Determinants of smallholder farmers' adoption of adaptation strategies to climate change in Eastern Tigray National Regional State of Ethiopia

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ABSTRACT

Climate change has been significantly affecting smallholder farmer's livelihood and food security. However, efforts to support farmer adaptation are hampered by the lack of scientific and context based evidences. Hence, this paper identified the major adaptation strategies to climate change (CC) and analysed the determinants of adoption of adaptation strategies to climate change in Eastern Tigray Region of Ethiopia. Three-stage sampling technique was used to select the study sites and sample households. Copies of 485 questionnaires were administered and complemented with data from focus group discussion and key informant interviews. Results of the descriptive analysis identified that use of soil and water conservation practices, planting trees, improved crop seeds, irrigation and use of non-farm income generating activities are the most utilized adaptation strategies to climate change. Results of the multinomial logistic regression (MNL) revealed that households' adaptation to climate change was found positively and significantly affected by education, livestock holding, cooperatives membership, extension services, farmers income and households perception to climate change. On the contrary, age of the household head, distance to market and agro-ecology were found negatively and statistically affecting smallholder farmers adoption of adaptation strategies to climate change. Thus, public policy on climate change adaptation need to take into account local people's resource base and their lifelong outlooks so as to reduce the potential drawbacks of climate change on farmers' livelihood.

1. Introduction

Human activities have already caused some irreversible changes to agro-ecosystems. Further damage is likely to be worsening as indicated by recent anthropogenic emissions of greenhouse gases as a result mass deforestation and complete dependence on non-electric vehicles are the highest in history resulting widespread impacts [1, 2, 3, 4, 5, 6, 7]. Previous studies confirmed that climate change is real challenge that people need deal with over the coming decades [10, 11]. Currently, climate change is getting global concern due to its transboundary multidimensional negative impacts. These are more devastating on agricultural livelihood and rural poverty [12]. The adverse effects of climate change on farm-based livelihoods are manifested through shifts in cropping seasons and a loss in agricultural productivity [3, 13].

According to the Paris Agreement report, 196 Parties including Ethiopia are already agreed to adopt the new legally-binding framework for an internationally coordinated effort to tackle the effect of climate change [14], which is necessary to achieve the goals of sustainable development. In regards to this, different countries face varying challenges and have different capacities to address the challenges. Yet, some developed countries with strong adaptation and mitigation capacity to reduce climatic problems have shown resistance to act according to the binding negotiation [3, 14], which has made the global effort full of challenge. Despite its less contribution to greenhouse gas emission, Africa is one of the most vulnerable continents to carry lions of share on the current and expected future climate variability and change with strong socio-economic impacts [3, 15, 16]. In connection to this, Ethiopia is often cited as best example [17, 18]. In Sub-Saharan Africa, majority (63%) of the population continues to depend on rain fed agriculture which is extremely susceptible to the impacts of climate change.
change. As a result, a study in Ethiopia evidenced that smallholder farmer's income reduced, food insecurity increased and the economic gap between the poor and the better off is widening while human population is increasing exponentially [20]. This aggravated the already existing problem of food supply shortage to feed the ever increasing population in general and worsening the livelihood situation of the smallholder farmers that are dependent on the subsistence agriculture in particular. Due to their limited capacity, low income countries like Ethiopia are responsible to plan and implement context based climate change adaptation measures [3].

Previous empirical studies reported that agricultural measures such as like use of improved crop varieties, planting trees, soil conservation, changing planting dates and irrigation as the most used adaptation strategies to climate change in African countries [21, 22]. Recent works of scholars have also showed that smallholder farmer's choices and usage of these adaptation strategies to climate change depends on a number of socio-economic and institutional factors [2, 23, 24, 25]. For instance, findings of previous empirical studies showed that gender, inadequate information, limited awareness and farming experiences, household size, years of education, access to credit facilities, access to extension services, off-farm income generating activities are among the accountable factors for hampering adaptation to climate change [17, 26, 27, 28, 29, 30, 31, 32]. Similarly, empirical studies in Ethiopia also reported that education level, livestock ownership, and availability of credit significantly influences the ability of farmers' adaptation in Ethiopia [27]. However, rural household's adaptation to climate change is not unique and the factors determining smallholder farmers for choosing and adopting climate change adaptation strategies have a dearth of information and it was demanded to be studied in the study district. Thus, the choice of climate change adaptation methods depends on a range of variables which are considered important for the availability, accessibility and affordability of particular adaptation procedures [21, 25]. This seeks situation based and an in-depth understanding of smallholder farmer's adaptation choices to climate change, identification of the socio-economic, institutional and environmental factors that are hampering adoption of farmers' adaptation strategies to climate change so as to carryout scientific research finding based appropriate policy measures accordingly that has been missed in the study area.

Therefore, this particular study has made its spotlight on location based understanding of smallholder farmer's choices of adaptation strategies to climate change, and analyzing what and how the social, economical, institutional and environmental factors affecting farmers in adopting the adaptation strategies to climate change that plays pivotal role in formulating appropriate on-farm and non-farm climate change adaptation strategies and policy measures in the study area. This is found to be very advantageous in the study area, where subsistence and climate change sensitive agriculture is the dominant sources of livelihood and economic development. Besides, it also plays imperative role in achieving the goals of economic development, food security, poverty reduction and livelihood improvement of the smallholder farmers while maintaining the ecological balance of the environment. Therefore, the objectives of this study were to: (1) assess smallholder farmers' adaptation strategies to climate change and (2) analyze determinants of smallholder farmers' adoption of adaptation strategies to climate change in Saeisetaeda Emba district of Eastern Tigray Region of Ethiopia.

2. Research methods

2.1. The study area

The study was conducted in Saeisetaeda Emba district, Eastern Tigray Region of Ethiopia. The district is located 883 km far from Addis Ababa, capital city of Ethiopia. The agro-ecology of the district experiences semi-arid climate which is naturally characterized by irregular rainfall, low vegetation cover, poor quality of soil fertility, severe degradation, and drought. The study district receives an average annual rainfall ranging from 350 to 500 mm and temperature ranging from 13 °C to 20 °C. The predominantly unimodal rainfall that usually runs from June to August is characterized by temporal and spatial variability [33]. This 3 months rain season is also continuously varying and getting decreased overtime because of unpredictable climatic variability and change and this has evidently resulted smallholder farmers food security crisis as a result of crop failure and widespread livestock diseases in the area.

2.2. Types and methods of data collection

Multi-stage sampling techniques were employed to select the study district and sample households. First, purposive sampling was applied to select Saeisetaeda Emba district from the seven districts in Eastern zone of Tigray. The key reasons were that the district is characterized by drought prone-area, high population growth with limited and eroded farmland, prevalence of food insecurity and widespread poverty [34]. Second, stratified sampling technique was used to select five rural Kebele administrations (KAs) out of the 25 rural KAs. The selected Kebeles are Raele, Hawile, May-megelta, Sendeda and Sewne (Figure 1). Finally, 485 sample households were selected using proportional sampling followed by systematic random sampling technique from the study Kebeles.

Primary data was collected using structured interview, focus group discussions and key informants interviews. One focus group discussions were carried out in each of the three agro-ecological areas (low land, mid-land and high land). Between 5 and 7 people where gender balance is considered (e.g., women, researchers, extension workers, climate change adaptation experts, and elders) were participated in the focus group discussion from each of the five rural Kebele administrations. Similarly, key informant interviews (KIs) were conducted with three researchers, five agricultural experts, three development project coordinators, 9 elders and religious leaders.

2.3. Method of data analysis

Simple descriptive statistics such-like percentage and frequency were applied to analyse demographic and socio-economic characteristics of the sample respondents. Content analysis was used to investigate the qualitative data collected using focus group discussions and key informant interviews.

Different scholars have used various empirical methods to analyse the factors influencing adaptation strategies to climate change. The choices of the analysis methods depend on the adaptation strategies used by the farmers and the types of data collected in attaining the objectives of the research study.

Making it different, this study is modelled as a choice between combined alternatives that a farmer was adopted at least SWCP + VAR, SWCP + VAR + IRR, SWCP + VAR + DIVIN, VAR + IRR + DIVIN or No adaptation options to climate change. Therefore, for the purpose of this study, multinomial logistic regression (MNL) analysis was estimated to analyse the socio-economic and institutional factors affecting climate change adaptation choices among smallholder farmers where the dependent variable has multiple-outcomes ($j = 1 \ldots 6$; where a farmer $j(1)$ = did not use any adaptation to climate change (NO), $j(2)$ = use SWCP + VAR; $j(3)$ = use SWCP + VAR + IRR; $j(4)$ = use SWCP + VAR + DIVIN; $j(5)$ = use VAR + DIVIN; and $j(6)$ = use VAR + IRR + DIVIN climate change adaptation strategies). The estimation of the MNL model was made by normalizing no adaptation strategy to climate change as reference category for analysis. The maximum likelihood estimates as indicated by the chi-square test was found to be highly significant. Before running the MNL model, seven continuous and seven discrete/binary

1 Kebele is the lowest administrative unit in Ethiopia as peasant association in other countries.
explanatory variables were checked for multicollinearity using Variation Inflation Factor (VIF) and contingency coefficient respectively. The VIF for all the seven continuous variables were less than 10 and greater than one. Similarly, the result of the contingency coefficient test revealed that there is no problem of association among the seven discrete explanatory variables. This indicates no serious problem of multicollinearity. Thus, MNL was used to analyse all the hypothesized explanatory variables which were expected to affect the choice and adoption of adaptation strategies to climate change using STATA software version 12.1 and only statistically significant explanatory variables are discussed.

3. Results and discussion

3.1. Farmers’ adaptation strategies to climate change

Farmers in the study sites have a long traditional history of adapting to the changes and effects of the biophysical environment using different local climate change adaptation strategies. The use of different risk-minimizing adaptation strategies includes both traditional knowledge and newly introduced adaptation choices. This study summarizes choices of farmer’s adaptation strategies to climate change into three broad categories. These are agricultural water additions and land management; adjustment of farm and crop-livestock management; and diversification to non-farm adaptation strategies (Table 1). These were helpful to understand the possible adaptation strategies that can be used by the smallholder farmers; how and what they perceive about the importance of the adaptation strategies; and to assess whether they had practised it before or not and why if not.

Results in Table 1 shows that majority of the sample farmers perceive the agricultural water additions and land management choices as good adaptation strategies to climate change such as implementation of soil and water conservation, change in the quantity of land under cultivation, leasing of land, moving to different farm site, deep tillage, pond-making, irrigation usage, water harvesting, compost preparation and usage, digging water wells, managing floods and droughts, and run-off harvesting adaptation measures in agriculture for addressing climate change in the study district. However, the majority of the sampled households had been engaged poorly in the agricultural water and land management adaptation choices except in soil and water conservation which is highly practised by 85.6% of the sample households.

These soil and water conservation becomes public and regular practices of the farmers under the environmental rehabilitation programme in the study district. All farmers who are in the range of productive age have a mandate to participate in the public soil and water conservation practices for 40 days of free labour during the dry season mostly in January and February months of every year. Apart from this, farmers also actively participated in food for work projects such as plantation of trees at summer time/rainy season, soil and water conservation practices, construction of small-scale irrigation dams, and rural road expansion programmes under the productive safety net programme (PSNP). The main aim of the project is to save life from climate change related disasters like drought and soil erosion while they are participating in different rural development activities.

With regards to the adjustment of farm and crop-livestock management adaptation choices more than 93% of the sample households perceive that all the adaptation strategies and reduction of livestock population (67.8%) are useful measures of adaptation to climate change. Whereas about 50% of the households responded that shifting from crop to livestock is not useful measure. Though there exists less participation of farmers in practising the water additions and land management adaptation choices; farmers showed better participation in adjustment of farm and crop-livestock adaptation choices. Especially, the use of new crop variety, crop rotation, use of short maturing drought resistant crop, usage of organic and inorganic fertilizer, and planting trees were among the dominantly used adaptation strategies. Whereas change in planting date, weeding and harvesting date, fallowing land, mixed crop-livestock
farming system, reducing livestock number, and managing pest and disease prevalence were found moderately practised by the sample households (Table 1). On the other hand, shifting from crop production to livestock husbandry and vice-versa and proper usage of pesticides and herbicides were reported least practised adaptation choices.

Furthermore, the sample respondents were asked to identify any livelihood diversification strategies they know as good adaptation measures to climate change and which they had practised before. Accordingly, results in (Table 1) indicate that resource rent income (92.2%), migration (92.2%), agricultural and non-agricultural wage labour (92.2%), remittance income (92.2%), crop insurance (92.2%), handcraft (92.2%), petty trading (92.2%), and usage of natural resources like forest for charcoal and wood (92.2%) were said as a highly advisable adaptation strategies to climate change. However, despite their good awareness on the role of non-farm income, majority of the sample households are less used in livelihood diversification strategies in response to climatic change.

Additionally, participants of focus group discussion were also identified that wild food gathering, reduction in food intake, livestock trade, seeking aid assistance (both food and finance), working as agricultural labourers, food reserve and storage, dissemination of drought-related early warning information, crop insurance, pricing reform, extension service, income diversification, improving weather forecasting, land-use change, and the development and adoption of new technologies as major adaptation strategies for the agricultural sector to cope with climate variability in drought-prone areas. Moreover, farmers often had been observed having good knowledge in identifying different adaptation measures to climate change from their long life farm experiences. However, low technical skill on the application of the adaptation measures, lack of capital, shortage of farm-land, high population pressure, lack of demand driven training in both crop and livestock production,

### Table 1. Choices of climate change adaptation strategies by smallholder farmers.

| Adaptation choices | Do you think as a good strategy? | Have you practiced it before? |
|--------------------|---------------------------------|------------------------------|
|                    | Yes    | No   | Yes    | No    |
| **Agricultural water and land management** |         |      |         |       |
| Innovative soil and water conservation methods | 99.2    | 0.8  | 85.6    | 14.4  |
| Change the quantity of land under cultivation | 86.8    | 13.2 | 36.3    | 63.7  |
| Leasing land to gain half of crop yield or immediate cash | 74      | 26   | 18.6    | 81.4  |
| Moving to different farm site | 84.1    | 15.9 | 16.1    | 83.9  |
| Deep tillage | 93.4    | 6.6  | 34      | 66    |
| Pond making for small scale-scale irrigation | 98.1    | 1.9  | 35.3    | 64.7  |
| Using irrigation from well, dam, river etc | 98.6    | 1.4  | 19.2    | 81.8  |
| Water harvesting | 97.1    | 2.9  | 29.7    | 70.3  |
| Compost preparation to increase land fertility | 93.6    | 6.4  | 26.2    | 73.8  |
| Digging water wells | 99      | 1    | 36.9    | 63.1  |
| Managing floods and droughts using reforestation program | 97.7    | 2.3  | 62.5    | 37.5  |
| Runoff harvesting to manage soil erosion | 81.6    | 18.4 | 38.8    | 61.2  |
| **Adjustments of farm and crop –livestock management** |         |      |         |       |
| New high yielding crop variety | 99.6    | .4   | 83.1    | 16.9  |
| Short maturing crop varieties | 98.6    | 1.4  | 84.9    | 15.1  |
| Crop rotation | 99.4    | .6   | 84.5    | 15.3  |
| Change in planting, weeding and harvesting dates | 95.5    | 4.5  | 57.3    | 42.5  |
| Apply inorganic fertilizer | 97.5    | 2.5  | 94.6    | 5.4   |
| Apply farmyard manure/organic fertilizer | 99      | 1    | 93.4    | 6.6   |
| Fallowing | 93.8    | 6.2  | 61.2    | 38.8  |
| Drought resistant crops | 93.4    | 6.6  | 71.3    | 28.7  |
| Managing pest and disease prevalence | 98.1    | 1.9  | 54.2    | 45.8  |
| Proper usage of pesticides and herbicides | 96.1    | 3.9  | 44.1    | 55.9  |
| Mixed cropping | 92.8    | 7.2  | 45.6    | 54.4  |
| Planting trees | 98.4    | 1.6  | 70.7    | 29.3  |
| Use mixed crop-livestock farming system | 95.9    | 4.1  | 55.7    | 44.3  |
| Changing from livestock to crop production | 51.3    | 48.7 | 28      | 72    |
| Changing from crop production to livestock | 44.5    | 55.5 | 11.3    | 88.7  |
| Reducing the number of livestock | 67.8    | 32.2 | 47      | 53    |
| **Diversification to non-farm adaptation choices** |         |      |         |       |
| Salaried/professional employment | 96.5    | 3.5  | 9.1     | 90.9  |
| Resource rent income | 92.2    | 7.8  | 5.2     | 94.8  |
| Migration to urban areas-temporary/seasonal migration | 78.6    | 21.4 | 37.5    | 62.5  |
| Wage work/daily labourer | 95.9    | 4.1  | 42.1    | 57.9  |
| Remittance income | 94.6    | 5.4  | 31.3    | 68.7  |
| Crop insurance | 78.9    | 21.1 | 3.5     | 96.5  |
| Handcraft | 88.9    | 11.1 | 4.3     | 85.8  |
| Petty trading | 96.9    | 3.1  | 13      | 87    |
| Preparation and selling of local beverages e.g. ‘siwa’, ‘mess’ | 92.6    | 7.4  | 3.3     | 96.7  |
| Natural resources (wood, charcoal, minerals) | 81.6    | 18.4 | 6.2     | 93.8  |
poor development of water infrastructure, lack of coordination and follow-up to work together were pointed out as core reasons for low application of the adaptation measures to climatic change in the study area.

3.2. Possible and actual combined climate change adaptation choices of smallholder farmers

Additionally, it was realized that the majority of the farmers were using combination of different adaptation strategies, while some few still did not use any adaptation measures to climate change. This was due to many socio-economic, institutional, and environmental factors that determine farmers to use combined climate change adaptation strategies in the context of this study. The actual adaptation strategies to climate change were regrouped into five broad climate change adaptation categories such as no adaptation (NO), soil and water conservation and planting trees (SWCP); improved crop varieties (new variety, drought tolerant, resistant to disease, short season) (VAR); irrigation (IRR); and diversification into off-farm and non-farm income (DIVIN). Again, the possible and the actual combined usage of the adaptation strategies by smallholder farmers were identified (Table 2).

The results as in Table 2 show that 6.2% of the farmers did not use any climate change adaptation strategies. This was reported due to health related problems such as physical disability and age. On the other hand, 21.4% of the farmers used a combination of soil and water conservation and planting trees together with improved crop varieties (SWCP + VAR) as leading climate change adaptation strategies. Similarly, 7.4% of the farmers used soil and water conservation and planting trees plus improved variety plus irrigation (SWCP + VAR + IRR) while 31.8% of the sample households used soil and water conservation and planting trees plus improved crop variety plus diversification into off-farm and non-farm income activities (SWCP + VAR + DIVIN). In fact, farmers were observed while using off-farm and non-farm income activities coupled with on-farm adaptation strategies to cope with the climatic related shock such as drought. For instance, 23.3% of the sample households used improved variety plus diversification into off-farm and non-farm income activities (VAR + DIVIN) whereas 9.9% of the sample households were found using improved crop variety + irrigation + diversification into off-farm and non-farm income activities (VAR + IRR + DIVIN) (Table 2).

Uses of soil and water conservation and tree plantings are common in the study area. All economically active labour force has a mandate to participate in the annual soil and water conservation practices and planting of trees in the area. Results further indicated that that the majority of the respondents engage in non-farm livelihood strategies as a response to climatic changes. This was basically due to the incapability of the poor agricultural production to feed the high population growth in the study area unless they can diversify their means of livelihood out of agriculture.

3.3. Determinants of smallholder farmers’ adaptation strategies to climate change

It was found that of the total 14 socio-economic, institutional and environmental factors (Table 3), majority (9) independent variables were found statistically affected smallholder farmers adaptation to climate change at different levels of significance (Table 4).

| Table 2. Percentage distribution of sample farmers across the possible adaptation choices. |
|---------------------------------------------------------------|
| **Choices (j)** | **Adaptation strategies** | **Soil & water conservation and planting trees (SWCP)** | **Crop varieties (short season and drought resistant) (VAR)** | **Irrigation (IRR)** | **Diversification into off + Non-farm income (DIVIN)** | **Percentage adopted** |
| 1. No adaptation (NO) | X | X | X | X | 6.2 |
| 2. Soil and water conservation and planting trees (SWCP) | X | X | X | X | 0 |
| 3. Crop varieties (short season and drought resistant) (VAR) | X | X | X | X | 0 |
| 4. Irrigation (IRR) | X | X | X | 0 |
| 5. Diversification into off + Non-farm income (DIVIN) | X | X | X | 0 |
| 6. SWCP + VAR | X | X | X | X | 21.4 |
| 7. SWCP + IRR | X | X | X | X | 0 |
| 8. SWCP + DIVIN | X | X | X | 0 |
| 9. SWCP + VAR + IRR | X | X | X | 7.4 |
| 10. SWCP + VAR + DIVIN | X | X | X | 31.8 |
| 11. SWCP + IRR + DIVIN | X | X | X | 0 |
| 12. SWCP + VAR + IRR + DIVIN | X | X | X | 0 |
| 13. VAR + IRR | X | X | X | 0 |
| 14. VAR + DIVIN | X | X | X | 23.3 |
| 15. VAR + IRRI + DIVIN | X | X | X | 9.9 |
| 16. IRR + DIVIN | X | X | X | 0 |
| **Total** | **100.0** |

*X* represents the possible adaptation combinations, total number of observation (**N** = 485).
Table 3. Description of the explanatory variables used in the model.

| Choices (j) | Adaptation strategies | Description and unit of measurement |
|------------|------------------------|-------------------------------------|
| 1. NO      |                        | No climate change adaptation (NO)   |
| 2. SWCP + VAR |                    | Soil and water conservation and planting trees (SWCP) + Crop variety (VAR) (new variety, drought tolerant, resistant to disease, short season) |
| 3. SWCP + VAR + IRR |                    | SWCP + VAR + Irrigation (IRR) |
| 4. SWCP + VAR + DIVIN |                  | SWCP + VAR + Diversification into off + non-farm income (DIVIN) |
| 5. VAR + DIVIN |                        | VAR + DIVIN |
| 6. VAR + IRR + DIVIN |                    | VAR + IRR + DIVIN |

Independent Variables |
| Description and unit of measurement | Expected sign |
|-------------------------------------|---------------|
| Sex                                | binary, 1 if the head is male and 0 if female | +/- |
| Age                                | continuous, age of household head in years | + |
| Education                          | continuous, education level of household head in years | + |
| Family size                        | continuous, family size of the household in adult equivalent | + |
| Income                             | continuous, total annual income of the household head in ETH | + |
| Land size                          | continuous, land size owned by the household head in hectare (ha) | + |
| Livestock                          | continuous, livestock hold by the household head in TLU | + |
| Wealth                             | categorical, community based relative wealth category of the household head (1 = better-off, 2 = less poor, 3 = poor) | + |
| Extension                          | binary, 1 if the head has access to extension services, 0 otherwise | + |
| Coopmem                            | binary, 1 if the head has access to formal cooperatives, 0 otherwise | + |
| Credit                             | binary, 1 if the head has access to credit, 0 otherwise | + |
| Mdtdista                           | continuous, distance from the nearest market (town) in km | |
| Ecology                            | binary, 1 if the head is from arid, 0 otherwise | +/- |
| Perception                         | binary, 1 if the head perceive climate change and 0 otherwise | + |

Table 4. Results of multinomial logistic regression on determinants of climate change adaptation choices.

| Climate change adaptation strategies by smallholder farmers |
|-----------------------------------------------------------|
| Variables | SWCP + VAR | SWCP + VAR + IRR | SWCP + VAR + DIVIN | VAR + DIVIN | VAR + IRR + DIVIN |
|-----------|------------|------------------|--------------------|-------------|------------------|
| Coef.     | Std. Err.  | Mar. effect      | Coef.             | Std. Err.   | Mar. effect      |
| Sex       | -0.462     | 0.860            | -0.540            | 0.249       | 1.036            | 0.292            | -0.379          | 0.861          | -1.091          | 0.913          | 0.944           | 1.467          | -0.321          | 1.004           | -0.0134         |
| Age       | -0.156***  | 0.008            | -0.145***         | 0.035       | 0.012            | -0.159***        | 0.0297          | 0.001           | -0.174***       | 0.032           | 0.0027          | -0.199***       | 0.035           | 0.0017          |
| Educatn   | 1.230***   | 0.045            | 1.001             | 0.660       | 0.0165           | 1.239***         | 0.587           | 0.0176          | 1.620***        | 0.624           | 0.0779          | 2.38             | 0.644           | 0.0792          |
| Famsize   | 0.0238     | 0.124            | -0.015            | 0.154       | -0.0005          | 0.0205           | 0.121           | 0.0159          | -0.177          | 0.138           | -0.0306          | 0.0937          | 0.147           | 0.0087          |
| Income    | -0.000     | 0.002            | -0.000            | 0.0925      | 0.0026           | -0.000           | 0.000           | -0.97            | -0.000          | 0.000           | 2.14             | -0.000          | 0.000           | 1.42e            |
| Farmland  | 0.395      | 0.350            | 0.130             | 0.377       | 0.0087           | 0.295            | 0.350           | 0.0277          | -0.014          | 0.365           | -0.0468          | 0.262           | 0.368           | 0.0021          |
| TLU       | 0.106**    | 0.016            | 0.092**           | 0.049       | 0.0004           | 0.087*           | 0.046           | -0.0047         | 0.016**         | 0.047           | 0.0018           | 0.121**         | 0.047           | 0.020           |
| Extension | 1.581*     | 0.832            | 0.840             | 0.947       | 0.0017           | 1.319            | 0.802           | 0.1499          | 0.582           | 0.852           | 0.0795           | 0.202           | 0.865           | -1.471           |
| Coopmem   | 1.493**    | 0.628            | 0.0298            | 2.091***    | 0.721            | 0.0337           | 1.594***        | 0.622           | 0.0374          | 1.646***        | 0.667           | 0.0049          | 2.239***        | 0.723           | 0.0456          |
| Credit    | -0.015     | 0.835            | -0.126            | -0.134      | 0.890            | -0.0155          | 0.224           | 0.813           | 0.0786          | -0.459          | 0.853           | -0.0908          | 0.525           | 0.879           | 0.0404          |
| Distance  | 0.0107     | 0.039            | 0.011             | 0.0745      | 0.048            | 0.0058           | -0.004          | 0.039           | 0.0040          | -0.023          | 0.047           | -0.0052          | 0.033           | 0.050           | 0.0024          |
| Wealth    | 1.700**    | 0.796            | 0.2725            | 4.128***    | 0.830            | 0.0645           | 3.084***        | 0.777           | 0.1234          | 5.106***        | 0.812           | 0.3303           | -3.499***       | 0.819           | 0.0131          |
| Ecology   | -1.290     | 0.861            | 0.1663            | -4.488***   | 1.40             | -0.0899          | -1.823**        | 0.845           | 0.1058          | -3.184***       | 0.983           | 0.1373           | -3.515***       | 1.134           | -0.0644         |
| Perception| 3.269***   | 0.831            | 0.0553            | 4.229***    | 1.05             | 0.1057           | 2.441***        | 0.782           | 0.2376          | 2.796***        | 0.836           | 0.0263           | 4.320***        | 1.096           | 0.1134         |
| Constant  | 12.064***  | 3.58             | 14.27***          | 3.89        | 16.788***        | 3.538            | 22.363***       | 3.688           | 11.354***       | 3.898           |

The reference category is no adaptation (NO)

Log Likelihood: -575.46743
Number of observation: 485
LR chi2 (70): 428.16
Prob > chi2: 0.0000
Pseudo R2: 0.2711

* ** *** denotes significant at less than 10%, 5% and 1% probability level respectively.

Contrary to prior expectation, age of household head (AGE) was found negatively and statistically affect use of SWCP + VAR, SWCP + VAR + IRR, SWCP + VAR + DIVIN, VAR + DIVIN, and VAR + IRR + DIVIN decreases by 0.08%, 0.12%, 0.01%, 0.27% and 0.17%, respectively as age of the household head increases by one year from the mean. Despite that old aged farmers were expected to have better farming experiences of knowing when climate change occurred, what types of climate change adaptation strategies best practised, and the challenges experienced; many of them have little knowledge about the
concept of climate change, its causes and its possible measures in the study area.

As expected, education of the household head (EDUCATION) was found to positively and statistically influence smallholder farmers choices of SWCP + VAR, SWCP + VAR + DIVIN, and VAR + DIVIN climate change adaptation strategies at 5%, 5% and 10% levels of significance, respectively. The results of the marginal effect depicted that keeping other factors constant, the probability of smallholder farmers to choose SWCP + VAR, SWCP + VAR + DIVIN, and VAR + DIVIN adaptation strategies to climate change increases by 0.45%, 1.76%, and 7.79% respectively as households level of education increases by one year from the mean. Higher educational credentials of the household in particular and the household members increased knowledge and skill required to respond to the adverse effects of climate change. It is also an instrument to equip with better knowledge, skill and develop positive attitude and the more likely to use better adaptation strategies to climate change. However, majority of households were illiterate and/or had been attended primary school. Result of the study is consistent with the findings of [27]. Similarly, household income (INCOME) was found to have positively and significantly affected households’ probability of adopting both soil and water conservation and planting trees (SWCP + VAR) and using improved crop varieties and diversification into non-farm income (VAR + DIVIN) adaptation strategies to climate change at 1% and 5% significance levels respectively. It was found that households with better income are the more likely able select and use combined climate change adaptation strategies.

Furthermore, livestock ownership (TLU) was found to have positively and statistically affected smallholder farmer’s probability to use soil and water conservation, planting trees and improved crop varieties (SWCP + VAR) at 5% significance level. It also positively and statistically impacted households choices of improved crop varieties plus diversification into non-farm activities (VAR + DIVIN); and improved crop variety + irrigation + non-farm livelihood diversification (VAR + IRR + DIVIN) adaptation strategies to climate change at 5% level of significance to both adaptation options. Households’ livestock ownership was found negatively and statistically influenced the probability of smallholder farmer’s choices of soil and water conservation and planting trees coupled with improved crop varieties plus irrigation (SWCP + VAR + IRR); and soil and water conservation and planting trees plus improved crop varieties plus diversification into non-farm activities (SWCP + VAR + DIVIN) at 5% and 1% significance levels respectively. Keeping other factors constant, smallholder farmers adoption of SWCP + VAR, VAR + IRR + DIVIN, and VAR + IRR + DIVIN adaptation strategies to climate change increases by 0.16%, 0.18% and 0.20% as households livestock ownership increases by one tropical livestock unit (TLU) from the mean. On the other hand, smallholder farmers adoption of SWCP + VAR + IRR, and SWCP + VAR + DIVIN adaptation strategies to climate change decreases by 0.04% and 0.47% respectively as households livestock ownership increases by one tropical livestock unit (TLU) from the mean. Livestock ownership is the most basic livelihood building asset next to crop production in the study area. Consistent with the study by [35], the result indicated that livelihood strategies plays a fundamental role in households decision making.

As expected, household’s access to extension services (EXTENSION) was found to have positively and statistically affected smallholder farmers participation in soil and water conservation and planting trees plus improved crop variety (SWCP + VAR) adaptation strategy at 1% significance level. The marginal effect in favour of smallholder farmers’ likelihood to choose and adopt SWCP + VAR adaptation strategy to climate change increases by 83.2% as household’s has access to formal extension services. In fact, extension services is important social mechanisms of interaction and enhance farmer’s potential for selecting and practicing climate smart agricultural adaptation strategies. However, limited number of degree graduates coupled with their poor knowledge on the impinging impacts of climate change and its possible measures are impacting the extension services. This could be an additional challenge to them for not providing adequate agricultural extension services to farmers on the required time and place and limited them to mainly focus on soil and water conservation, planting trees and improved crop varieties (SWCP + VAR) adaptation choices. This is similar to the findings of [27, 36].

As hypothesized, the estimated coefficient for households access to cooperatives (COOPMEM) has been found to have positive relationship with the choices and adoption of the combined adaptation strategies to climate change and statistically significant at 1% and 5% probability levels. This implies that as farm households membership to formal cooperatives increases by one unit likelihood of farmers’ to choose and adopt combination of soil and water conservation, planting trees and use of improved crop varieties (SWCP + VAR); soil and water conservation and planting trees coupled with improved crop varieties plus irrigation (SWCP + VAR + IRR); and soil and water conservation and plantings of trees plus improved crop varieties plus diversification into non-farm income (SWCP + VAR + DIVIN) adaptation strategies to climate change increases by 2.98%, 3.37%, 3.74% respectively. Similarly, keeping other factors constant, the marginal effect in favour of smallholder farmers choices and adoption of improved crop varieties plus diversification into non-farm activities (VAR + DIVIN), and improved crop variety + irrigation + non-farm livelihood diversification (VAR + IRR + DIVIN) adaptation strategies increases by 0.49%, and 4.56% respectively as households membership to agricultural cooperative increases by one unit. Farmers who have access to formal agricultural cooperative membership have smooth access to credit, updated market information on farm produce, improved agricultural inputs and different farm equipments which are crucial for adaptation to climate change. They also share experience on how to make business out of farming (e.g. trading). This is in line with the findings reported by [20, 24].

As expected, households’ relative wealth status (WEALTH) was found to have positively and statistically affected smallholder farmers likelihood into SWCP + VAR, SWCP + VAR + IRR, SWCP + VAR + DIVIN, VAR + DIVIN, and VAR + IRR + DIVIN adaption strategies to climate change at 5%, 10%, 10%, 10% levels of significance respectively. If other factors are held constant, interpretation of the marginal effect in favour of smallholder farmers adoption of SWCP + VAR, SWCP + VAR + IRR, SWCP + VAR + DIVIN, VAR + DIVIN, and VAR + IRR + DIVIN adaption measures to climate change increases by 27.25%, 6.45%, 12.34%, 33.03%, and 1.31% respectively as households’ relative wealth status shifted from poor to less poor or from less poor to better off. In fact, the better off households have high probability to choose combination of relatively best adaptation measures to climate change and are able to reduce their vulnerability. The result of this study is consistent with the finding by [20].

As expected, agro-ecology (ECOLOGY) was found to negatively and statistically influence smallholder farmers to choose and adopt SWCP + VAR + IRR, SWCP + VAR + DIVIN, VAR + DIVIN, and VAR + IRR + DIVIN adaption measures to climate change at 10%, 5%, 10%, and 10% significance levels, respectively. However, households’ probability of using SWCP + VAR + DIVIN adaption measures was found increased by 10.58% as smallholder farmers’ residence in the arid and semi-arid agro-ecology. The study sites are drought prone and agriculture is at its subsistence stage which is almost entirely rainfall dependent and water is very scarce for irrigation unless irrigation dams are constructed in the future. This all together with other factors are challenging smallholder farmers life and force them to be dependent on external support in the study area. This might be the possible reasons for households to mainly focus on adaption measures such as soil and water conservation and planting trees (SWCP + VAR) + livelihood diversification into non-farm income generating activities (DIVIN). The result is similar to the findings by [37].

As hypothesized, the estimated coefficient for farmers perceived climatic change (PERCEPTION) in rainfall, temperature and precipitation were found to have positively and statistically affected smallholder farmers’ choices and adoption of SWCP + VAR, SWCP + VAR + IRR,
SWCP + VAR + DIVIN, VAR + DIVIN, and VAR + IRR + DIVIN adaption strategies to climate change at 10% level of significance for all strategies. If other factors are held constant, interpretation of the marginal effect in favour of smallholder farmers adoption of SWCP + VAR, SWCP + VAR + IRR, SWCP + VAR + DIVIN, VAR + DIVIN, and VAR + IRR + DIVIN adaption strategies climate change increases by 5.53%, 10.57%, 23.76%, 2.63%, and 11.35%, respectively as households perception on climate change increases by one person. This implies that smallholder farmers who have observed climate change with respect to rainfall and temperature for the past two decades had 5.53%, 10.57%, 23.76%, 2.63%, and 11.35% higher probability of adopting SWCP + VAR, SWCP + VAR + IRR, SWCP + VAR + DIVIN, VAR + DIVIN, and VAR + IRR + DIVIN strategies to climate change than those who had not observed change in rainfall and temperature. Smallholder farmers who perceive changes in rainfall decrease and temperature increase are most likely observed to use adaptation measures such as drought tolerant and short season crops, soil and water conservation practices, and planting trees during rainy season. The survey result (Table 2) also suggested that about 6.2% of the smallholder farmers were not sure to take any adaptation strategies to climate change at all. However, perception on climate change is not necessarily a pre-condition for adaptation since farmers who perceive climate variability also observed using different climate change adaptation measures. The result is similar to the findings of [32, 38].

4. Policy implication of the study

The finding of this paper implies that raising awareness and perception of farmers are the pre-requisite for selecting and practicing appropriate climate change adaptation strategies and policy measures. Adaptation to climate change is a prevalent and imperative response to the climate change vulnerable smallholder farmers especially in rain fed agriculture and drought prone areas that demands due attention by policy. Also, the paper commendably attested that climate change adaptation strategies and household livelihood diversification strategies are two sides of the same coin. Without integrating them, it is impossible to attain the goals of household food security and reduce poverty in areas where high population growth and climate change induced risks are common. In addition, this study underscored the importance of considering socio-economic, institutional and farmer's perception for choice and adoption of climate change adaptation strategies.

5. Conclusion and recommendations

The study concludes that context ad location specific adaptation measures which are developed from farmers real life experiences and innovative culture as the most needed methods to cope with the changing climate and to improve smallholder farmer's livelihood. Smallholder farmers perceive real change in climate. Besides, the study clearly identified use of physical and biological adaptive technologies such as use of soil and water conservation methods, planting trees, use of improved crop seeds, irrigation practices and livelihood diversification as menu of choices to climate change adaptation. The paper identified that soil and water conservation together with planting trees as environmentally friendly adaptation practices to climate change in the study sites. Income generated from non-farm livelihood diversification activities also play massive role in selecting and combined usage of better adaptation strategies in response to climate change. In addition, this study underscored the importance of considering socio-economic, institutional and farmer's perception for choice ad adoption of adaptation strategies.

Finally, the study recommends that concerned development stakeholders need to give capacity building training in climate change so as to raise smallholder farmers awareness on the adaptation choices to climate change and its measures; farmers access to worth schooling will enhance the rural households' perception on climate change and enable them to use environmentally friendly best adaptation practices to climate change and to further scaled-up in other parts of the nation; and enhancing access to updated climate change information and recognizing farmers' lifelong experience on adaptation measures would be pivotal to the ongoing government efforts on climate change adaptation.

Declarations

Author contribution statement

Gebrehiwot Weldegebrhal Gebre: Conceived and designed the experiments; Performed the study; Analyzed and interpreted the data; Wrote the paper.

Hyacinth Ementa Ichoku, Philip Ogbounnia Phil-Eze: Analyzed and interpreted the data.

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Competing interest statement

The authors declare no conflict of interest.

Additional information

No additional information is available for this paper.

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