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## Article

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## DEVELOPMENT ECONOMICS | RESEARCH ARTICLE

# The cost and benefit analysis of climate change adaptation strategies among smallholder crop producers in the case of Sekela district, West Gojjam zone, Ethiopia

Yaregal Tilahun<sup>1\*</sup>

**Abstract:** Climate change has adversely affected the livelihoods of people in Ethiopia since a large proportion of the population is heavily dependent on agriculture as their adaptive capacities are perceived to be below. Therefore, this study aimed to identify determinants of farmer adaptation strategies with their costs and benefits of each adaptation strategy. The data were collected from 155 farm households using a random sampling method through semistructured questionnaires. The result of the multivariate probit model revealed that the likelihood of farmers to adopt adjustment of planting date, changing crop varieties, intercropping, crop rotation, irrigation, and minimum tillage were 51.6%, 61.9%, 56.1%, 38.1%, 10.3%, and 27.1%, respectively. The joint likelihood of using all adaptation strategies was 4.2%, while their failure to adopt all the adaptation strategies was 9.8%. Among the given adaptation options, intercropping, adjusting planting dates, crop rotation, and changing crop varieties are economically viable climate adaptation strategies. Regarding the intensity of adaptation, 78% of sampled respondents were used more than one adaptation option, and their NPV and BCR were higher



Yaregal Tilahun

### ABOUT THE AUTHOR

Yaregal Tilahun (MSc) is a lecturer and researcher in the department of Agricultural Economics at Mizan-Tepi University, Ethiopia. He is currently engaged in teaching, research and community service work at Mizan-Tepi University. His research interests are mainly focused on market chain analysis, value chain analysis, climate change, food economics, food security, willingness to pay, and green-economy development. He conducts collaborative research works including value chain analysis of *enset*, production and marketing constraint of tea, spices, coffee, honey and livestock in Southwest Ethiopia.

### PUBLIC INTEREST STATEMENT

Climate change is a global issue that affects all countries in the world. Particularly, the occurrence of climate change extremely affects agricultural production, productivity, and quality. Smallholder farmers in sub-Saharan Africa, including Ethiopia, are more vulnerable to climate change due to substance nature and low capacity to adopt technologies. In this regard, adaptation can be taken to minimize the harm or maximize the gains from weather variability and climate change. However, every adaptation is not advantageous for farmers to adopt; only the selected adaptations whose benefits exceed costs are advantageous and worthwhile. Adjustment of planting date, changing crop varieties, intercropping, crop rotation, irrigation, and minimum tillage are the six strategies practiced to override the negative impacts of climate change. Policies from different stakeholders that build farmers' capacity to adapt to climate change based on economic efficiency are critical for the successful responses to climate change impacts.

when they used at least one adaptation option. Farmers who did not adopt any adaptation options were able to receive the lowest income per unit production. The study recommends that households should use multiple combinations of adaptation practices rather than the use of a single adaptation option. Thus, the government and stakeholders must provide educational and extension service, training, and updated climate information to smallholder crop producers to use and select the best and combination of adaptation strategies.

**Subjects:** Agriculture & Environmental Sciences; Agricultural Economics; Environmental Studies; Climate Change; Environment & Economics

**Keywords:** Climate change; adaptation strategies; cost-benefit analysis; net present value; determinants; multivariate probit

## 1. Introduction

Climate change is a global concern as it severely affects the livelihoods of the world community in general and the agricultural production and food security of the farming community in particular (Connolly-Boutin & Smit, 2016; Thompson et al., 2010). Its consequences are severe in developing countries in which agriculture is the primary source of livelihood (Maharjan & Joshi, 2013; Morton, 2007). It could hurt various biophysical and economic activities like agriculture, water resources, forestry, human health, biodiversity, and wildlife (Ahmed, 2016; Chalchisa, 2016).

Even though climate change is a global problem, the need for adaptation is considered higher among developing countries where vulnerability is presumably higher and in the interest of individual farmers who rely on the revenue generated from agricultural production (Holzkämper, 2017; Williams et al., 2019). The adaptation strategy of climate change and its impact is mainly dependent upon the influencing determinants related to smallholder farmers' perception about the phenomena and intervention of the policy to practice properly (Azumah et al., 2020; Holzkämper, 2017; Osewe et al., 2020). Adaptation policy was designed by considering the knowledge and perceptions of smallholder farmers and their adaptation strategies can bring a fruitful and sustainable adaptation response to the effect of climate change (Niles & Mueller, 2016).

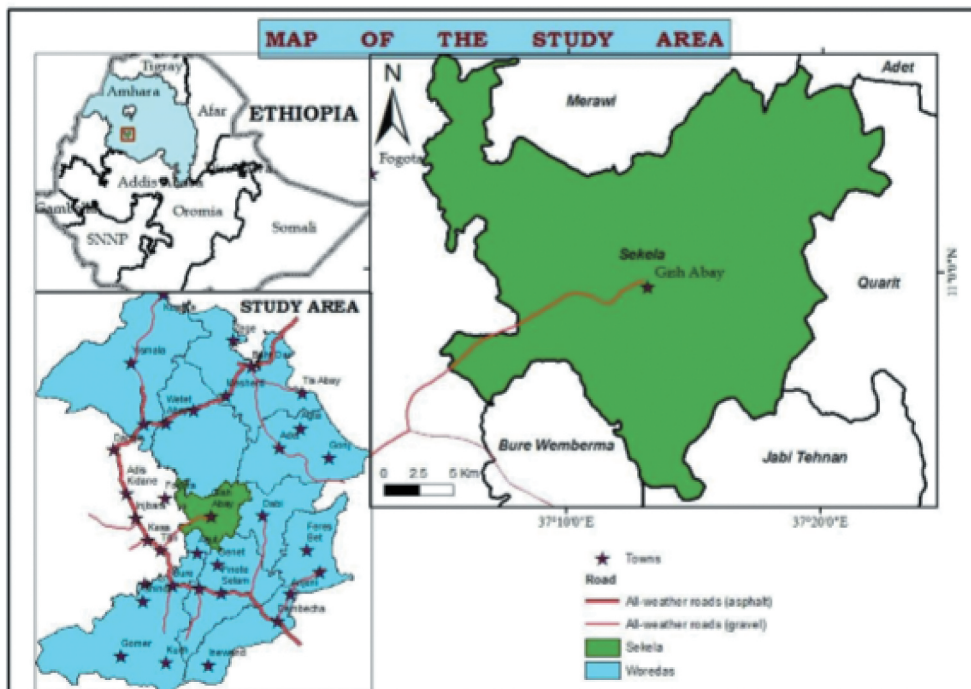
Smallholder farmers' perception plays a big role in the successful implementation of adaptation strategies to mitigate climate change impacts as agricultural practices are concerned (Arsiso et al., 2017; Gebreyes, 2018). Some of the adaptation measures are crop rotation, mixed farming, early planting, soil conservation, crop diversification, and minimum tillage practices (T. T. Deressa et al., 2009; Tazeze et al., 2012; Legesse et al., 2013; Addisu et al., 2017; Devkota et al., 2018; Upadhyay, 2019). However, adaptation decision is location-specific and influenced by key drivers, such as socio-economic, environmental, and institutional factors (Asrat & Simane, 2018). T. T. Deressa et al. (2009) found that adaptation at the farm level involves two stages: perceiving a change in climate and deciding whether to adopt or not (including which adaptation strategy to use). Thus, there is a need to understand location-specific drivers of perception and adaptation to climate change among smallholder farmers (Asrat & Simane, 2017). This helps to design applicable policy responses based on the liability and sensitivity level of each location, as well as the convenience of the adaptation methods (Asrat & Simane, 2017, 2018; Simane et al., 2016).

In this regard, adaptation can be taken to minimize the harm or maximize the gains from weather variability and climate change (Devkota et al., 2018). In the same vein, efficient adaptations are the set of adaptations that maximize net benefits (Mendelsohn, 2000; Devkota et al., 2018). However, not every adaptation is advantageous for farmers to adapt, only the selected adaptations whose

benefits exceed costs are advantageous and worthwhile (Devkota et al., 2018; Pant, 2013). Such adaptations, which maximize benefits, should be encouraged. To understand this, an economic analysis is necessary to determine whether or not it is advantageous to do any adaptation at all (Devkota et al., 2018). This involves calculating and comparing all costs and benefits expressed in monetary terms (De Bruin et al., 2014). Therefore, understanding the costs and benefits of climate change adaptation in agriculture is important for mobilizing support and providing timely resources to the institution to improve resilience and adaptive capacity (Sova et al., 2012; Shongwe et al., 2014; Mugula et al., 2015; Devkota et al., 2018).

There have been extensive research studies have been performed on the perceptions and impact of climate change (Ali & Erenstein, 2017; Morton, 2007; Mulwa et al., 2017; Nkondze et al., 2013; Ojo & Baiyegunhi, 2019), the effect of climate change and variability (Nkondze et al., 2013; Minwuye, 2017; Arsiso et al., 2017;) and climate adaptation strategies (Addisu et al., 2017; Adeagbo et al., 2021; Ahmed et al., 2019; Asrat & Simane, 2018; Belay et al., 2017; Gebru et al., 2020). So far, there have not been any research studies on the cost and benefit of climate change adaptation strategies in Ethiopia in general and in the study area in particular. This left a knowledge gap in the assessment of the cost and benefits of adaptation to climate change adaptation strategies for crop producers. Therefore, this study aims to contribute to addressing this research gap. With this background, these studies were focused on identifying farmer adaptation strategies with their determinants implemented in crop production and quantify the costs and benefits of farmers' adaptation strategies to climate change in the study area. Findings from the present study are relevant for formulating climate-related policies for adapting against climate change in the study area as well as other areas in Ethiopia. In the same way, the findings of the study would result in a reference for other studies who want to conduct further research on a similar topic within the country or abroad [Figure 1](#).

Figure 1. Location of the study area.



## 2. Literature review

### 2.1. *Climate change and crop production*

Studies indicate that Africa's crop production is negatively affected by climate change (Fankhauser, 1997; McCarthy et al., 2001). Climate change has resulted in increased temperatures, which increase transpiration and evapotranspiration rate causing severe water stress as plants lose a lot of water and soil moisture is depleted (Aydinalp & Cresser, 2008). Reduced soil moisture decreases available water for irrigation and hinders plant growth in non-irrigated plants. Higher temperatures, reduced rainfall, and increased rainfall variability reduce crop productivity that would be affecting food security in low-income and agriculture-based economies (Gezie, 2019).

Climate change is a global concern as it severely affects the livelihoods of the world community in general and the crop production of the farming community in particular. Its impacts disproportionately affected sub-Saharan African countries, such as Ethiopia because their economies are highly dependent on climate-sensitive activities with low adaptive capacity (Minwuye, 2017). It could hurt various biophysical and economic activities like agriculture, water resources, forestry, human health, biodiversity, and wildlife (Chalchisa, 2016).

Climate change alters the distribution, incidence, intensity of pests, diseases, and invasion of alien species. High temperatures coupled with wet conditions create new niches and favor the growth of pests and pathogenic organisms (Selvaraju, 2011). Droughts and floods kill animals that are used by small-scale farmers for plowing, thereby leaving them with no choice, but to hire tractors. However, most rural households do not afford such services because of their poor financial background. Planted areas are therefore reduced and food insecurity increases, forcing them to rely on food aid.

### 2.2. *Adaptation strategies to climate change*

Adaptation to climate change refers to the adjustment of natural or human systems in response to actual or expected climatic stimuli and/or their effects, which moderates harm or exploits beneficial opportunities. The common adaptation methods in agriculture in different literature include the use of new crop varieties, irrigation, crop diversification, adoption of mixed crop and livestock farming systems, use of organic fertilizers, planting drought-resistant varieties, changing planting dates, minimum tillage, soil conservation, agroforestry practice, different farming system, and fallowing (Abdulai, 2018; Adeagbo et al., 2021; Ahmed et al., 2019; Atube et al., 2021; Chalchisa, 2016; Diallo et al., 2020; Fagariba et al., 2018; Kassie et al., 2017; Lemessa et al., 2019; Minwuye, 2017; Osewe et al., 2020; Tadesa, 2020).

Tesfaye and Seifu (2016) conducted a study on climate change perception and choice of adaptation strategies based on empirical evidence from smallholder farmers in eastern Ethiopia. The study found that the major adaptation strategies used by farmers in response to adverse effects of climate change include cultivating different crops, planting different crop varieties, changing planting dates, use of soil and water conservation techniques, conservation agriculture practices and engaging in non-farm income activities. The MVP model result revealed that the choice of adaptation strategies is influenced by the gender of household head, household size, farm size, distance from market and number of farm plots.

Belay et al. (2017) investigated smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia using descriptive statistics and the MNL model. It is found that farmers made attempts to adapt using practices like crop diversification, planting date adjustment, soil and water conservation and management, increasing the intensity of input use, integrating crop with livestock, and tree planting. The econometric model result



indicated that education, family size, gender, age, livestock ownership, farming experience, frequency of contact with extension agents, farm size, access to market, access to climate information and income were the key factors determining farmers' choice of adaptation practice.

According to Atube et al. (2021), farmers' adaptation of climate change adaptation strategies is influenced by access to credit, gender, access to extension services, farming experience, time taken to market and farm income. Minwuye (2017) found that agroecological setting, sex, education level, landholding, farm income, non-farm income, livestock ownership, access to credit, extension visit, farmer-to-farmer extension, access to climate information, and the average distance from home to the farm have a significant influence on the choice of climate adaptation strategies. Karki et al. (2020) revealed that changing crop types and varieties, adding fertilizers, the use of new technologies, soil and water management, diversification of income sources, and migration are the climate change adaptation options used by subsistence and smallholder farmers in Nepal.

### 3. Methodology

#### 3.1. Description of the study area

Sekela Woreda is one of the 15 Woredas in the West Gojjam Zone of Amhara National Regional State. It is located 459 km to the North West away from Addis Ababa, the capital city of Ethiopia, 160 km away to the South East from Bahir Dar, the capital of Amhara National Regional State, and 74 km away North East from Finote Selam, the capital town of West Gojjam Zone. The administrative center of Sekela Woreda is Gish Abay town. The district has a total of 27 kebeles of which 26 are rural-based kebeles and only 1 urban kebele .

According to the Sekela Wreda Health Office (2017), the total population of the district was 162,204 of which male accounts for 79,071 (48.7%) and female accounts 83,133 (51.3%) of the total population. Besides 48.7% of the male population of the district, 92.65% of them are living in rural areas and the remaining 7.35% are urban residents. The estimated total area coverage of the district is 6534.5 hectares. It is located at an elevation of 3062 meters above sea level and 10°55'0" N latitude and 37°31'6" E longitude. The average annual rainfall of the area ranges from 1600 mm to 1800 mm with an average temperature of 18°C. The district is characterized by 70% highland (*Dega*), 18% midland (*Woynadega*), and 12 % lowland (*Qola*) agro-ecological zones (SWAO, 2017).

#### 3.2. Sources and methods of data collection

The study used both primary and secondary data sources to collect qualitative and quantitative data. Data were obtained from the 2019/2020 cropping season. A semi-structured questionnaire was used to gather primary data on socioeconomic characteristics, crop management, farm inputs and output, access to institutional services, current adaptation measures are undertaken, and limitations to adaptation. Before the data collection, the questionnaire was pretested and amended based on the feedback received during the pretest to evaluate the appropriateness of the design, clarity, interpretation of the questions, and the relevance of the questions. Subsequently, appropriate modifications and corrections were made to the questionnaire based on their answers. The enumerators received field training on the study objectives and farm household survey.

In addition to the questionnaire, a focus group discussion consists of 10 purposely selected participants and five key informants were interviewed to obtain additional supporting information for the study. Secondary data on climate change adaptation options with their costs and benefits for each adaptation strategy were collected from different sources like the Meteorological Service Department and from reviewing documents such as reports and databases of government institutions and from published and unpublished documents to secure relevant secondary information.

### 3.3. Sampling procedure and sample size determination

A two-stage random sampling technique was applied to select sample households. In the first stage, four kebeles were randomly selected. In the second stage, a total of 155 household heads were selected randomly with a probability proportional to size. The reason for using simple random sampling is that the kebeles are located in the same agro-ecological zone. Therefore, the sample selection was free of bias. The formula provided by Yamane (1967) was used to determine the required sample size at 95% confidence level and 8% level of precision. In total, 155 sample households were selected from a total of 21,615 households in the selected kebeles.

### 3.4. Methods of data analysis

**Descriptive analysis:** A cost-benefit analysis for the different adaptation strategies was conducted using net present value (NPV) and benefit-cost ratio (BCR). A high NPV indicates the most efficient and economical adaptation strategy. Similarly, adaptation strategies with the highest BCR were the most economical compared to those with low BCR. This can be done by;

- (i) Identifying the adaptation strategies employed in the communities.
- (ii) For each adaptation strategy, the total costs incurred when using that strategy and benefits were identified and used to compute the net benefit for that particular adaptation strategy.

$$NB = \sum TB - \sum TC \tag{1}$$

Where; NB represents the net benefits

TB represents the total benefits

TC represents the total costs

For adaptations that do not have direct costs and benefits, the shadow pricing and opportunity costs were used to quantify and computed.

NPV is computed as:

$$NPV = \sum_{t=0}^T B_t(1+r)^{-t} - \sum_{t=0}^T C_t(1+r)^{-t} \text{ or } NPV = \sum_{t=0}^T B_t - C_t(1+r)^{-t} \tag{2}$$

$$BCR_i = \frac{\sum_{t=0}^T B_t(1+r)^{-t}}{\sum_{t=0}^T C_t(1+r)^{-t}} \tag{3}$$

where:  $BCR_i$  = Benefit Cost Ratio of the  $i$ th strategy; NPV = Net Present Value;  $B_t$  = Total benefit in year  $t$ ;  $C_t$  = Total cost in year  $t$ ;  $r$  = Discount rate and  $(1+r)^t$  = Discount factor for year  $t$

Since the practice of climate adaptation strategies was recorded for one year, adoption with immediate costs and benefits ( $t$ ) was assumed to be one, while  $r$  was assumed to be 15%. Then, the decision was drawn and concluded based on the value of NPV and BCR for each adaptation strategy. Generally, the higher the BCR, the better the adaptation strategy, while the lower the BCR, the less economically viable the adaptation practice.



#### 4. Econometric analysis: determinants of farmers' choice on adaptation strategies (MVP)

A multivariate probit (MVP) approach was used for the empirical analysis. MVP models the effect of a set of regressors for each of the adaptation strategies simultaneously while allowing free correlation among the unobserved factors (Lin et al., 2005). The multivariate probit model is a form of a correlated binary response regression model that simultaneously estimates the influence of independent variables on more than one dependent variable, and allows for the error terms to be freely correlated. The dependent variable represents positive (chosen or 1) or negative (not chosen or 0) responses to the question regarding the importance of each factor on the adaptation option.

The general specification for a multivariate probit model of dependent variables (or alternatives) can be expressed as (Greene, 2003). In the study area, six adaptation options were used by farmers to mitigate the effect of climate change on their farms. These variables were adjusting planting date, change crop varieties, intercropping, irrigation, crop rotation, and minimum tillage. The observed outcome of adaptation strategies can be modeled following a random utility formulation. Let  $U_k$  represent the benefit of the farmer in choosing the  $K$ th adaptation options: where  $K$  denotes the choice of different adaptation strategies. The farmer decides to choose the  $K^{\text{th}}$  adaptation strategies if  $Y_{ik}^* = U_k^* - U_0 > 0$ . Where  $U_0$  refers to alternative adaptation strategies.

$$Y_{ik}^* = X_i \beta_k + \epsilon_i \quad \text{With } k = 1, 2, 3, 4, 5, 6 \quad (4)$$

$$Y_{ik} = 1 \text{ if } Y_{ik}^* > 0 \text{ and } 0 \text{ otherwise}$$

The net benefit ( $Y_{ik}^*$ ) that the farmer drives from choosing climate adaptation strategies is a latent variable determined by observed explanatory variables ( $X_i$ ) and the error term ( $\epsilon_i$ ), and ( $k = 1, 2, 3, 4, 5, 6$ ) represents the various practices used by smallholder crop farmers in the study area.  $X_i \beta_k$  is a vector of explanatory variables used in the model for  $k = 1$  (adjusting planting date),  $k = 2$  (irrigation),  $k = 3$  (change crop varieties),  $k = 4$  (intercropping),  $k = 5$  (crop rotation) and  $k = 6$  (minimum tillage). Thus empirically, the model can be specified as follows:

$$Y_{i1}^* = X_{i1} \beta_{i1} + \epsilon_{i1} \quad (5)$$

$$Y_{i2}^* = X_{i2} \beta_{i2} + \epsilon_{i2} \quad (6)$$

$$Y_{i3}^* = X_{i3} \beta_{i3} + \epsilon_{i3} \quad (7)$$

$$Y_{i4}^* = X_{i4} \beta_{i4} + \epsilon_{i4} \quad (8)$$

$$Y_{i5}^* = X_{i5} \beta_{i5} + \epsilon_{i5} \quad (9)$$

$$Y_{i6}^* = X_{i6} \beta_{i6} + \epsilon_{i6} \quad (10)$$

In the multivariate model, where the choice of several adaptation options is possible, the error terms of the above equations ( $\epsilon_{i1}, \epsilon_{i2}, \epsilon_{i3}, \epsilon_{i4}, \epsilon_{i5}$  and  $\epsilon_{i6}$ ) may be correlated and jointly follow a multivariate

normal distribution (MVN) with zero conditional mean and variance normalized to unity (for identification of the parameters),  $MVN \sim (0, \Omega)$ . The log-likelihood function associated with a sample outcome is then given by:

$$\ln L = \sum_{i=1}^N \omega_i \ln \Phi_i(\mu, \Omega) \tag{11}$$

where  $\omega_i$  is an optional weight for observation  $i$ , and  $\Phi_i$  is the multivariate standard normal distribution with arguments  $\mu_i$  and  $\Omega$ , and  $\mu_i$  can be denoted as:

$$\mu_i = (K_{i1}\beta_1 X_{i1}, K_{i2}\beta_2 X_{i2}, K_{i3}\beta_3 X_{i3}, \dots, K_{in}\beta_n X_{in}), \text{ While } \Omega_{jk} \text{ for } j = k \text{ and} \tag{12}$$

$$\Omega_{jk} = \Omega_{kj} = K_{ij}K_{ik}\rho_{jk} \text{ for } j, k = 1, 2, 3, 4, 5, 6 \text{ with } K_{ik} = 2Y_{ik} - 1 \tag{13}$$

The dependent variables in the empirical estimation are the choice of adaptation strategies from the set of adaptation measures listed in Table 2. The choice of dependent and explanatory variables is based on data availability and different works in the literature. I might choose independent variables (Table 1) and dependent variables (adaptation options) (Table 2) based on

**Table 1. Socio-demographic characteristics of sampled crop producers**

| Variables                    | Description of variables                         | Mean     | SD     |
|------------------------------|--|----------|--------|
| <b>Dependent variables</b>   |  |          |        |
| CCAS Adoption                | If HHs adopted climate change 1 and 0, otherwise | 0.77     | 0.32   |
| Intensity of CCAS            | Numbers of climate change adaptation strategies  | 3.89     | 2.15   |
| <b>Independent variables</b> |  |          |        |
| Sex                          | 1 if HH head is male, 0 if female                | 0.87     | 0.28   |
| Age                          | Age of HH head (years)                           | 41.62    | 13.63  |
| Access to training           | 1 if HH has access to training, 0 if otherwise   | 0.37     | 0.51   |
| Climate change perception    | 1 if HH perceived climate change, 0 if otherwise | 0.51     | 0.43   |
| Education level              | Years of education of HH head                    | 0.48     | 2.38   |
| Farming experience           | Years of household experience in crop production | 35.64    | 10.53  |
| Family size                  | Number of family size                            | 5.32     | 2.75   |
| Landholding                  | Total land owned by HH in hectares               | 2.32     | 0.98   |
| Farm income                  | The total amount of money from farming (Birr)    | 15,235.4 | 7512.7 |

(Continued)

| Variables               | Description of variables                          | Mean | SD   |
|-------------------------|---|------|------|
| Off-farm income         | 1 if HH engages in any off-farm activity          | 0.39 | 0.48 |
| Access to credit        | 1 if HH has access to credit, 0 if otherwise      | 0.36 | 0.51 |
| Access to information   | 1 if HH has access to information, 0 if otherwise | 0.42 | 0.45 |
| Access to extension     | 1 if HH has access to extension, 0 if otherwise   | 0.51 | 0.43 |
| Farmer-farmer extension | 1 if HH has access to contact, 0 if otherwise     | 0.56 | 0.38 |

Source: Own survey results, 2020

**Table 2. Adaptation strategies used by sampled households in response to climate change (n = 155)**

| Adaptation strategy options | Frequency (Use) | Percentage (Use) | Frequency (Not use) | Percentage (Not use) |
|-----------------------------|-----------------|------------------|---------------------|----------------------|
| Adjust planting date        | 80              | 51.6             | 75                  | 48.3                 |
| Change crop varieties       | 96              | 61.9             | 59                  | 38.1                 |
| Intercropping               | 87              | 56.1             | 68                  | 43.9                 |
| Irrigation                  | 16              | 10.3             | 139                 | 89.7                 |
| Crop rotation               | 59              | 38.1             | 96                  | 61.9                 |
| Minimum tillage             | 42              | 27.1             | 113                 | 72.9                 |

Source: Own survey results, 2020

being aware of pieces of literature in the same subject area and background knowledge of farmers practicing different climate change adaptation options in the study area.

## 5. Results and discussion

### 5.1. Socio-demographic characteristics of sampled households

The result of the study revealed that the average age of total sampled households was about  $41.62 \pm 13.63$  years. In line, the average years of experience for crop production for the entire sampled households was about  $35.64 \pm 10.53$  years. This indicates that most of the crop producers in the study area were young and more experienced, enlightening farmers about climate change and the possible ways that they could be used to adapt. Older farmers are more perceptive about climate change and are more likely to have experienced past and present climatic conditions over a long time horizon (Kibue et al., 2015; Maddison, 2006)

An increase in the level of education of the household head creates a positive attitude towards adaptation to climate change (Kibue et al., 2015), while the mean educational level of sampled households was  $0.48 \pm 2.38$  years. Even if education is important to manage the business as well

as decision-making, the educational statuses of more sampled respondents in the study area are illiterate. Regarding family size, the average family size of the sampled farmers was  $5.32 \pm 2.75$ . From the total sampled households, the average annual cash income generated from on-farm (selling crops, livestock, and livestock products), non/off-farm activities (trading, daily labor, sale of *tella*, and tea) were 15,235.4 and 1,612 Ethiopian birr, respectively. The results in [Table 1](#) showed that 56% of sampled respondents could get climate adaptation options from other farmers. Frankenberger et al. (2013) pointed out that the interaction of crop producers with their colleagues can be easily aware of climate information and the mechanism to adapt to climate change.

Access to extension and credit services can provide farmers with quality information and enhance their capacity to purchase improved agricultural inputs to increase farm-level productivity and to tackle climate change and its effects on their farms (Ojo & Baiyegunhi, 2019). Consistent contact between the farmers and the extension agents will provide relevant information such as farm management, technical assistance, practice information on improved varieties, and agricultural technologies (Kibue et al., 2015). However, only about 51% and 36% of the respondents have contact with extension agents and have access to credit as a major determinant in crop production. Since the adequate flow of information and training access to the farmer is important to reduce the impact of climate change (Isabirye et al., 2010) and Dinku et al. (2014), only 42% and 37% of the sampled farmers can have access to training and climate information, respectively.

### **5.2. Climate change adaptation strategies employed by households**

Sofoluwe et al. (2011) and Juana et al. (2013) indicated that agriculture is negatively affected by climate change, while adaptation reduces the impact and increases resilience to climate change such that those farmers who adopt are less vulnerable to these negative impacts of climate change. Adaptation plays a key role in determining the economic and social cost of climate change as its cost estimation is vital to gear up climate talk and other activities (Sarkar et al., 2012). Several adaptation options employed by households are indicated in ([Table 2](#)). The majority of the sampled respondents revealed that almost all respondents use at least one type of adaptation option.

Based on the results in ([Table 2](#)), the most common adaptation practices made by crop producers in the study area are changing crop varieties (61.9%), adjusting planting dates (51.6%), intercropping (56.1%), and crop rotation (38.1%). Adaptation strategies that received the least responses were the use of minimum tillage (27.1%), and irrigation (10.3%). Since irrigation involves high capital investment, farmers in the study area cannot use it to reduce the impact of climate change due to the lack of major rivers nearby and poor financial background. In line with this, farmers' ability and willingness to switch crops became limited due to the limited availability of alternative seeds and lack of adapted varieties to resist different abiotic stresses.

### **5.3. Intensity of use of adaptation strategies**

The intensity of the use of adaptation strategies was measured by the number of adaptation strategies practiced by respondents on their cropland. Farmers are not restricted to single adaptation options; rather, they practice multiple adaptation strategies in which 78% of crop producers practice more than one adaptation strategy to reduce the effect of extreme climate conditions. Likewise, 9.1% practiced four strategies, 23.87% practiced three strategies, 30.96% practiced two strategies, 13.54% practiced one strategy, and the remaining 22% of the sample respondents did not practice any type of adaptation practices. This result supported the previous findings of Mohammed et al. (2013) and Devkota et al. (2017) who observed that farmers practiced adaptation strategies in a combination way rather than taking them as an independent strategy.

Costs and benefits are other important components to know how many and which combination of adaptation strategies is more appropriate for farmers to increase their profit as they receive from

such practices. In line with this, average landholding is crucial to use adaptation practices to reduce the impact of climate change. In the study area, the total average landholding is minimal for the farmers who do not adopt any adaptation strategies. The result is consistent with the finding of Devkota et al. (2017) who found that the small size of landholding farmers is the one that adopts fewer adaptation strategies compared to the large size of landholding. It is also indicated that both NPV and BCR of using no adaptation practice are lower than other intensities of adaptation practices.

Similarly, for every adaptation option strategy used by the farmers, NPV is positive and BCR is greater than 1 which indicates farmers can earn profit for all adaptation options they use for their land to protect climate change. This indicates that farmers who can use the available adaptation options are profitable either using a single or a combination of adaptation option strategies (Shongwe et al., 2014; Devkota et al., 2018).

Regarding NPV and BCR, the above (Table 3) showed that farmers who do not adopt any type of adaptation practices have the lowest average net profit. For farmers who adopt several adaptation options, the farmers who practice two adaptation options have the highest average net profit followed by the farmers who practice three adaptation options. In line with this, for every adaptation option, BCR is greater than 1, which indicates farmers will be in profit for any type of use of adaptation options. It is also found that most of the respondents who have adopted adaptation option practice a combination of two and three adaptations rather than only a single adaptation option and the net profit is also shown to be higher for such two and three adaptation practices. The result is consistent with the finding of Devkota et al. (2017) who revealed that farmers using a multiple adaptation practice can earn more profit than the use of a single adaptation option.

#### 5.4. Cost-benefit analysis of climate change adaptation strategies

The study divides costs and benefits into two. The first one is inputs and outputs, which have been expressed and calculated through direct market price and the other is inputs and outputs, which cannot be expressed in terms of the market price. The inputs which included under costs in the given adaptation strategies were as follows: land preparation, cleaning, plowing, harvesting, seed purchasing, weeding, nursery bed preparation, manure, fertilizer application (NPS and Urea), crop protection (chemicals, herbicides and pesticides), oxen, hired and family labor, own land and rented land, preparation of seasonal dams, moisture conservation. Since most households used their family labor, oxen and land for crop production, opportunity costs were used to compute costs of adaptation strategies. On the revenue part, the direct output of crops and by-products of each crop were considered to calculate the profit of crop production. The overall revenue received from both production and by-product is calculated. Direct output is calculated through market price, while by-products are estimated through

**Table 3. Costs and returns of adaptation strategies based on their intensity of adaptation practice**

| Intensity of adaptation options | No. of farmers | Average land holding in hectare | NPV    | BCR  |
|---------------------------------|----------------|---------------------------------|--------|------|
| 0                               | 35             | 1.73                            | 56.83  | 1.46 |
| 1                               | 21             | 2.14                            | 89.75  | 1.35 |
| 2                               | 48             | 2.73                            | 168.18 | 2.07 |
| 3                               | 37             | 2.58                            | 139.73 | 1.87 |
| 4                               | 14             | 2.42                            | 104.64 | 1.24 |

Source: Own survey results, 2020

shadow price. Examples, to estimate the amount of fertility change brought by legumes fixing nitrogen (improvement of soil fertility and soil nutrients), were estimated through shadow pricing.

The results in (Table 3) showed that all adaptation strategies are economically viable since the estimated BCRs are above 1 and their NPV becomes higher. Overall, the six strategies with the highest NPV and BCR are intercropping, changing crop varieties, adjusting plant date, and crop rotation, while the strategies with the lowest NPV and BCR are minimum tillage and irrigation. The study by Shongwe et al. (2014) found that irrigation, crop rotation, and minimum tillage are economically viable climate adaptation strategies. Azumah et al. (2020) also found that the most profitable strategies were strip cropping, repeated sowing, refilling, zero tillage, and row planting. Thus, to promote climate adaptation strategies and improve the economic returns from adoption, strategies with higher NPV and BCR should be encouraged.

The number of households (61.9%) in (Table 2) reported that they have adapted to climate change by changing crop varieties. Therefore, the NPV for these varieties is calculated based on the average revenue for those using improved varieties and those producing their traditional seeds. The result indicated that the NPV for those producing their seeds was lower than those using improved seed varieties (Table 4). This is because most rural households are financially challenged, and they cannot afford most inputs including hybrid and/or improved varieties. Since most sample households use the previous harvest as a seed for the next season, the NPV for using improved seed is higher than the NPV for using traditional seeds.

Households (38.1%) indicated that they are using crop rotations as an adaptation strategy. Crop rotation was done with maize and leguminous crops. The advantage of this system is that it does not only lead to an increase in yield but also improves the fertility of the soil, enhances an effective utilization of fertilizer, and reduces soil depletion. Shadow pricing was used to estimate the amount of fertility change brought by legumes fixing nitrogen. This is calculated as a proportion of the fertilizer applied by the households per hectare.

Farmers in the study area more practically use intercropping strategies to produce a greater yield by allocating limited resources efficiently and effectively. The results in (Table 2) revealed that 56.1% of the sample respondents were using intercropping to reduce the effect of climate change since intercropping is important to increase the rate of crop production through increased soil fertility. The result is consistent in (Table 4) which indicated that the NPV for those who use

**Table 4. Cost-benefit analysis of climate adaptation options among sample respondents**

| Adaptation strategy options | TC    | TB    | NB    | NPV    | BCR  |
|-----------------------------|-------|-------|-------|--------|------|
| Adjust planting date        | 135.4 | 287.5 | 152.1 | 63.74  | 2.63 |
| Change crop varieties       | 259.7 | 424.3 | 164.6 | 102.52 | 2.31 |
| Intercropping               | 86.6  | 223.2 | 136.6 | 86.63  | 3.01 |
| Irrigation                  | 204.3 | 295.4 | 91.1  | 178.93 | 1.94 |
| Crop rotation               | 98.7  | 206.7 | 108   | 67.84  | 2.58 |
| Minimum tillage             | 65.8  | 147.3 | 81.5  | 44.73  | 2.16 |

Source: Own survey results, 2020



**Table 5. Multivariate Probit estimations results for households' climate change adaptation decisions**

| Explanatory variables            | Adjusting planting date | Irrigation   | Changing crop varieties | Intercropping | Crop rotation | Minimum tillage |
|----------------------------------|-------------------------|--------------|-------------------------|---------------|---------------|-----------------|
|                                  | Coff (Std.)             | Coff(Std.)   | Coff (Std.)             | Coff (Std.)   | Coff (Std.)   | Coff (Std.)     |
| Sex                              | .042(.34)               | -0.452(.34)  | .342(.18)               | .081***(.28)  | -.038(.35)    | -.204*(.28)     |
| Farming exp.                     | .019(.01)               | -.004(.02)   | .053*(.04)              | -.012(.015)   | .012(.01)     | -.047**(.03)    |
| Family size                      | -.21***(.05)            | .191**(.17)  | .23**(.45)              | .17***(.042)  | -.12**(.21)   | -.245(.02)      |
| Livestock o:ship                 | -.034(.041)             | -.025(.032)  | .012(.062)              | -.091*(.051)  | .23**(.45)    | .632(.24)       |
| Education level                  | -.176(.24)              | .021**(.03)  | .132***(.14)            | .53***(.28)   | .57<br>*(.34) | .463(.52)       |
| Farm income                      | .022*(.012)             | .023*(.016)  | .023**(.011)            | -.169(0.16)   | .035(0.16)    | .045(.18)       |
| Off-farm income                  | .783**(.25)             | .074**(.03)  | .062*(0.03)             | .028(.033)    | -.058(0.03)   | -.003(.01)      |
| Land holding                     | .077(0.18)              | -.41***(.12) | -.503 (0.13)            | -.127(.13)    | -.026(0.06)   | .107(.18)       |
| Extension contact                | .13***(.065)            | -.081(.065)  | .041(.062)              | -.006(.09)    | .037(.053)    | .231(.31)       |
| Credit taken                     | .603***(.23)            | .055(.24)    | .493(.25)               | -.079(.24)    | .523**(.23)   | 1.821*(.31)     |
| Farm-farmer ext.                 | .863***(.52)            | -.237(.34)   | .187(.415)              | .046(.37)     | .63**(.25)    | .325(.54)       |
| Access to info.                  | .045*(.026)             | .273(.298)   | 1.021(.012)             | .194(.28)     | .287(.34)     | 1.104**(.41)    |
| Access to training               | .212**(.26)             | .491(.37)    | .189(.291)              | .586*(.46)    | .341(.312)    | .748**(.76)     |
| Constant                         | .084***(.62)            | .145(.242)   | .672(.542)              | 1.136(1.34)   | .459(.98)     | -.934(1.61)     |
| Predicted probability            | .516                    | .103         | .619                    | .561          | .381          | .271            |
| The joint probability of success |                         |              |                         |               | 0.098         |                 |
| The joint probability of failure |                         |              |                         |               | 0.042         |                 |
| Observations                     |                         |              |                         |               | 155           |                 |
| Log-Likelihood                   |                         |              |                         |               | -364.38       |                 |
| Wald $\chi^2$ (64)               |                         |              |                         |               | 134.26        |                 |
| Prob > $\chi^2$                  |                         |              |                         |               | 0.0001***     |                 |
| P > $\chi^2$ (7)                 |                         |              |                         |               | 0.0039        |                 |

\*\*\*, \*\*, and \* signify level of significance at 1%, 5%, and 10% respectively.

Source: Own computation from survey data, 2020

intercropping is higher than their counterparts and its BCR is also greater than 1. The result is supported by the finding of Azumah et al. (2020) who revealed that the use of intercropping is vital to increase yield through improving soil fertility and effective utilization of fertilizers.

Minimum tillage reduces the cost of plowing and conserves moisture. These improved the water-holding capacity of the soil, reduce evaporation, and make more water available for the plants. However, most households are not using the right to implement minimum tillage such that the benefits are not maximized. Households are using hand hoes for digging and this makes the plant roots not to be deep enough, such that during very hot days, the plants easily wilt.

### **5.5. Factors influencing the choice of climate change adaptation strategies**

The Chi-square statistic with 64 degrees of freedom is 134.26 indicating rejection of the null hypothesis at a 1% significance level. This indicates that the subset of coefficients in the model is jointly significant and that the explanatory power of factors in the model is satisfactory. The result of the log-likelihood ratio test indicated that the multivariate Probit model fits the data reasonably well and that the choices of climate change adaptation strategies are not mutually independent. Furthermore, the result of the multivariate Probit model shows that the probability of households to adjust planting date, changing crop varieties, intercropping, irrigation, crop rotation, and minimum tillage was 51.6%, 61.9%, 56.1%, 10.3%, 38.1%, and 27.1%, respectively. The result also conveyed that the joint probability of using all adaptation strategies was only 9.8% and the joint probability of failure to adopt all the adaptation strategies was 4.2%.

#### **5.5.1. Adjusting planting date**

The result in Table 5 indicates, except family size, farm income, off-farm income, frequency of extension contact, credit being taken, farmer-to-farmer extension, access to information, and training affect adjusting planting date positively and significantly. The negative coefficient of the family size indicates that the increase in family size reduces the probability of farmers selecting a change in planting date as an adaptation option. The result is consistent with the finding of Tesfahunegn et al. (2016) and Sani et al. (2016) who found that family size affects adjusting planting dates negatively and significantly. Meanwhile, an increase in income, extension services, training, and market information had an increase in the probability of a change in planting date. This result is reliable with the outcomes of Tazeze et al. (2012), Tambo and Abdoulaye (2013), Devkota et al. (2017), Ahmed et al. (2019), and Ishfaq (2019).

#### **5.5.2. Irrigation**

The probability of farmers selecting irrigation practice as an adaptation strategy was affected positively by family size (5%), an education level (5%), farm income (10%), off-farm income (5%) and negatively by farm size 1% significant level. This indicated that the probability of using alternative irrigation was higher for farmers whose education and income levels of the household increased. The implication of the result implied that farm improvement and off/non-farm income improves farmers' financial position, which enables them to purchase farm inputs such as seeds, fertilizers, and other materials needed for irrigation. This finding is in line with the investigation of Tazeze et al. (2012), Sani et al. (2016), and Mulwa et al. (2017), and Devkota et al. (2017). The landholding of the households hurts the use of irrigation as an adaptation strategy. According to the focus group discussions, they reach a consensus that farmers who have a very limited land size could use irrigation. The result is agreed to by Temesgen et al. (2008), Seid et al. (2016), and Lemessa et al. (2019) that revealed large landholding size decreases the use of irrigation.

#### **5.5.3. Changing crop varieties**

The likelihood of selecting different crop varieties as adaptation options was affected by farming experience (10%), family size (5%), an education level (1%), farm income (5%), and off-farm income

(110%) positively and significantly with their significance level. This implies that as farmers were more educated the readiness to accept new ideas, innovation, farm income, and off/non-farm becomes improved which consequently enhances farmers' willingness to change more on crop varieties as an adaptation strategy to climate change. Changing crop varieties through the adoption of improved varieties with early maturity, drought tolerance, and pests and disease resistance can slow down or even halt the adverse effects of climate change (Abdulai & Abdulai, 2016; Kassie et al., 2017; Tadesa, 2020). Thus, smallholder farmers adopt and cultivate such varieties that are highly resistant to the adverse effects of climate change and that can provide high yields (Lemessa et al., 2019; Zizinga et al., 2017). Emphasis on more drought-resistant varieties of drought-prone areas could help in reducing vulnerability to climate change (Akinngbe & Irohibe, 2015; Mburu et al., 2015; Ngigi, 2009). The result is also consistent with the finding of T. T. Deressa et al. (2009), Legesse et al. (2013), Sani et al. (2016), Minwuye (2017), Belay et al. (2017), and Abdulai (2018) pointed out that increasing farming experience, education level and their farm income can increase their farm productivity through selecting improved varieties.

#### 5.5.4. Intercropping

Factors that affected the choice of intercropping as an adaptation option were affected by sex, family size, education level, and access to training positively and by livestock ownership negatively and significantly. Intercropping of different crop varieties in the same field is identified as one of the adaptation strategies to climate change as it is widely applied in the study area. Since farm size in the study area is very small, farmers use their limited land by choosing intercropping rather than the use of crop diversification. The result is in contrast to Tesfaye and Seifu (2016), Sani et al. (2016), and Belay et al. (2017) that revealed crop diversification was identified as adaptation strategies rather than intercropping as a suitable strategy. The significant positive coefficient of education and training access showed that farmers with higher educational attainment and more trained were more likely to use intercropping to combat adverse climate change effects. A positive relationship between family size and education level on the adoption of climate change adaptation strategies through intercropping methods exists in previous studies (T. T. Deressa et al., 2009; Abid et al., 2015; Gautam & Andersen, 2016; Ali and Erenstein, 2017; Adeagbo et al., 2021).

The knowledge gained through training can capacitate farmers with the technical know-how required for implementing adaptation measures in their agricultural production system and make them far-sighted to look for long-term benefits rather than immediate gains obtained. This is in agreement with the finding of Ketema and Bauer (2012), Guteta and Abegaz (2016), and Asrat and Simane (2017) who reported that access to extension and training is instrumental in promoting sustainable use of land-based climate change adaptation measures.

#### 5.5.5. Crop rotation

The likelihood of using crop rotation practice was affected by livestock ownership, education level, credit access, and farmer-to-farmer extension positively and family size negatively and significantly at different significance levels. Crop rotation can improve yield and profitability, control weeds, break disease cycles, provide an alternative source of nitrogen, reduce soil erosion, and increase soil organic matter and nutrients. This result is consistent with the finding of Holzkämper (2017) and Gebru et al. (2020) who found that access to credit, farmer-to-farmer extension, and education level of the household head were affected crop rotation significantly.

Inline with sampled respondents, focus group discussions and key informants pointed out that producers who are implementing in diversifying their cropping systems and management strategies will be more successful than others who are not. In line with this, they found that extensive crop rotations are largely considered an age-old farming practice that has many agronomic, economic, and

environmental benefits over continuous cropping. The result consistent with the finding of Wittwer et al. (2017), and Degani et al. (2019) who revealed that long-term rotation of crops with high levels of replication is essential to improve crop production and food security in an uncertain future climate.

#### 5.5.6. *Minimum tillage*

Climate adaptation options through minimum tillage practice were negatively affected by sex and farming experience and access to training, information, and extension contact positively and significantly. Since minimum tillage is part of the solution to mitigate climate change effects and to ensure sustainable agriculture through a reduction in soil erosion and improve soil organic matter content, farmers who can be more trained, informed, and in contact with extension, agents can improve their crops. The result is consistent with the finding of Lenka and Lenka (2014), and Osewe et al. (2020) who revealed that extension contact and access to training and climate information to farmers can be reducing cultivation costs, reducing soil temperature fluctuation, and conserving soil moisture. Osewe et al. (2020) also found that minimum tillage adoption has positive impacts on reducing total household labor demands and improve smallholder households' per capita net crop income.

### 6. Conclusions and recommendations

Climate change is one of the most important factors in agricultural production, which could have a direct and indirect influence on production since the climate is linked to biological processes. Therefore, it is essential to understand the various strategies used by farmers to mitigate the adverse effect of climate change and the factors that influence farmers' adoption and intensity of climate change adaptation strategies among smallholder crop farmers in the Sekela district. Results from the study show that only 77% of the farmers had used any type of adaptation strategies to mitigate climate change.

Regarding NPV and BCR, farmers who do not adopt any type of adaptation practices have the lowest average net profit, and farmers who adopt two adaptation options have the highest average net profit followed by the farmers who practice three adaptation options. So, farmers should use a combination of two or more adaptation strategies rather than a single type of adaptation option to increase their farm income and to reduce the negative impact of climate change.

To reduce the impact of climate change, farmers can use a climate adaptation option of changing crop varieties, adjusting planting dates, intercropping, crop rotation, minimum tillage, and irrigation. The result of the multivariate probit model revealed that the probability of using adjusting planting dates was significantly affected by family size, farm and off-farm income, extension contact, credit taken, farmer-to-farmer extension, and access to training and information. The probability of using irrigation was significantly affected by family size, education level, landholding, and farm, and off-farm income. The probability of using changing crop varieties was significantly affected by the farming experience, family size, education level, and farm and off-farm income. Similarly, the probability of using intercropping, crop rotation, and minimum tillage was affected by credit taken, livestock ownership, education level, and access to training and information.

Since farmers are agents who undertake adaptation to climate change, their outlooks towards adaptation are a key determinant of the success or failure of adaptation options. This study recommends that there is a need to improve the dissemination of up-to-date climate information and training to smallholder farmers to select the best adaptation strategies based on their economic efficiency. Access to up-to-date climate information and training for farmers will improve their knowledge and enhance their decision-making. Access to reliable climate information will improve their knowledge and enhance their decision-making. Therefore, its policies and strategies of the government should be geared towards supporting improved extension service to

extension agents and with other farmers and disseminating information about climate change adaptation strategies among smallholder farmers to increase crop productivity.

It is recommended that households should consider planting drought-tolerant crops like leguminous crops. This is because the improved adaptive capacity of crops can contribute to reducing the adverse effects of climate change and generally help to raise agricultural outputs. Finally, the study recommends that the concerned stakeholders should give capacity-building training and awareness on climate change to raise smallholder farmers consciousness on the adaptation options to climate change; farmers access to worth schooling to enable them to use environmentally friendly and best adaptation practices to climate change, and enhancing access to updated climate change information and farmers extension service on adaptation measures would be key to the development of government efforts on climate change adaptation. Therefore, in addition to assessing the determinant of climate change adaptation strategies in smallholder crop producers, future studies should evaluate the impact and determinants of adaptation strategies on environments as well as on societies.

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