*, 2019; Gedefaw *et al.*, 2018; Weldegerima *et al.*, 2018; Kompas *et al.*, 2018; Kebede and Gizachew, 2017). Currently, the unfolding change in climate with its effect on temperature and rainfall affects all aspects of the food system including, food production and availability, access, quality, utilization and stability of food systems (Collins *et al.*, 2013; Bryan *et al.*, 2013); and it is also true in Ethiopia (NAP-ETH [Ethiopia's National Adaptation Plan], 2019). Developing countries with high levels of hunger are highly vulnerable to climate change impacts and have a low capacity to adapt. Specifically, smallholder farmers are in danger due to the multiple effects of climate change as they are susceptible because of their socioeconomic situation (De Souza *et al.*, 2015).

Improvement of smallholder understanding of climate change, the availability of alternative adaptation strategies and look for determinants of farmers adaptation capacity are among the strategic means of reducing climate change effects and also ensuring food security issues in most developing countries (Berhanu and Beyene, 2015; Wondim *et al.*, 2018). However, farmers' decision to use adaptation strategies, adaptation level and choice among the available adaptation options have been affected by demographic characteristics, agro-ecological setting, socioeconomic factors and other institutional constraints (Paulos and Belay, 2018). In this regard, numerous national and international research institutions and other stakeholders have been engaged in providing alternative adaptation strategies to enhance farm adaptation capacity. For instance, the Ethiopian government made numerous investments to enhance the generation and dissemination of new agricultural technologies (NAP-ETH [Ethiopia's National Adaptation Plan], 2019).

Also, location-specific information about each adaptation strategy is required for different stakeholders to make positive interventions in the adaptation process (Kahsay *et al.*, 2019; Yamba *et al.*, 2019). Different studies have been conducted to provide information on farmers' perception toward climate change, adaptation level and factors affecting the adaptation level of smallholder farmers by using Probit, Logit, Tobit and Heckman econometric models to enhance their adaptation level in a different region of Ethiopia (Gedefaw *et al.*, 2018; Paulos and Belay, 2018; Birhane *et al.*, 2020; Debela *et al.*, 2015; Habtemariam *et al.*, 2016; Abrha *et al.*, 2017; Addisu *et al.*, 2016; Belyneh *et al.*, 2013). However, the majority of the literature in the field of climate change in Ethiopia including literature reviewed for this study are largely documented based on information from smallholders farmers adaptation habits in the Northern and Northwestern part of Ethiopia and only a few from the Eastern part of Oromia region. Smallholder farmer's perception of climate change existed adaptation strategies used by farmers, factors affecting adaptation level of farmers and their choice among the available alternative adaptation strategies are not still investigated in a different part of Ethiopia, including Central province. Thus, this study aimed to narrow the existed information gap of literature by providing information about smallholder farmer's adaptation status and adaptation strategies choices in Central Ethiopia. Also, this study provides information about the possible supplementary and complementarily association among adaptation strategies by using the multivariate probit (MVP) model, which is still scantily documented in the literature.

The Central part of Ethiopia is among the potential area suitable for crop production and smallholder farmers are vulnerable to frequent climate change challenges (Befikadu *et al.*, 2019; Eshetu *et al.*, 2016). As a result, enhancing the adaptation capability of smallholder farmers in the region is the primary means of increasing income, livelihood situation and reducing food insecurity problems for millions of smallholders farmers in a changing climate. The present study was, therefore, planned to elucidate farmers' perception toward climate change, factors determining the choice of adaptation options and their best combinations of adaptation options in Central Ethiopia. The information so generated will be useful in optimizing the future adaptation strategies in the study area.

Methodology

Description of the study area

This study was conducted in Gurage Zone; Central Ethiopia situated 188 km south of Addis Ababa and 214 km in the southwest part of the regional capital city of South Nation Nationalities and Peoples Region of Ethiopia (Hawassa). Its geographical location is between 7° 44' 46" and 8° 28' 29" N latitude and 37° 27' 30" and 38° 42' 42" E longitudes (Figure 1). Gurage administrative zone has 15 districts with a land size of 593,200 hectares, of which about 52% of the land has been cultivated, 13.04% are grazing, 9.9% are covered natural and plantation forest. The remaining 7.3% is unproductive (GZoLR [Gurage Zone office of Agriculture Livelihood Report], 2019).

The agro-ecological category of the Gurage zone has split into lowland (3%), midland (62%) and the highland agro-ecology zone (35%). Rain-fed agriculture is the main economic activity in all agro-ecological categories of the zone. Crop and livestock mixed farming systems are practiced in the majority of areas of the zone. Stimulant cash crops such as

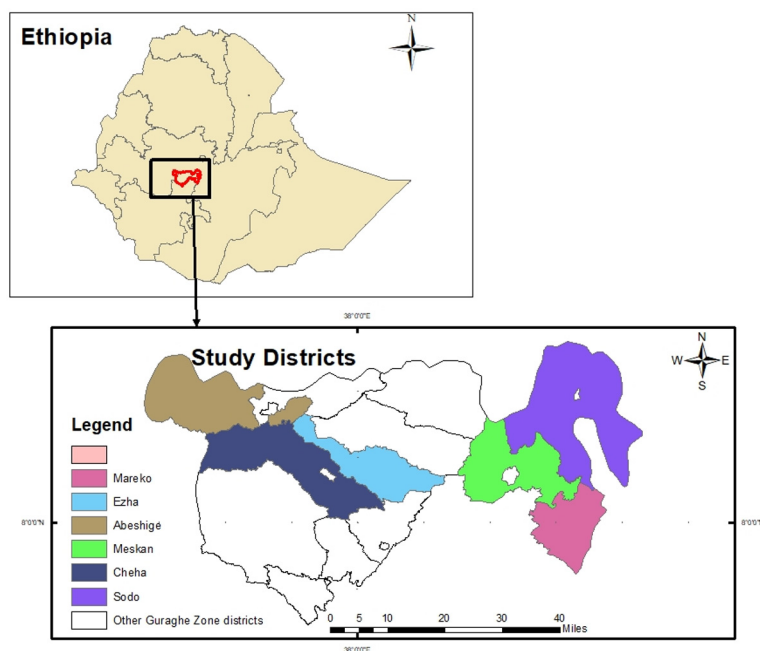


Figure 1.
Location map of the study area

coffee and khat are cultivated in the zone in addition to cereal (*tef*, wheat, maize and barley), horticultural (*inset*, Irish potato and cabbage) and pulses (faba bean and field pea) (SARI [South Ethiopia Agricultural and Research institute], 2017).

Source of data and methods of collection

The study data were collected from both primary and secondary sources. Primary data were collected from 340 farm households through the cross-sectional households survey method. The primary data consisted of demographic, basic socioeconomic characteristics, institutional factors and perceived change in climate situations and adaptation practices in the past two decades. The related kinds of literature in the field of climate change and researchers' experience in the study site were used as an input to prepare questionnaires. The study also used secondary data from journals, bulletin and governmental offices to supplement data from primary sources.

Sampling procedure and sample size

Gurage zone was selected purposively because this region is the most vulnerable to climate variability and change among others in Central Ethiopia (Zelalem and Belay, 2019). The survey populations for this study were smallholder farm households who own or cultivate less than 2 ha of land and heads of households were the units of analysis. In this study, Yamane (1967) was applied to estimate the required sample size from the study population. Accordingly, a sample size of 340 household heads was used for the study.

$$n = \frac{N}{1 + N(e)^2} = \frac{2274}{1 + 2274(0.05)^2} = 340 \quad (1)$$

where N is the population size and e is the level of precision. The sample for this study is calculated by assuming a 95% confidence level, the study used this formula for the population, in which $N = 2,274$ with $\pm 5\%$ precision.

In this study, for the selection of samples, multistage sampling procedures were used. In the first stage, 14 districts of the Gurage zone were stratified into 3 categories of agro-ecological zones such as lowland, midland and highland. In the second stage, six districts (two each from stratum), namely; Maraqa and Abeshgye from the lowland; Cheha and Mesqan from midland; and Sodo and Ezia from highland were randomly selected. In the third stage, from the selected districts, a total of 6 *kebeles*[1] (one each from the district) were randomly chosen in this study. Finally, on the basis of probability proportional to the size sampling method, 340 farm households were randomly drawn from the selected *Kebeles*.

Method of data analysis

Descriptive statistics such as frequency, mean, percentage and standard deviation were used to summarize the socio-economic, demographic and institutional characteristics of households. It was also used to examine and describe perceptions of climate change and adaptation strategies used by smallholder farm households in the study area. An MVP model was fitted to evaluate different factors affecting the choice of adaptation methods and possible interdependence among these chosen adaptations strategies used by smallholder farmers.

Analytical framework

Smallholder farmers' adaptation strategy choice is based on the theory of rational choice, which assumes that smallholder farmers are rational and can rank alternative adaptation strategies for utility maximization. This study used random utility maximization modeling to conceptualize smallholder farmers' adaptation strategy choice. This model is predominantly applicable for representing discrete choice decisions such as adaptation strategy choice based on the principle that the smallholder farmers chosen the strategies, which maximizes his/her utility (Ben-Akiva and Boccara, 1995).

On the basis of demographic, institutional factors, socio-economic characteristics and relevant issues, farm households will have an average utility level from each alternative adaptation strategies choices. In this case, smallholder farmers are expected to make a comparison on marginal profit and cost considering on the utility gained from using a combination of adaptation strategies. The utility from each adaptation strategies cannot be directly observed rather it can be indirectly obtained from the choice made by the farmer that revealed, which adaptation strategies provide the better utility subject to its determinants (Greene, 2012; Djalalou-Dine *et al.*, 2015; Tarekegn *et al.*, 2017). For this study case, smallholder farmers choose an alternative adaptation strategy if utility (U) of that alternative is greater than other alternatives, expressed as $U_{in} > U_{jn} \forall j \neq i$, where j are the different choices of adaptation strategies from the available choice set C_n and smallholder farmers is labeled n . Also, the researcher cannot distinguish the complete aspects of smallholder utility function, and thereby a representative utility function $V_{jn} = V(x_{jn}, S_n)$ is considered, with $x_{nj} \forall j$ the characteristic of the choice and S_n , some characteristic of smallholder farmers (Kamba *et al.*, 2015). Consequently, the utility is decomposed into deterministic (V_{ij}) and random (ε_{ij}) component:

$$U_{jn} = V_{jn} + \varepsilon_{jn} \quad (2)$$

where ε_{jn} indicates the factors that affect utility but are not observed by the researcher, and therefore, are not included in V_{jn} . The probability that a smallholder farmer chooses a certain alternative adaptation strategy is expressed as follows.

$$P(i|C_n) = \Pr(U_{in} \geq U_{jn}, \forall j \in C_n, \quad (3)$$

Empirical estimation of multivariate probit model

Farm households possibly use more than one adaptation strategy simultaneously to confront climate change consequences. The adaptation strategies used by farmers share the same background and scenario and there is a possible correlation among these adaptation strategies as they share the same background and scenario. This interaction has its own role in policymaking but for the possible correspondence among different adaptation strategies have clearly been investigated. An MVP model is a qualified discrete choice model to estimate the possible multi-entity interactions among choices in a real-world situation (Chen *et al.*, 2018). The model is efficient in investigating the effect of several independent variables on dependent variables simultaneously and allows the error terms to correlate.

Given a set of explanatory variables used in MVP, the multivariate response assumes to have arisen from a multivariate normal distribution and falls within a certain interval (Ademe *et al.*, 2019). Following Greene (2000), the MVP model assumes that the response variable has K distinct binary response. Let Y^* refers to unobserved latent variable; $\mathbf{i} = 1 \dots \mathbf{n}$ be the individual observation; $\mathbf{K} = 1 \dots \mathbf{K}$ is the available options of binary response and X_i is the list of

explanatory variables. Thus, $\mathbf{Y}_{ij} = (\mathbf{Y}_{i1}, \dots, \mathbf{Y}_{ik})$ represent the K dimensional vector of observed binary response taking value either 0 or 1 on the i^{th} households and $\mathbf{Y}^*_{ij} = (\mathbf{Y}^*_{i1}, \dots, \mathbf{Y}^*_{ik})$ represents a K variant normal vector of latent variables; $\beta = (\beta_1, \dots, \beta_k)$ represents a matrix of the regression coefficient, ε_i represents a vector of residual error distributed as a multivariate normal distribution with zero mean and variance of one; $\varepsilon_i \sim N(0, \Sigma)$ where Σ represents the variance-covariance matrix and also the relationship between $\mathbf{Y}^*_{ij} = \mathbf{Y}_{ij}$ is given as follows:

$$Y^*_{ik} = (X_i\beta + \varepsilon_i), \quad Y_{ik} = \begin{cases} 1 & \text{if } Y^*_{ik} > 0; \\ 0 & \text{otherwise} \end{cases} \quad i = 1, \dots, n \quad \text{and } k = 1, \dots, k \quad (4)$$

The likelihood of the households to adopt the given adaptation methods data is then obtained by integrating over the latent variables:

$$Y^* = P(Y_{ik} = 1 | X_i, \beta, \varepsilon) \int A_{k1} \varphi_k(z_{ik} = 1 | x_i, \beta, \Sigma) dY^*_{ik} \quad (5)$$

where A_{k1} is the interval $(0, \infty)$ if $\mathbf{Y}_{ik} = 1$ and the interval $(-\infty, 0)$ otherwise and $A_{k1} \Phi_k(\mathbf{Z}_{ik} = 1 | \mathbf{X}_i, \beta, \Sigma) d\mathbf{Y}^*_{ik}$ is the probability density function of the standard normal distribution.

Interpretation of MVP results is based on marginal effects rather than the parameter estimates. Thus, the marginal effects of independent variables on the propensity to adopt different adaptation options were calculated by the following equation (Charles *et al.*, 2014):

$$\frac{\partial P_i}{\partial x_i} = \phi(x^*\beta) \beta_i, \quad i = 1, 2, 3, \dots, n \quad (6)$$

Accordingly, this study identified five main different adaptation strategies (ADS) choices used by smallholder crop-producing farmers. Following the specification in equation (2) and the information indicated above, the MVP model deployed for this study is estimated as follows:

$$Y^*_{i1} = (x^*_i\beta + \varepsilon_i, \quad Y_{i1} = \begin{cases} 1 & \text{if } Y^*_{i1} > 0; \\ 0 & \text{otherwise} \end{cases}, \quad Y_{i1} \text{ refers crop diversification strategy} \quad (7)$$

$$Y^*_{i2} = (x^*_i\beta + \varepsilon_i, \quad Y_{i2} = \begin{cases} 1 & \text{if } Y^*_{i2} > 0; \\ 0 & \text{otherwise} \end{cases}, \quad Y_{i2} \text{ refers improved varieties and input use intensity} \quad (8)$$

$$Y^*_{i3} = (x^*_i\beta + \varepsilon_i, \quad Y_{i3} = \begin{cases} 1 & \text{if } Y^*_{i3} > 0; \\ 0 & \text{otherwise} \end{cases}, \quad Y_{i3} \text{ refers adjusting plant date strategy} \quad (9)$$

$$Y_{i4}^* = (x_i^* \beta + \varepsilon_i, Y_{i4} = \{1 \text{ if } Y_{i4}^* > 0; 0 \text{ otherwise}\},$$

Y_{i3} refers soil & water conservation practices

Farmers' perception of climate change (10)

$$Y_{i5}^* = (x_i^* \beta + \varepsilon_i, Y_{i5} = \{1 \text{ if } Y_{i5}^* > 0; 0 \text{ otherwise}\}, Y_{i3} \text{ refers change crop type strategy}$$

(11)

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Description of variables and sample statistics

The dependent variable, farmers' adaptation strategies to climate change, was a binary choice dependent variable and five adaptation strategies were identified [equations (3)–(7)]. Explanatory variables used for the study were chosen by considering previous works of literature related to the field of climate change and the experience of the researchers in the study area. Thus, the description of explanatory variables used in the analysis and measurements expressed in the table below:-

Results and discussion

Description of variables and sample statistic

Table 1 describes the socio-economic, demographic and institutional characteristics of sampled household heads of the study. Sample households were predominantly male-headed (65.59%) and about 51.47% of farmers belonged to an adult stage (varied between 35 and 55 years). The remaining 31.76% and 16.77% consisted of young (less than 35 years) and older (greater than 55 years), respectively. Sample household heads on average had 24.64 years of farming experience and about half (50.29%) of them were literate. On average, households owned 1.07 ha of land for crop production, and they received an income of about ETB15,119.55 per annum. The result revealed that about 62.65% were members of local farmers' cooperatives and about 44.71% had received extension services. Likewise, only about 32.35% had credit access from formal financial institutions.

Farmers' perceptions of climate change

Smallholder farmers were not directly examined on what they perceive toward climate change, rather they were asked about what they had observed the trend of the main climate indicators, particularly rainfall, temperature and drought for the past two decades. The result confirmed changes in raining time and rainfall problem had observed in the past two decades, such as about 49.41% perceive rainfall amount had decreased, about 4.71% perceive as it had increased, about 18.53% had not observed the trend and about 27.35% perceive rainfall as it had remained the same. Furthermore, they revealed an onset rainfall problem (51.18%), rained after the perceived time (42.06%), cessation rainfall problem (71.18%) and end up before the perceived time (61.18%) (**Figure 1**). For this reason, smallholder farmers have been challenged by unpredictable rainfall nature as crop farming largely depends on rainfall. Thus, pre-production, pre-harvest and post-harvest production activities depend on rainfall characteristics and, in turn, determines overall farm-level productivity.

In the past two decades, smallholder farmers of Central Ethiopia perceived and observed temperature variability and change, such as about 71.98% of the respondents perceive as the temperature had increased, about 4.42% as it had decreased, about 27.35% revealed as it had unchanged and about 18.53% of respondents not observed the change. Also, the study considered drought as an important climatic indicator variable and about 69.41% of the

Table 1.
Description variables
used in the analysis
and sample statistics

Variable	Description and measurement	Expected effect (dep. variable)	Mean/ proportion	SD
<i>Sex of HHH</i>	1 if is a household head male; 0 otherwise	±	0.656	
<i>Age of HHH (adult)</i>	0 ^a if young (<34); 1 if adult (b/n 35 and 55)	±	0.515	
<i>Age of HHH (older)</i>	0 ^a if young (<34); 1 if older (>55)	±	0.167	
<i>Family size of HHs</i>	Number of household members (man equivalent)	±	5.64	2.108
<i>Literacy status of HHH</i>	1 if a household head is literate; 0 otherwise	+	0.503	
<i>Land size</i>	Cultivated land in hectare (ha)	±	1.07	0.847
<i>Farming experience</i>	Years of engagement in farming (year)	+	24.64	12.824
<i>Extension service of HHs</i>	Whether or not a household received frequent extension service in 2018/2019 (1 = frequent use, 0 otherwise)	+	0.447	
<i>Credit accesses of HHs</i>	1 if a household has access to formal credit facilities; 0 otherwise	+	0.325	
<i>HHs income</i>	A total income per annual from both farm and nonfarm activities in ETB ^b	±	15,119.55	11,033.03
<i>HHs distance from research/university</i>	Households residence from nearest research institution/university in Km	–	37.40	22.373
<i>HHs distance from the market</i>	Households place of residence from input or output market in Km	–	6.02	3.448
<i>HHs social capital</i>	Whether or not a household received support from friends, relatives or in 2018/2019 (1 = received and 0 otherwise)	±	0.388	
<i>Cooperative membership</i>	Membership to farmers cooperatives (1 if a member of cooperatives, 0 otherwise)	+	0.626	
<i>Climate information</i>	1 if a household received early warning and readiness information; 0 otherwise	+	0.45	
<i>Mid land agro ecology</i>	1 if midland; 0 ^a if lowland	±	0.376	
<i>Highland agroecology</i>	1 if highland; 0 ^a if lowland			
<i>Crop damage history</i>	1 if the households faced crop failure problem; 0 otherwise	–	0.45	

Notes: ^aTaken as the base for analysis; ^bETB is Ethiopian currency (\$1 = 32.7ETB); HHH: household head; HHs: households

respondents confirmed the frequent occurrence of drought, but about 43.24% and 6.18% of the respondents perceived the frequency of drought occurrence as decreased and remained unchanged, respectively. The remaining 17.65% had no clear information about temperature change (Figure 2). The result indicated that the farming business in the study area is heavily influenced by the frequent occurrence of drought and increased temperature. In addition, flooding was another climatic indicator that smallholder crop-producing farmers perceived changes in the past two decades. However, about 7.94% of the respondents perceived the frequency of flood as increased, 43.24% decreased, 38.8% unchanged and the remaining 10% of the respondents had not observed the flooding pattern

in the past two decades. A change in climate could be a reason for the worse level of production, productivity and livelihood situations of the majority in the study area. This can possibly decrease the sectorial contribution of crop sub-sector nationally. The result is in line with the findings of [Zerihun *et al.* \(2018\)](#) in Ethiopia and [Asayehegn *et al.* \(2017\)](#) in central Kenya ([Figure 3](#)).

Farmers' adaptation strategies to climate change

[Table 3](#) presents the adaptation options that were used by smallholder farmers across different agro-ecologies of the study area. In response to climate variability and change, the majority (91.47%) of surveyed households have practiced adaptation strategies to reduce the effect of climate change. The main adaptation strategies used by smallholder farmers in the study area were crop-diversification (51.47%), improved crop varieties and input use intensity (62.65%), adjusting planting date (45.59%), soil and water conservation (49.12%) and changing of the crop type (50.59%).

Agro-ecologically, soil and water conservation activities were largely practiced by households in the midland agro-ecology as about 55.09% of the respondents used this as an adaptation measure. About 53.71%, 28.57% and 17.71% of the surveyed households in the

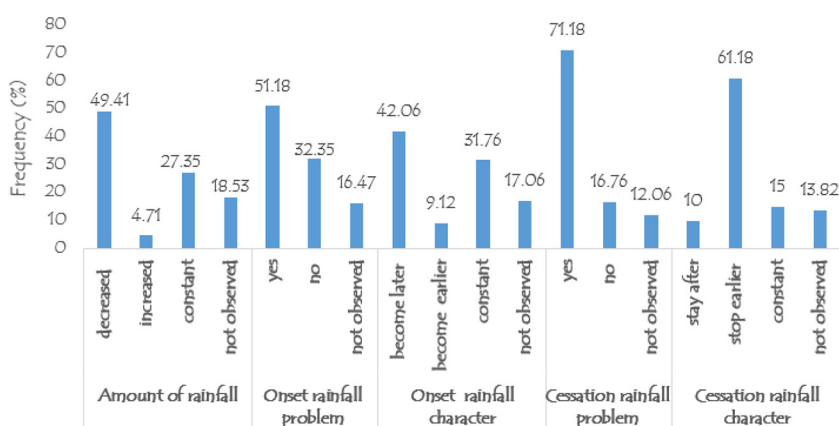


Figure 2. Smallholder farmers' perceptions about current rainfall variability and change in Central Ethiopia

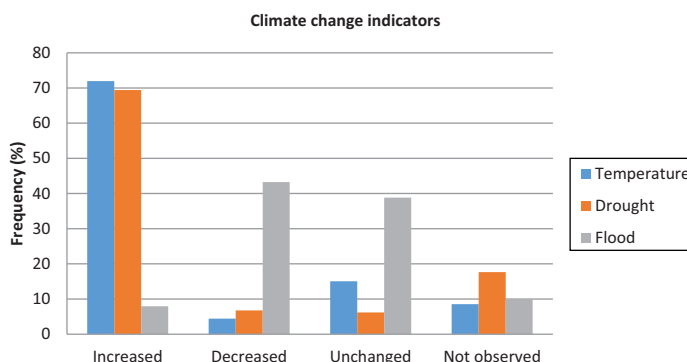


Figure 3. Farmers' perception of change in temperature, drought and flood in Central Ethiopia

midland, highland and lowland agro-ecology, respectively, adopted crop diversification strategy. Improved crop varieties and input use intensity are widely practiced by farm households in the midland and highland agro-ecology. Also, about 38.5% of households found both in midland and highland agro-ecology adopted improved crop varieties and input use intensity, compared to sample farm households in the lowland agro-ecology that was only about 23%.

Furthermore, about 40% and 35.48% of the farm households in the lowland and highland agro-ecology, respectively, used adjusting plant date adaptation strategy. Sample households exist in the midland agro-ecology widely used four from the identified five adaptation strategies, namely, the use of crop diversification, improved crop varieties and input intensity, soil and water conservation and changing the crop type. However, adjusting plant date adaptation strategy is not well-practiced in the midland agro-ecology. This could be due to the raining season in lowland agro-ecology is shorter than highland and midland agro-ecology and this might influence households' decision to practice the planting dates adjustment adaptation option. This result is in agreement with [Abraham et al. \(2017\)](#) in Ethiopia and [Dasmani et al. \(2020\)](#) in Ghana that revealed crop diversification is largely practiced as an adaptation by the majority of smallholder farmers but soil and water conservation practices and adjusting planting date adaptation strategy also practiced well ([Table 2](#)).

Table 2.

Major adaptation strategies used by farmers in the Central part of Ethiopia

Adaptation strategies identified	Total adopter household (%)	Agro-ecological distribution of adopter (%)		
		Lowland	Midland	Highland
Crop diversification strategies (yes)	51.47	17.71	53.71	28.57
Use of improved crop varieties and input intensity (yes)	62.65	23	38.5	38.5
Adjust of planting date (yes)	45.59	40	24.52	35.48
Soil and water conservation practices (yes)	49.12	13.77	55.09	31.14
Changing the crop type (yes)	50.59	26.74	40.70	32.56

Table 3.

Correlation matrix among farmers' adaptation strategies (from the multivariate probit estimation)

Climate change adaptation strategy	Coefficient	Standard error
Use of improve verities and intensity and crop diversification	0.11	0.1043
Adjust planting date and crop diversification	-0.13	0.1010
Soil and water conservation practices and crop diversification	0.28***	0.0919
Changing crop type and crop diversification	0.06	0.0955
Adjust planting date and use of improved crop varieties and input intensity	0.58	0.1008
Soil and water conservation and use of improved varieties and input intensity	0.07	0.1017
Changing crop date and use of improved varieties and input intensity	0.29***	0.0935
Soil and water conservation practices and adjust planting date	-0.06	0.0987
Changing crop type and adjust planting date	-0.15*	0.0908
Changing crop type and soil and water conservation practices	0.07	0.0977

Notes: Likelihood ratio test of $\rho_{21} = \rho_{31} = \rho_{41} = \rho_{51} = \rho_{32} = \rho_{42} = \rho_{52} = \rho_{43} = \rho_{53} = \rho_{54} = 0$: $\chi^2(10) = 23.9732$ Prob > $\chi^2 = 0.0077$ * and *** means statistically significant at 10 and 1% probability level, respectively

Empirical model results

Correlations among adaptation strategies. Table 3 presents the correlation coefficients of the climate change adaptation strategies from the MVP estimation in this study, which test either the adaptation strategies are independent or not. The likelihood ratio test of independence of the error terms of the different adaptation strategies used for this study is rejected at a 1% level of significance ($\chi^2(10) = 23.97, p < 0.0077$) (Table 3). The result shows the presence of mutual interdependence among five adaptation strategies and supports the appropriateness of an MVP model for this study data set. Thus, smallholder farmers of Central Ethiopia practiced more than one adaptation strategy concurrently, and a few of these adaptations choice correlated significantly.

Majority of the pairwise correlations among these adaptation strategies are positively correlated implying the presence of a complementarily relationship. The pairwise correlations are significant in 3 of the 10 pairwise correlation coefficients. For instance, soil and water conservation practices correlate positively with crop diversification strategies and showing that undertaking soil and water conservation practices increase the cultivated land for diversifying different crops. Similarly, the use of improved crop varieties and input intensity correlated with changing crop type positively, indicating that accesses to improved varieties and other input influence decisions on what and how much to produce. This result was true at a 1% level of significance. Also, farmers might replace the old crop varieties by new varieties or completely change the crop type for more additional benefit and production if they have accessed improved crop varieties and inputs.

On the other hand, surprisingly, changing the crop type adaptation strategy negatively correlated with adjusting the planting date and the relationship was significant at 10% ($p = 0.087$) level of significance. This could be because of crop production in Ethiopia being largely rainfall dependant and seasonal; and the majority of crops are grown at the same period. This indicates farm households in Central Ethiopia used planting date adjustment and changing crop type as substitute adaptation options; as households who used changing crop type adaptation are less likely to use planting date adjustment as an adaptation option and vice versa.

The model results also revealed that the use of crop diversification, adjust planting date, improved crop varieties and input use intensity, soil and water conservation and changing of crop type adaptation strategies in the study area increases by 51.7%, 62.4%, 45.6%, 49.1% and 50.03%, respectively. Also, households are more likely to use all the adaptation strategies jointly than fail to use all these adaptation strategies. Thus, the likelihood of households using all the five adaptation strategies simultaneously was about 6.71% while the likelihood households failed to use all adaptation strategies were about 5.63% (Table 4).

Factors affecting farmer's adaptation strategies choice. Table 5 presents significant factors affecting farmer's choice of adaptation measures. The result of a MVP model

Table 4.
Predicted probabilities of using each adaptation strategies in the Central Ethiopia (from the multivariate probit estimation)

Predicted probability of adaptation strategies	Mean	SD
Use of crop diversification	0.517	0.2667
Use of improved crop varieties and input use intensity	0.624	0.2299
Adjusting plant date	0.456	0.2092
Soil and water conservation practices	0.491	0.2499
Change crop type	0.503	0.1854
Joint probability (success)	0.067	0.0915
Joint probability (failure)	0.056	0.0738

Table 5.
Parameter estimates
from multivariate
probit for estimating
factors affecting
farmer's choice of
adaptation strategies
to climate change

Explanatory variables	Crop diversification	Improved varieties and input intensity	Adjust on planting date	Soil and water conservation	Changing crop type
<i>Constant</i>	-2.37 (1.127) ^{**}	-2.13 (1.149) [*]	-0.6 (0.325) [*]	-2.10 (0.395) ^{***}	-1.49 (0.401) ^{***}
<i>Sex of HHHs</i>	0.31 (0.167) [*]	0.33 (0.159) ^{**}	0.25 (0.158)	0.34 (0.162) ^{**}	-0.16 (0.156)
<i>Adult age category HHHs</i>	0.26 (0.216)	0.38 (0.2) [*]	-0.04 (0.192)	-0.10 (0.208)	-0.13 (0.187)
<i>Older age category HHHs</i>	0.17 (0.403)	-0.02 (0.399)	0.29 (0.381)	0.13 (0.388)	0.08 (0.364)
<i>Family size of HHHs (labor)</i>	0.10 (0.046) ^{**}	0.01 (0.043)	N/U	0.13 (0.039) ^{***}	N/U
<i>Literacy status of HHH</i>	0.22 (0.159)	0.23 (0.161)	0.13 (0.157)	0.12 (0.161)	0.56 (0.153) ^{***}
<i>Cultivated land size of HHHs</i>	0.13 (0.126)	0.15 (0.111)	0.03 (0.101)	0.09 (0.107)	0.11 (0.104)
<i>Farming experience of HHHs</i>	0.002 (0.0105)	0.02 (0.016) ^{**}	0.001 (0.0101)	0.003 (0.0108)	0.02 (0.0102) [*]
<i>Accesses to extension service</i>	0.02 (0.154)	0.44 (0.152) ^{***}	0.58 (0.152) ^{***}	0.34 (0.152) ^{**}	0.32 (0.147) ^{**}
<i>Crop failure history of HHHs</i>	0.62 (0.159) ^{***}	0.39 (0.156) ^{**}	0.35 (0.155) ^{**}	0.14 (0.156)	0.04 (0.147)
<i>Annual income of HHHs (log)</i>	0.01 (0.119)	0.08 (0.123)	N/U	N/U	N/U
<i>Accesses to credit service</i>	0.44 (0.163) ^{***}	0.08 (0.123)	N/U	N/U	N/U
<i>Distance to the nearest market</i>	-0.02 (0.023)	-0.07 (0.021) ^{***}	0.02 (0.022)	0.001 (0.022)	0.03 (0.021) ^{***}
<i>Distance to the research institution</i>	N/U	0.003 (0.041)	N/U	N/U	0.01 (0.0036) ^{***}
<i>Membership to cooperative</i>	-0.05 (0.162)	0.22 (0.163)	0.005 (0.152)	-0.14 (0.156)	-0.16 (0.151)
<i>Social capital</i>	0.19 (0.164) ^{***}	-0.007 (0.156)	N/U	-0.02 (0.152) ^{***}	N/U
<i>Climatic information accesses</i>	0.41 (0.151) ^{***}	0.03 (0.151)	0.43 (0.147) ^{***}	0.40 (0.152) ^{***}	-0.05 (0.145)
<i>Midland agro ecology</i>	1.22 (0.201) ^{***}	0.19 (0.192) ^{***}	-1.10 (0.191) ^{***}	1.33 (0.197) ^{***}	0.3 (0.189)
<i>Highland agro ecology</i>	0.37 (0.204) [*]	0.52 (0.197) ^{***}	-0.53 (0.189) ^{***}	0.53 (0.196) ^{***}	0.29 (0.205)
<i>Model summary</i>					
Number of observation				340	
Wald chi-square (76)				391.54 ^{***}	
Log-likelihood				-951.65691	

Notes: N/U not used as an explanatory variable, HHHs household head; HHHs households. Figures in parentheses are robust standard errors ^{*}, ^{**} and ^{***} refers statistically significant at 10, 5 and 1 % probability level, respectively

indicated that the explanatory power of independent variables on a dependent variable are satisfactory because the authors failed to accept the null hypothesis because the likelihood function from an MVP model was significant (Wald $\chi^2 = 308.93$ with $P < 0.001$). Among the hypothesized variables in determining the choice of adaptation strategies the sex of a household head, age category, family size, literacy status, farming experience, access to extension service, the crop failure history, accesses to credit, distance to research, distance to market, accesses to climate information, agro-ecological category significantly determine the choice of adaptation methods among farmers.

Sex of household head showed a positive and significant effect on crop diversification ($p < 0.1$), the use of improved crop varieties and input use intensity ($p < 0.05$), and also adaptation by soil and water conservation ($p < 0.05$) adaptation strategies (Table 5). Based on the estimated marginal effect from an MVP model presented in Table 6, male-headed households were 9% more likely to diversify crops, 10% more likely to use improved crop varieties and input intensity and 11% more likely to conserve soil and water. This is associated with the fact that male-headed households have a better opportunity to exchange ideas with other farmers and development agents about climate change adaptation techniques. Also, male-headed households are more likely to engage in labor share work groups, which might influence their involvement in labor-intensive adaptation options such as soil and water conservation practices. This is in line with studies by Harvey *et al.* (2018) in Central America and Ademe *et al.* (2019) in Ethiopia as male-headed households are more likely to use crop diversification and using crop varieties adaptation strategy. Also, the finding that revealed male-headed households practiced adaptation methods requiring labor is in agreement with this study (Paulos and Belay, 2018).

The age category of the household head showed a positive and significant effect on improved crop varieties and input intensity at $p < 0.05$ (Table 5). As compared to older households, those households within the adult age group were 11% more likely to use improved crop varieties and deal with input intensity (Table 6). It might possibly because of adults are more energetic, self-motivated and actively ready to use new technology including improved crop varieties, fertilizers and, in turn, for securing their future lives. This result is consistent with earlier findings by Sisay *et al.* (2019) in Ethiopia and Kamba *et al.* (2015) revealed a significant relationship between household head age (not to be an older) with the use of improved crop varieties.

The available family labor within a household showed a positive and significant effect on households' decision to use crop diversification ($p < 0.05$) and soil and water conservation practices ($p < 0.01$) adaptation strategies (Table 5). The estimated marginal effect for the family size variable showed that one additional family labor in man equivalent increases the probability of diversifying different crops and using soil and water conservation practices by 3% and 4%, respectively (Table 6). Farmers' preference of adaptation measures might depend on the accessibility of labor for preparation, production and harvesting time. Different crops require similar action at a time and, in turn, failure to do so might result in a possible loss from their produce, and therefore, households with a better source of labor within a family were more likely to diversify crop production and conserve soil and water. This finding opposes the study by Ademe *et al.* (2019) in Ethiopia who revealed large family size decline the probability of using portfolio diversification but, in agreement with the finding by Birtukan and Abraham (2016), who revealed having large family size are more likely to use crop diversification and soil and water conservation practices.

The literacy status of a household head in formal education significantly determines the use of changing crop type ($p < 0.01$) as an adaptation strategy (Table 5). The result showed that households who accessed formal education were 19% more likely to change the crop

Table 6.
Marginal effect
because of
independent
variables

Explanatory variables	Crop diversification	Improved varieties and input intensity	Adjust on planting date	Soil and water conservation	Changing crop type
<i>Sex of HHs</i>	0.09 (0.0494)*	0.1 (0.0478)**	0.08 (0.0527)	0.11 (0.0149)**	-0.06 (0.0553)
<i>Adult age category HHs</i>	0.07 (0.0644)	0.11 (0.0605)*	-0.01 (0.1283)	-0.03 (0.0653)	-0.04 (0.0663)
<i>Older age category HHs</i>	0.05 (0.1208)	-0.007 (0.1221)	0.09 (0.1283)	0.04 (0.1223)	0.03 (0.1292)
<i>Family size of HHs (labor)</i>	0.03 (0.0136)**	0.004 (0.0133)	N/U	0.04 (0.0121)**	N/U
<i>Literacy status of HH</i>	0.06 (0.0476)	0.07 (0.0485)	0.04 (0.0528)	0.03 (0.0503)	0.19 (0.0511)***
<i>Cultivated land size of HHs</i>	0.04 (0.038)	0.05 (0.0338)	0.01 (0.0339)	0.03 (0.0337)	0.04 (0.0366)
<i>Farming experience of HHs</i>	0.007 (0.0031)	0.08 (0.0032)**	0.0005 (0.0034)	0.001 (0.0034)	0.006 (0.0036)*
<i>Accesses to extension service</i>	0.006 (0.0466)***	0.14 (0.0455)***	0.19 (0.0482)**	0.1 (0.047)**	0.11 (0.0513)**
<i>Crop failure history of HHs</i>	0.18 (0.0451)	0.12 (0.047)**	0.12 (0.0511)**	0.04 (0.049)	0.02 (0.0522)
<i>Annual income of HHs (log)</i>	0.003 (0.0361)	0.02 (0.0375)	N/U	N/U	N/U
<i>Accesses to credit service</i>	0.13 (0.0481)	0.005 (0.0511)	N/U	N/U	N/U
<i>Distance to the nearest market</i>	-0.005 (0.007)	-0.002 (0.051)***	0.006 (0.0074)	0.006 (0.0069)	0.01 (0.0075)***
<i>Accesses to the research institution</i>	N/U	0.001 (0.0015)	N/U	N/U	0.003 (0.0012)***
<i>Membership to cooperative</i>	-0.01 (0.0489)	0.06 (0.0495)	0.001 (0.0515)	-0.04 (0.0492)	-0.05 (0.0533)
<i>Social capital</i>	0.05 (0.0493)	-0.002 (0.0477)	N/U	-0.006 (0.0478)	N/U
<i>Climatic information accesses</i>	0.12 (0.0437)***	0.008 (0.046)	0.14 (0.0477)***	0.13 (0.0462)***	-0.02 (0.0514)
<i>Midland agro ecology</i>	0.37 (0.0498)***	0.06 (0.0583)	-0.37 (0.0549)***	0.42 (0.0485)***	0.11 (0.0661)
<i>Highland agro ecology</i>	0.11 (0.0607)*	0.15 (0.0585)***	-0.17 (0.0624)***	0.17 (0.0597)***	0.1 (0.0721)

Notes: N/U not used as an explanatory variable, HHs household head, HHs households. Figures in parentheses are robust standard errors , *** and ** refers statistically significant at 10, 5 and 1% probability level, respectively

types for adaptation measures (Table 6). Literate farmers may possibly have better awareness about cost, productivity, market value, soil fertility, crop character and also agricultural uncertain events such as climate change. On the contrary, uneducated farm households might relatively passive and old-fashioned to take counteractive measures. This result is in consonance with the finding by Adégnandjou *et al.* (2018) in South Benin that revealed literate farmers reached with information and makes more competent choices among adaptation strategies.

Farming experience showed a significant and positive effect on adaptation to the use of improved crop varieties and input intensity and changing crop type as adaptation strategies at $p < 0.05$ and $p < 0.1$, respectively (Table 5). The probability of using improved crop varieties and input intensity and changing crop type adaptation measures increases by 8% and 6%, respectively, for each additional year of farming experience (Table 6). Observation, model farmers and formal training approach enhance farmers' knowledge of production or risk management strategies and the experience might enhance farmers' knowledge of the right adaptation strategies. The result showed the use of improved crop varieties and input use intensity, and more experienced farmers use changing crop type adaptation strategies. This result is in line with a study by Zerihun *et al.* (2018) in Ethiopia that revealed the positive correlation of farming experience with improved crop varieties use and input use intensity adaptation strategy, respectively.

Access to extension service had a significant and positive influence on all adaptation strategies except crop diversification. The result showed that compared to these households heads who did not receive extension service, households who received extension service are more likely to use of improved crop varieties and input use intensity and adjusting planting date an adaptation strategy (both at $p < 0.01$). Similarly, it would also influence the choice of soil and water conservation practice and changing crop type adaptation strategy (both at $p < 0.05$) [Table 5]. The availability of extension advise increases the probability of using improved crop varieties and other inputs by 14%, adjust planting date by 19%, soil and water conservation practices by 10%, changing crop type by 11% in southwest Ethiopia (Table 6). The study result by Abrham *et al.* (2017) in Ethiopia and Charles *et al.* (2014) in South Africa revealed the significant relationship between extension service and farmers' choice of most adaptive measures, including the use of improved crop varieties; adjusting planting date, soil and water conservation and changing planting date adaptation measures are consistent with this finding.

The crop failure history of households showed a significant and positive correlation with the most identified adaptation choices, including crop diversification ($p < 0.01$), the use of improved crop varieties and input intensity ($p < 0.05$) and adjustment in crop date ($p < 0.05$) (Table 5). The results showed that households who faced crop failure problems were 18% more likely to diversify crop production, 12% more likely to use improved crop varieties and inputs and 12% more likely to adjust planting dates (Table 6). This is because most farm households are relatively risk-averse and need to use measures that can protect or cut from the previous risk. The result by Zerihun *et al.* (2018) that revealed the positive association of crop failure history with changing crop date adaptation strategy is in line with this result. Surprisingly, households with crop failure history was expected to use soil and water conservation practices and change the crop type adaptation strategies, but the result showed insignificantly correlated and probably the problem for their crop failure might not be associated with flooding, drought and site selection problem.

Accesses to credit services showed a significant ($p < 0.01$) effect on the use of crop diversification strategies to lessen climate change effects (Table 5). The availability of credit

services increases the probability of using crop diversification by 13% (Table 6). Credit helps to strengthen households' purchasing power of agricultural inputs, and augments the likelihood of households to diversify their crop production. The study finding by Arun and Jun (2019) in Nepal revealed the positive correlation of credit service, and using improved crop varieties agrees with this result.

A distance of households residence from the nearest market showed a negative and significantly associated with the use of improved crop varieties and input use intensity ($p > 0.01$) (Table 5). The computed marginal effect indicated that as the distance from the nearest input and output market increases by one kilometer, the probability of using improved crop varieties and other inputs decreases by 0.2% (Table 6). A village market is the most relevant source of information for farmers and those farmers found in the different communities probably share their experience in such a market. On the other hand, those farmers far away from the market might not receive timely farming information, including improved crop varieties and the transaction cost of improved crop varieties might exert influence on farmers' use of improved crop varieties. The result is in agreement with a study by Abrham *et al.* (2017) in Ethiopia and Diallo *et al.* (2020) in southern Mali revealed that market accesses increases the likelihood of changing the input use intensity as an adaptive measure.

Distance to a research center has a significant ($p < 0.01$) positive effect on the use of changing crop type adaptation strategies (Table 5). Increase in the households' residence from the research center by 1 km increases the probability of changing crop type adaptation by 0.3% (Table 6). Thus, households who are close to research service centers can use updated information on the productive crop in their locality and thereby more likely focus on these researched crops. However, those households who are far from a research center may not receive researched information and they would possibly change the crop type to combat climate change rather than simply stick to researched resistant varieties. The result is consistent with a finding by Adimassu and Kessler (2016) that revealed the negative relationship between distance from the farming service center and change crop type adaptation strategies.

The availability of climate information like an early warning and preparedness affects households' adaptation strategies choice significantly. Thus, households who took climate information more likely used crop diversification, adjust planting date and soil and water conservation practices at $p < 0.01$ as compared to counterparts (Table 5). Compared to household heads who did not receive climate information, household heads that got climate information were 12% more likely to diversify their crop production, 14% more likely to adjust planting date and 13% more likely to conserve soil and water (Table 6). Smallholder farmers might be limited by capital to run their farming business and prefer to choose adaptation strategies largely managed at the household level that did not require much cost of adoption. A study by Chalmers *et al.* (2017) in Malawi revealed the positive and significant effect of climate information on the choice of most adaptation strategies is in covenant with this result.

The agro-ecological category (midland) showed a positive and significant effect on the use of crop diversification and soil and water conservation practices but negatively correlated with adjusting the planting date at $p < 0.01$ (Table 5). The marginal effect result estimated from the MVP model showed that compared to households living in the lowland agro-ecological category, farm households in the midland agro-ecology were 37% more likely to diversify their production, 37% less likely to adjust planting date and 42% more likely to conserve soil and water. Also, households living in the highland agro-ecology were 11% more likely to diversify crop production, 15% more likely to use improved crop

varieties and manage input use, 17% less likely to adjust planting date and 17% more likely to conserve soil and water (Table 6). Thus, households in different agro-ecology have different experiences of farming as they differ in the crop is grown, farming system and vulnerability to climate. For instance, households in the lowland agro-ecology were more likely to use adjust planting dates because crops in such agro-ecology acquire a short duration. However, such adaptation measure is risky to practices it in midland and highland agro-ecology. A study by Birtukan and Abraham (2016) that revealed the positive and significant relationship of the midland agro-ecological zone and the use of crop diversification support this finding.

Conclusions

The study concludes that the surveyed farm households in the Central part of Ethiopia observed changes in three climatic indicators, including rainfall, temperature and drought in the past two decades. In response, the majority (91.47%) were used adaptation methods to reduce the adverse effect of climate variability and change. The adaptation strategies used by crop-producing smallholders are interrelated to one another as the coefficient of the parameter significantly showed complementarities and substitutability relationships. The study indicated farmers of choice of adaptation were not largely affected by socio-economic factors rather demographic factors (sex, family labor, age groups, farming experience and literacy status) and institutional factors (access to credit, access to extension service and distance from market and research center) were largely determining farmers' choice of adaptation.

The policy should aim at looking for farm financing, strengthen extension service (climate change inclusive, considering the technical language usage and location-specific), ensuring farmer's accessibility to market infrastructure (road accesses, market accesses and transport service) and developing farmer's experience (training, model farmer's field visit and guest speaker). Moreover, developing socio-economic, resource and farm management strategies to farmers (family labor management, farm decision-making, use of adopting technology and a potential loss from exaggerated social life and expenses), encouraging women involvement in the affairs of the community and continuous awareness to farmers on the existed and updated farming technology would be grateful in enhancing adaptation practices in the Central part of Ethiopia.

This research is mainly targeted on assessing farmer's perception of climate change, adaptation strategies used by farmers and factors affecting the choice of adaptation strategy by smallholder farmers in Central Ethiopia. Therefore, the future research should focus on the impact of climate change and use of each adaptation strategy on the livelihood of smallholder farmers in Central Ethiopia.

Note

1. The smallest administrative unit in Ethiopian context.

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About the authors

Yonnas Addis is a Lecturer and Researcher at Wolkite University, Ethiopia. He has MSc degree in Agribusiness and Value Chain Management. Yonnas's main research interests are in the areas of climate change and agricultural risk management, value chain, commercialization and sustainable development. He has published several works in the field of agribusiness. Yonnas Addis is the corresponding author and can be contacted at: yonnas.addis@wku.edu.et

Solomon Abirdew has an MSc degree in agro-meteorology and natural risk management and he is working as Lecturer and Researcher at the Department of Natural Resource Management, Wolkite University, Ethiopia. As a researcher, Solomon Abirdew published about seven research papers in indexed and scientifically well-known reputable journals including Springer and IWA publishing group.

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