Climate change adaptation strategies in response to food insecurity: The paradox of improved potato varieties adoption in eastern Ethiopia

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Abstract: The non-avoidable nature of climate change occurrences and their adverse effects on smallholder farmers’ livelihood and food security status calls for urgent interventions. In this study, we used a cross-sectional survey method. Data were collected from 365 sampled households in eastern Ethiopia to identify different climate change adaptation strategies and the associated factors in response to food insecurity. Three-stage probit model was employed for data analysis. Three adaptation strategies, namely: adoption of improved varieties, irrigation usage and intercropping were identified. The study result shows that Shantam, an improved potato variety, is the most widely grown in the study area. Frost, known as wurchi/amadey by its local name, was found to be the worst types of climate change incidence that severely affects potato production in the study area. The analysis of sociodemographic variables showed mixed results on each of the three adaptation strategies. Moreover, the regression revealed paradoxical results whereby irrigation usage and intercropping as climate change adaptation strategies recede the adoption of improved potato varieties.

PUBLIC INTEREST STATEMENT
Climate change is a global issue. It affects all countries in the world. Particularly, climate change extremely affects agricultural production, productivity, and quality. Smallholder farmers in Sub-Saharan Africa including Ethiopia are more vulnerable to climate change impacts. This is because of its substance nature and low capacity to adopt technologies.

The adverse effects of climate change are unavoidable. Thus, adaptation strategies are the way forward. Smallholder farmers in the study area are challenged by different climate change-induced problems. Some of the identified problems are drought, frost and pests and diseases. This study identified three adaptation strategies practiced in eastern Ethiopia. Adoption of improved crops, irrigation, and intercropping as climate change adaptation strategies recede the adoption of improved potato varieties.

Policy and supports from different stakeholders that builds stallholder capacity to adapt to climate change effect is critical for the successful responses to climate change impacts.

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1. Introduction, problem justification, and objectives

Smallholder farmers in Sub-Saharan Africa (SSA) region in general and eastern African countries in particular are facing considerable multifaceted challenges. This is mainly due to the adverse effects of ceaseless population growth, high dependence on degraded natural resources, low crop yields, poor market access, and food insecurity (Abegaz, 2017; Kristjanson et al., 2012; Nelson et al., 2010; Yamano, Otsuka, & Place, 2011). The adverse climate change impacts on agricultural production have added other critical challenges on the top of the aforementioned specters in the region.

Climate change which is the mean change or variability of its properties for long period (Tesfahun, 2018) is a global issue as it affects all countries in the world (Asiedu, Adetola, & Odame Kissi, 2017). Climate change-induced challenges such as temperature variability, changes in rainfall pattern and pest and diseases outbreaks negatively influence agricultural production, productivity, and quality (Tesfahun, 2018). The combined effects of climate change and population growth in SSA countries are growing fast and are major hindrances to the growth of the region. For instance, rainfall has been rapidly decreasing (Williams et al., 2012), whereas temperature has been alarmingly increasing (Cairns et al., 2012) in the region. The world development indicators (WDIs)—compiled by the World Bank (WB)—shows SSA population is growing at 2.7% as compared to the middle income (1.1%) and the upper middle income (0.8%) countries (WB, 2016). These interwoven problems threaten food and livelihood security for a large number of people in SSA (Tesfaye & Seifu, 2016).

The SSA agriculture is inherently vulnerable to climate change-induced risks due to its dependency on highly volatile rainfall in volume and distributions (Belay, Recha, Woldeamanuel, & Morton, 2017; Gbegbelegbe et al., 2017). Recent empirical studies contend that risks in agriculture (climate and non-climate related) such as high frequency of pests and disease outbreaks, wilt incidence, more frequent and extreme weather events, and market shocks are factors that affect food production of many SSA farmers (Lobell et al., 2008; Morton, 2007; Shikuku et al., 2017; Tesfaye & Seifu, 2016). The vulnerability of the SSA countries to the effects of climate change is also caused by their geographical and climatic conditions, high dependence on agriculture- and natural resources-driven activities and weak adaptive capacity to the threats of changing climate (Eriksen, O’Brien, & Rosentrater, 2008).

As is in the case of other SSA countries, poverty and food insecurity remain to be the major challenges to achieve economic development in Ethiopia (Asfaw, Coronado, & Lipper, 2015; Mulugeta, Tiruneh, & Alemu, 2018). This is mainly due to the subsistence nature of Ethiopian agriculture, its mere dependence on rainfall (Asfaw et al., 2015), and low level of technology adoption (Lemessa, 2017). These incidences have made Ethiopian smallholder farmers highly vulnerable to climate change risks such as famine and food insecurity particularly in the rural areas of the country (Belay et al., 2017; Mulatu, 2013). Historically, the country has been also suffering from natural catastrophes and is prone to extreme weather events (Tesfaye & Seifu, 2016). Moreover, geographical location, topography and low adaptive capacity by smallholder farmers further exacerbate the situation (Asfaw et al., 2015).

Given the unavoidability of climate change (Measham et al., 2011; Preston, Westaway, & Yuen, 2011) and the severity of its adverse impacts, adaptation actions to reduce risks of climate change are urgent (Campbell et al., 2016). In the view of Asfaw et al. (2015) adaptation to climate change is an adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities.
The literature on climate change impacts and the vulnerability of agricultural sector is increasingly recognizing the important role of adaptation strategies (Smit & Skinner, 2002). Adaptation strategies are required as they contribute to mitigate the high incidence of climate change related problems. These strategies are relevant for smallholder farmers who are highly exposed to the threats of climate changes.

The relevance of adaptations strategies plied by smallholders farmers are pronged into four folds: (i) it enables them to evaluate and choose the best alternatives, (ii) it helps them to practice new way of production system to address climate-related shocks and ensures their survival, (iii) it assists them to change/modify production systems in line with the effect of climate change, and (iv) it helps to design policies to tackle the challenges that climate change is posing on smallholder farmers. Moreover, identifying the adaptation strategies for particular crop than for the entire agricultural sector helps to device an appropriate climate change policies.

Climate change adaptation strategy studies on agriculture are abundant (Belay et al., 2017; Campbell et al., 2016; Gbegbelelere et al., 2017; Mulatu, 2013; Tesfaye & Seifu, 2016), but adaptation strategies on root crops, particularly potato (Solanum tuberosum L.) production was forlorn. While potato is the most popular human staple crop in Ethiopia with the highest economic importance, it is highly susceptible to rapid climate changes and related risks. In Ethiopia, potato is grown by about 1.2 million smallholder farmers on about 70, 131 ha of land (CSA, 2017). It is the fourth widely grown crops worldwide, surpassed only by wheat, rice, and corn. Potato plays a pivotal role in improving food security, increasing smallholder farmers’ income and reducing poverty (Hirpa et al., 2010; Abebe et al., 2013; Liu, Langemeier, Small, Joseph, & Fry, 2015; Mardani & Salarpour, 2015; Tufa et al., 2015).

Literature on the significance of potato as staple food crop for resource-poor farmers is profusely documented. For instance, Hirpa et al. (2010) suggested that potato has high potential to ensure the availability of food for the growing population because of its short crop cycle. In the same vein, Abebe et al. (2013) stated that potato is an important crop in terms of its potential for food security, export, and income generation. Potato is also an important source of starch (Birch et al., 2012). In spite of potato's paramount contributions to the national food balance sheet (Abebe & Bekele, 2015; Hirpa et al., 2010), its production and productivity remain low. This is due to the low level of adoption of high-yielding technologies and less climate adaptation strategies by smallholder farmers.

Eastern Ethiopia, the focus area of this study, is mainly characterized by dense population, small farm size, declining soil fertility, severe land degradation, fragile ecosystems and recurrent weather-induced shocks such as drought (Tesfaye & Seifu, 2016). It is among the chronically food insecure areas of the country facing recursive drought situation (Mulugeta et al., 2018). Smallholder farmers in this region face frequent risks to their potato production such as disease outbreaks, pest damage, wilt incidence, storage problems and occurrence of extreme weather events commonly called frost (Wurchi/Amadey). According to Tesfaye and Seifu (2016), the eastern Ethiopian highlands suffer from food production deficits and of high livelihoods vulnerability due to the aforementioned climate change-induced risks. Therefore, the rate of food production has failed to keep pace with the high rate of population growth resulting in high levels of food insecurity.

Despite the relevance of studying climate change adaptation strategies in response to food insecurity, empirical studies are strikingly scant on climate change adaptations strategies for root crops. Even the few existing empirical studies considered bundles of adaptation strategies as independent of one another. Moreover, these studies failed to capture the possibilities of reverse causation between the strategies (Acquah, 2011; Belay et al., 2017; Deressa, Hassan, Ringler, Alemu, & Yesuf, 2009; Fosu-Mensah, Vlek, & MacCarthy, 2012; Tesfaye & Seifu, 2016).
However, adaptation strategies are interrelated. Hence, there is a need to test the interdepen-
dence of the bundles of strategies in response to strategy choice. There is also a need to under-
stand forms of possible adaptation strategies in response to food insecurity in the study area.
Moreover, past studies identified adaptation strategies that are less suitable to the context of the
study area. For instances, Tesfaye and Seifu (2016) identified crop diversification and switching as
adaptation strategies in an area where the farm size is very small. Given the above lacuna, this
study aimed to: (i) identify the most widely practiced adaptation strategies in the study area; (ii)
assess factors that affect strategy choices; and (iii) assess the interrelationships and reverse
causation between the bundles of identified adaptation strategies.

2. Methodology

2.1. Study setting
This study was carried out in eastern part of Ethiopia, particularly eastern Hararghe Zone of Oromia
National Regional State. The study area is characterized by high population density, rainfall
variability, frequent drought occurrence, crop failure, severe land degradation, and increased
vulnerability to chronic food insecurity (Tesfaye & Seifu, 2016).

Although the amount and pattern vary locally, rainfall is bimodal in distribution; a short season
from March to May is known as Belg, and a longer rainy reason from July to September is known as
Kiremt seasons. The amount of rainfall varies between 650 and 750 mm, while the average
mean annual temperatures for the area are 23.8°C and 9.6°C, respectively (Alemayehu, Furi, &
Legesse, 2007; Mulugeta et al., 2018).

Smallholder farmers in the zone have rich experience in root crops and vegetable production,
irrigation usage and intercropping. The major crops grown are sorghum and maize under rainfed
conditions, as well as Khat, potato, and vegetables, e.g. lettuce, carrot, onion, tomato, and
cabbage, under irrigated conditions (Setegn, Chowdary, Mal, Yohannes, & Kono, 2011). There are
19 districts in the zone of which 14 are agro-pastoralists.

2.2. Data type and analysis methods
This study was conducted in three districts of east Hararghe zone of Oromia National Regional
State, Ethiopia, namely: Haramaya, Kombolcha, and Kersa. The districts were selected purposively
as they have high proportion of potato production coverage to their farmland allocated for annual
crops. The study used primary data that are context specific to achieve the predefined objectives. A
multi-level mixed method sampling technique was employed to select sample households and
collect the data. First, sample districts that have high potato production coverage were selected
purposively. Second, sample kebeles that are intensively involved in potato production were
selected purposively from these districts. Accordingly, five kebeles from Haramya district and
three kebeles from both Kombolcha and Kersa districts were selected by considering district
sizes in terms of both farm household population and number of kebeles in each district.

Finally, a representative sample of 365 smallholder farmers who adopted Improved Potato
Verities (IPVs) was selected using systematic sampling. The lists of adopters were obtained
from Kebele’s Agricultural Development Agent (ADA). A structured questionnaire was
designed and enumerators who know the local language and culture of the study area
collected the data. For the purpose of data analysis, descriptive (mean, percentage, and
graphs) and econometric (three-stage probit) model were employed. A Focus Group
Discussions (FGDs) was also organized with model farmers and Development Agents (DAs)
in each district. The FGDs results were used in order to triangulate the survey results.
2.2.1. Econometric model specification

Behavioral response models with more than two possible outcomes are either multinomial or multivariate. Multinomial models are suitable when respondents can choose only one outcome among the set of mutually exclusive and collectively exhaustive choices (Kouame, 2010). Mostly, smallholder farmers use bundles of different adaptation strategies to combat the negative effect of climate change. These strategies are not only non-mutually exclusive but also complementary. Despite the fact that strategies are many and interrelated, previous studies used discrete choice models (binary and multinomial choice models, for example) which overlooked the possible interrelationships that exist among these strategies (Acquah, 2011; Belay et al., 2017; Desessa et al., 2009; Fosu-Mensah et al., 2012). Other studies, on the other hand, used multivariate probit technique that considers the possible interrelationship between adaptation strategies, but failed to examine the possible existence of reverse causation between them (Nhemachena and Hassen, 2007; Tesfaye & Seifu, 2016).

Given the identified methodological limitation, three-stage probit model was adopted as it takes into account the existence of interrelationships between the adaptations strategies and reverse causation between them (Alemayehu, Beuving, & Ruben, 2018). The three-stage probit model is a combination of both multivariate regressions (seemingly unrelated regression (SUR)) and two-stage probit regression. In a situation whereby cross-equation error terms are correlated and some explanatory variables are endogenous (as in our case), the three-stage probit approach is suitable. The use of such model can generate more efficient parameter estimates than other simultaneous equation estimation approaches such as SURE and two-stage probit. The three-stage probit estimator satisfies the requirements for an instrumental variable (IV) estimator, and it is asymptotically efficient among all IV estimators that use only the sample information (Greene, 2012). In this model, the exogenous variables are taken as instruments for the endogenous variables.

A regression model is described as:

\[ Y_{ij} = X_{ij}'B_j + Y_{im}'\theta_m + \epsilon_{ij} \]  

Where: \( Y_{ij} (j = 1, \ldots, m) \) represents the adaptation strategy (in our case \( m = 3 \)) practiced by the \( i \)th farmer (\( i = 1, \ldots, n \)), \( X_{ij} \) is a \( 1 \times k \) vector of observed variables that are hypothesized to affect the adaptation strategy practiced by smallholder farmers, \( B_j \) and \( \theta_m \) are \( k \times 1 \) vectors of unknown parameters (to be estimated), and \( \epsilon_{ij} \) is the random error term. In this specification, each \( Y_j \) is a binary variable and, thus, Equation (1) is actually a system of \( m \) equations (\( m = 3 \), in this case) to be estimated:

\[
\begin{align*}
Y_1 &= \alpha_1 + X\beta_1 + Y_2\theta_1 + Y_3\lambda_1 + \epsilon_1 \\
Y_2 &= \alpha_2 + X\beta_2 + Y_1\theta_2 + Y_3\lambda_2 + \epsilon_2 \\
Y_3 &= \alpha_3 + X\beta_3 + Y_1\theta_3 + Y_2\lambda_3 + \epsilon_3
\end{align*}
\]  

Where: \( Y_1, Y_2, Y_3 \) a set of three latent variables underlying each of the adaptation strategy choice decision such that \( Y_j = 1 \) if \( Y_j > 0 \); 0 otherwise.

The explanatory variables were selected on the basis of the literature review and data availability. They were categorized as household characteristics (key demographics, size, and composition), wealth attributes (various assets and technologies), and endogenous variables (improved potato variety use, irrigation practicing and Intercropping) in which each explanatory variable would have location and adaptation specific effect.

3. Results and discussions

3.1. Description of the socioeconomic characteristics of sampled households

In Table 1, we presented the summary statistics of the socioeconomic characteristics of the sampled smallholder farmers. The socioeconomic distribution of smallholder farmers shows that the average age of the respondents is about 36 years with 3.4 mean years of schooling and
average family size of six members. Regarding the gender distribution of the sampled households, in the study area, the majority (98.8%) of the households are male-headed. Landholding of farm households is very small averaging to about 0.35 ha per household. Many past studies also reported similar results (Alemayehu et al., 2018; Debela, Diriba, & Bekele, 2018). The size of landholding ranges between 0 and 3 ha. The main job in the study area is farming. Majority, as responded by 90%, do not have additional employment to subsidize their livelihood. Our dataset also shows that the average livestock holding is about 2.5.

Regarding distances to different information center, the descriptive statistics shows that sampled households travel on average 46.9 min to the nearest market center. Finally, 73% and 79% of the sampled households have reported that they have an access to transportation and credit services, respectively.

### 3.2. Potato varieties grown in the study area

In the study area, smallholder farmers grow different varieties of local and improved potatoes. Figure 1 shows the percentage distributions of the varieties. Accordingly, Shantam is found to be the most widely grown improved potato variety (IPV) (39.34%) followed by Bubbu (13.86%). On the other hand, Illiiii Dima (18.56%) is the most popularly grown local potato variety (LPV) in the study area.

Though improved varieties are important to increase yield and address food security problem, paradoxically, smallholder farmers in the study area have shown high interest in the LPVs. It can be expected that there would be tendencies to dis-adopt the IPVs. During one of the focus group
discussions (FGDs) organized with the model farmers and development agents (DAs), the farmers reported their preference for LPVs to IPVs. Some of the reasons mentioned by smallholder farmers for their choice of LPVs were (i) provision of incomplete package of the IPVs and complementary inputs, (ii) short shelf life of IPVs (e.g. Gudanne) as compared with LPVs, (iii) high vulnerability to pests and diseases, wilt incidence, decay and weight loss, and (vi) low crop aftermath of the IPVs as compared with LPVs which is an important animal feed in the study area.

3.3. Climate change-induced problems and their intensity

Smallholder farmers in the study area reported different types of climate change problems that challenge the production of potatoes. Some of the identified problems were: water log during early raining season, soil erosion, drought, frost (wurchi/amadey), and pests and diseases. The adverse effects of these problems and their intensity are depicted in Figures 2 and 3, respectively. More than
60% of the respondents reported the prevalence of all of the aforementioned climate change-induced problems in their locality. Similar to the finding of the study by Tesfahun (2018), drought, soil erosion, and water log were intensively challenging potato production in the study area as reported by quite half of the respondents. Frost (wurchi/amadey) is the worst type of climate change-induced problem to potatoes production as reported by 90% of the respondents, see Figure 4. Frost (wurchi/amadey) which occurs in two-to-three laps of years not only affects potatoes production but also the production of khat (Chata edulis forsk), the most widely grown cash crop in the study area. As smallholder farmers' livelihood mainly depends on the production of the two crops, the adverse effects of climate change on their production aggravate food insecurity in the area.
3.4. Three-stage probit regression results

Smallholder farmers adopt and exercise different strategies that can reduce the adverse effects of climate change on economic livelihoods and food security. Three major climate change adaptation strategies, namely: adoption of IPVs, irrigation usage and intercropping were practiced in the study area. This paper assessed the relationships between socioeconomic variables and the identified strategies used by smallholder farmers. The findings discussed in previous studies explained on how households mitigate the effects of climate change they face, and they unveil the specific strategy to be adopted. This study empirically justifies whether these explanations fit with our data set or not.

We computed the pair-wise correlations of the error terms associated with each specific strategy adopted and tested their significance. The pair-wise correlations are statistically significant. This implies that adaptation strategies are interrelated. The effects of different socioeconomic variables on adaptation strategies used by smallholder farmers were assessed. The estimation was done jointly for dependent variables using three-stage probit regression model; the regression results are given in Table 2.

3.4.1. Discussion of factors influencing smallholders’ choice of adaptation strategies

One of the adaptation strategies discussed in this study is adoption of IPVs. The adoption of improved varieties in general and IPVs in particular is recognized as one of the most frequently advocated strategies for climate change adaptation in agriculture (Abdulai, 2018; Belay et al., 2017; Smit & Skinner, 2002).

The adoption of improved varieties with early maturity, drought tolerance and pests and diseases resistant can slowdown or even halt the adverse effects of climate change (Abdulai & Abdulai, 2016; Kassie et al., 2017). Thus, smallholder farmers adopt and cultivate such varieties that are highly resistant to adverse effects of climate changes and that can provide high yields (Zizinga et al., 2017).

Moreover, this study identified factors affecting the adoption of IPVs as one of the adaptation strategies used by smallholder farmers in the study area. The analysis included important household characteristics without specifying any a priori expectations.

The results of the three-stage probit model show that farmers’ educational level negatively affects the adoption of IPVs by smallholder farmers. This finding confirms with the findings of past studies by Dadi, Burton, and Ozanne (2004), and Beyene and Kassie (2015) in which education level was found to reduce the tendency to adopt improved crop varieties. This is mainly due to either farmers with higher educational attainment are reluctant to adopt improved crop varieties as they always calculate the cost-benefit of adopting the improved varieties. Put it differently, educated smallholder farmers can better evaluate and choose the best strategy compared with uneducated farmers. on the other hand, some technology adoption studies by Abdulai and Huffman (2005), Murage et al. (2011), Abebe and Bekele (2015) and Lemessa (2017) state that education level promotes adoption of improved crop varieties.

One of the household attributes, farmer’s age, is inversely related to the adoption of IPVs in the study area alike past studies (Belay et al., 2017; McKillop, Heanue, & Kinsella, 2018). This implies that as farmer’s age increases, they become less interested to adopt IPVs similar to the finding of the study by Bekele (2015) which showed the tendency of older farmers to avert risk than their younger counterparts. It is a usual practice that older farmers tend to experience much with their traditional farming practices than to adopt improved crop varieties. Albeit older farm households have relatively better physical and social capital, they are unwilling to adopt IPVs.
The parameter estimate of farm household family size is directly related to the adoption of IPVs. This is because households with high family size can easily provide the required labor inputs to adopt IPVs which require intensive care including proper land preparation, timely weeding and harvesting. The finding of this study is in line with the studies by Zizinga et al. (2017), Shikuku et al. (2017) and Belay et al. (2017) which revealed the positive influences of household family size on the adoptions of improved crop varieties.

Among wealth-related variables, access to non-farm income and fertilizers usage explain farmers’ adoption of IPVs to a significant extent. Access to non-farm income influences a household’s decision to adopt IPVs positively and significantly. We surmise that this is because income obtained from non-farm activities can be utilized for the purchase of different types of

| Table 2. Three-stage probit regression model results |
|-----------------------------------------------------|
| Variables                                           | Adaptation strategies |
|                                                    | Potato variety adoption strategy | Irrigation usage strategy | Intercropping strategy |
| Household characteristics                          |                         |                         |                         |
| District                                           | -0.020                  | -                        | -                        |
| Gender                                             | 0.102                   | 0.464**                  | -                        |
| Family size                                        | 0.023***                | -                        | -                        |
| Age                                                | -0.003**                | -0.003                   | -                        |
| Education                                          | -0.003**                | -0.012*                  | 0.006**                  |
| Religion                                           | -                        | 0.025                    | -                        |
| Extension visit                                    | -                        | -0.123**                 | -0.041                   |
| Marital status                                     | -                        | -                        | -0.020                   |
| Availability of farm training center               | -                        | -                        | 0.077**                  |
| Wealth Variables                                   |                         |                         |                         |
| Access to non-farm income                          | 0.028*                  | -0.043*                  | -0.029                   |
| Improved potato seed adoption                      | 0.006                   | 0.017                    | 0.015                    |
| Herbicide use                                      | -0.002                  | -                        | -                        |
| DAP fertilizer use                                 | 0.004**                 | -0.007**                 | -0.0004**                |
| Urea fertilizer use                                | 0.002**                 | -0.0005                  | -0.0001*                 |
| Manure use                                         | 0.0008                  | -0.0002                  | 0.0002                   |
| Plot fertility status                              | -                        | -0.004                   | -0.030                   |
| Compost use                                        | -                        | 0.095**                  | -                        |
| Access to credit                                   | -                        | -0.099*                  | -                        |
| Family labor                                       | -                        | -0.0008                  | -                        |
| Water log problem                                  | -                        | -0.020                   | -                        |
| Access to irrigation                               | -                        | -                        | -0.005                   |
| Endogenous variables                               |                         |                         |                         |
| Potato variety adoption strategy                   | -0.572***               | -0.481                   | -0.102***                |
| Irrigation usage strategy                          | -0.711***               | -0.195                   | -                        |

***, ** and * indicate the tests are significant at 1%, 5%, and 10% probability level, respectively.

1We excluded some variables from each regression equation to attenuate the problem of multicollinearity.

The parameter estimate of farm household family size is directly related to the adoption of IPVs. This is because households with high family size can easily provide the required labor inputs to adopt IPVs which require intensive care including proper land preparation, timely weeding and harvesting. The finding of this study is in line with the studies by Zizinga et al. (2017), Shikuku et al. (2017) and Belay et al. (2017) which revealed the positive influences of household family size on the adoptions of improved crop varieties.
agricultural inputs including fertilizers, pesticides, and herbicides. On the other hand, the positive coefficient of non-farm income also indicates that farmers with higher and diversified income are more interested to adopt new crop varieties than others since more investment is required not only for the adoption but also for undertaking adoption of complimentary activities.

The second considered adaptation strategy in this study was irrigation usage. Household characteristics showed mixed effects on farmers’ irrigation use as an adaptation strategy to climate change, see Table 2. Variables such as age and religion were found not statistically significant. Gender of the household head showed a significant positive effect on farmers’ irrigation facilities usage. This shows that male-headed households are more interested to use irrigation facilities than their female-headed counterpart. Likewise, the study by Shikuku et al. (2017) found that male-headed households have had higher climate change adaptation index.

We expect that variables such as education and extension visit can improve farmers’ analytical capacity to evaluate the available strategies for the selection of feasible strategies. Therefore, these variables are expected to have a positive effect on farmers’ irrigation usage positively. Unexpectedly, however, these variables showed significant negative effects on farmers’ irrigation usage. Smallholder farmers found this strategy less feasible than others or there is a paradox on farmers’ choice of adaptation strategies.

Wealth-related variables also had mixed effects on farmers’ irrigation usage. Variables such as chemical fertilizer (DAP, for example), non-farm income and access to credit have negative effects on farmers’ irrigation usage, whereas other variables like compost (organic fertilizer) had a positive effect as the combined usage of irrigation and organic fertilizers boosts farmers’ productivity. Compost usage along with irrigation would also yield crop aftermath that would be important for compost preparation. Our finding is in line with Di Falco, Veronesi, and Yesuf (2011) who found that inputs such as seeds, fertilizers, manure, and labor are significantly associated with an increase in the quantity produced per hectare by the farm households that adapted to climate change. This is also consistent with predictions of economic theory.

The negative effects of farmers’ access to non-farm income on their irrigation usage are practically and conceptually reasonable because irrigation is a labor-intensive activity on the one hand and the search for non-farm income releases labor from agriculture.

Thirdly, intercropping of potatoes with different crop varieties is identified as one of the adaptation strategies to climate change as it is widely applied in the study area. Unlike the studies by Tesfaye and Seifu (2016) and Belay et al. (2017) in which crop diversification and switching were identified as adaptation strategies, we rather opted for intercropping as suitable strategy. This is because the farm size in the study area is very small and hence unsuitable for crop diversification and switching. Factors that positively affect this strategy choice are found to be education, availability of farmers’ training centers close to farmers’ homestead and fertilizer usage by smallholder farmers. The significant positive coefficient of education shows that farmers with a higher educational attainment are more likely to use intercropping to combat adverse climate change effects.

In this study, we obtained mixed results regarding the effects of wealth-related variables on intercropping as an adaptation strategy. Most of these variables exhibited insignificant effects on intercropping. Whereas variables like usage of chemical fertilizer affects intercropping negatively. The positive coefficient for the usage of chemical fertilizer shows the efficient use of the input as multiple crop varieties are cultivated on a given plot.
3.4.2. Interrelationships and reverse causation among adaptation strategies

The three-stage probit model results regarding the interdependence and reverse causation of the three adaptation strategies are negative. This implies that the usage of one strategy precludes the other. For instance, irrigation usage and intercropping strategies have significant negative effects on adoption of IPVs. This could be because smallholder farmers can still obtain better yield and cope up with climate change risks either through intercropping or irrigation usage as strategy with the local varieties. Other adaptation strategies do not have significant effects on farmers’ irrigation usage as an adaptation strategy to climate change. On the other hand, adoption of IPVs and irrigation usage affect intercropping negatively. This is due to the fact that improved crop varieties are not mostly compatible to intercrop with other varieties. The negative effect of irrigation on intercropping implies that the intensity of water consumption patterns for the intercropped varieties may not be at the same pace.

4. Conclusion and policy implications

Climate change is one of the most daunting challenges facing the world in the twenty-first century. It has obvious and direct effects on agricultural production, productivity, and quality. The non-avoidable nature of climate change occurrence and its adverse effects on smallholder farmers’ livelihood and food security calls for urgent interventions. Unlike past studies, this study analyzed the different climate change adaptation strategies applied in the study area. The interrelationships and reverse causation of the strategies and the associated factors were identified. The study identified three most commonly practiced climate change adaptation strategies in the study area, namely: adoption of IPVs, irrigation usage and intercropping. The descriptive result shows that Shantam is the most widely grown IPVs in the study area. Among the identified climate change-induced problems, frost (wurchi/amadey) is the worst climate change incidence that severely affects potato production.

The three-stage probit model results regarding the interdependence and reverse causation of the three adaptation strategies are negative in a sense that the usage of one strategy precludes the other. The model results also revealed that education level affects adoption of IPVs and irrigation usage negatively and significantly while it affects intercropping positively. Chemical fertilizer usage has a significant positive effect on adoption of IPVs and negative effect on irrigation usage and intercropping. Wealth related variables showed mixed results regarding their influences on strategy choices. The main epilogue of this study is that smallholder farmers are inclined to grow LPVs than IPVs. While education failed to support adoption of IPVs and irrigation usage, extension visit didn’t also support irrigation usage as climate change adaptation strategy.

The following practical implications can be drawn from the findings of this study: Firstly, based the findings of this study, as also recommended by Tesfaye and Seifu (2016), farmers’ adaptive capacity to the adverse effects of climate change should be strengthened and enhanced. Secondly, as suggested by Belay et al. (2017) and Abdulai (2018), the study results alluded that irrigation usage, non-farm income, and adoption of IPVs reduce the effects of adverse climate change. Therefore, future interventions that increase agricultural production, productivity and quality and reduce farmers’ risk exposure should consider the provision of irrigation facilities improved agricultural technologies and access to off-farm work opportunities. Thirdly, in order to improve agricultural production, productivity and quality and reduce climate change risks, smallholder farmers’ adoption strategy choice to climate change should be prioritized based socio-demographic factors. Fourthly, the agricultural research system in the country should assist the smallholder farmers in the identification of improved crop varieties that are suitable for intercropping and irrigation use.

We also recommend the following future research directions on climate change: Firstly, studies which include more climate variables and more adaptation strategies should be carried out. Secondly, future studies should also consider the use of panel data to come up with more robust findings as climate change adaptation strategy choice as a response to food security is a longitudinal issue.
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Competing Interests
There are no any competing interests on this manuscript as the university granted the authors a full right to disseminate the research findings of this study by publishing it on journals of high repute like that of the Journal of Agriculture and Food Security (JAFS).

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All the three authors have made equal contributions in producing this manuscript except the first author had initiated the very idea.

Availability of data and materials
Data collected for this research are available with the authors and they are the property of the Office of the Vice President for Research Affairs of the Haramaya University for the office had financed the data collection task.

Conflict of Interest
We would like to declare that there is no conflict of interest.

Ethical Approval
This article does not contain any studies with human participants performed by any of the authors participated in this study.

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Notes
1. WurchiAmadey is a local name for frost in Amharic and Afan Oromo, respectively.
2. Kebele is the smallest administrative unit in Ethiopia.

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