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# EXPLORING POTENTIAL ADAPTATION STRATEGIES FOR SMALLHOLDER FARMERS TO CLIMATE CHANGE: A CASE STUDY AT ABALA ABAYA, WOLAITA ZONE, SOUTH ETHIOPIA

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**Background:** The frequency and intensity of extreme weather events are expected to increase as a result of climate change, which will contribute to changes in precipitation and temperature, and therefore will affect food security. Research issues related to increasing the sustainability of the agricultural sector, eliminating climate risks in agriculture are coming to the fore. This is especially relevant in arid regions. **Objectives:** This study aimed to assess the adaptation strategies of smallholder farmers to climate change in Abala Abaya, Wolaita Zone, Southern Ethiopia. Finding optimal practices adapted to random extreme events is fundamental for sustainable food production. In particular, the study attempted to understand the preferences of smallholder farmers in adaptation strategies to climate change in the study area; the main influencing factors determining the choice of adaptation strategies to climate change by smallholder farmers in the study area. **Methods:** To investigate this issue, qualitative and quantitative data were used within a descriptive research approach to assess potential adaptation strategies of smallholder farmers to climate change. Data on demographic, socio-economic, institutional, physical and psychological factors for adaptation strategies of smallholder farmers were collected through specially designed and pre-tested questionnaires, interviews and focus group discussions (FGDs). Rural counties for the study were selected using simple random sampling due to the same agroecology. The Multi-Variate Probit (MVP) model was used as it is a type of correlated binary response regression model that allows for the simultaneous identification and assessment of the impact of a set of independent factors on each of the possible approaches. Five adaptation methods are identified as dependent variables for the Multi-Variate Probit. These include Soil and Water Conservation (SWC) practices, use of drought-tolerant varieties, adjustment of planting dates, use of agroforestry, and implementation of water harvesting. The following were selected as independent variables for the current study. **Results:** Most farmers (96.7%) acknowledge the ongoing climate change and are concerned that their agriculture will not suffer under the new conditions. This is justified by the fact that farmers confirm their observations regarding the increase in air temperature, the increase in the frequency of plant diseases and the decrease in precipitation. At the same time, only 36.2% of the surveyed farmers reported that society is aware of the possible risks associated with global warming and is trying to adapt agricultural activities to new climatic conditions. In particular, the current study revealed for the first time that smallholder farmers in Abala Abaya primarily prefer approaches such as soil and water conservation (71.6%), adjustment of planting dates (59.4%), and agroforestry (44.5%). **Conclusion:** The study identified the most influential factors on the adoption of adapted agricultural practices in a specific region of Abala Abaya (Wolaita Zone, Southern Ethiopia), namely, household heads' access to education, frequency of extension visits, access to climate information and land slope. Thus, decision makers can design and adopt appropriate programs based on the current results to preserve smallholder farming and maintain food security at the national level.

**Keywords**: climate change; crop vulnerability; drought; land degradation; sustainable development; agriculture.

## INTRODUCTION

Extensive research has now been conducted to study and understand the relationship between climate change, rising temperatures, drought, desertification, floods and the impacts of these phenomena (Javan & Darestani, 2024). The frequency and intensity of extreme weather events due to climate change are also expected to increase (Jung et al., 2024; Clemens & Beckage, 2023). Continued global warming, which causes changes in precipitation and temperature, is projected to significantly impact future crop yields and disrupt food production systems (Atiah et al., 2021). In this regard, scientists are conducting research aimed at increasing the resilience of the agricultural sector, namely, assessing the financial implications for agriculture and crop selection for cultivation in dryland regions (Javan & Darestani, 2024), understanding the impact of climate change on legume yields (Yeleliere et al., 2023), addressing climate risks in agricultural systems through the use of innovative adaptation techniques and soil-based strategies (Deng et al., 2023; Hasegawa et al., 2022), etc.

Developing countries are particularly vulnerable to the impacts of climate change due to their low adaptive capacity, over-reliance on the agricultural sector, and the presence of many other stressors (Yeleliere et al., 2023; Deng et al., 2023; Sinore & Wang, 2024). Sustainable Development Goal 2 (SDG 2) aims to end hunger, achieve food security and improved nutrition and promote sustainable agriculture. FAO has repeatedly reported in 2017 (FAO, 2017) that extreme climate conditions are reducing crop yields in Asia and Africa, which in turn impedes the achievement of SDG 2. Today, most African countries cannot achieve SDG 2, and the prevalence of undernourishment is increasing, so hunger levels are higher than the global average (FAO, 2020). Regardless of that, Africa as a whole, including Ethiopia, has a low adaptive capacity to withstand extreme events associated with climate change; farmers are implementing (testing/experimenting/applying) their adaptation strategies for crop cultivation. The practical approaches to overcoming difficulties indicated are highly relevant in drought-prone areas and frequent climate hazards. Deressa & Hassan (2009) conducted a study based on farmer responses to climate change and agricultural production in different agroecological zones of Ethiopia. The findings predicted a gradual decline in net income per hectare by 2050, indicating the detrimental effects of climate change. Strengthening the adaptation of agricultural systems is crucial to reducing the impact and vulnerability to climate change (Pörtner et al., 2022).

## BACKGROUND

### Characteristics of the phenomenon "climate change" and associated risks

Climate change is a variation of meteorological parameters in a region from the usual (long-term historical data and expectations) for a given climate zone. The annual increase in the concentration of greenhouse gases in the atmosphere contributes to the rise in the Earth's temperature. The quality of ecosystem services is highly dependent on climate change (Yang et al., 2020; Rastegaripour et al., 2024). Climate change impacts many components of nature, including water resources, the agro-industrial sector, food security, infrastructure, biogeocenosis, the diversity of flora and fauna, population health, and coastal zones.

Climate change-related risks include temperature increases, extreme precipitation events leading to floods, droughts, and drying up of natural water bodies, especially in semi-arid and arid regions (Vogel et al., 2019; Wang et al., 2024). Precipitation and temperature are susceptible parameters that may be affected by climate change more than any other hydrological components (Nigatu et al., 2023). Precipitation extremes are projected to increase with global warming over much of the globe. A study (Yang et al., 2023) found that precipitation compared to annual precipitation and temperature compared to historical averages are projected to increase by 8.6% to 24.8% and 1.84°C to 4.08°C, respectively, from 2071 to 2100. Climate change is the primary driver of more frequent floods and droughts in the future, and the impact of regional land use changes cannot be ignored. Further deforestation and cropland expansion will slightly increase average annual run-off and exacerbate future flood risks (Yang et al., 2023; Rastegaripour et al., 2024).

Research studies over the years have shown that rising temperatures and floods are among the major natural disasters in Ethiopia, which can significantly reduce crop yields or destroy crops in some parts of the country (Masih et al., 2014; Nigatu et al., 2023; Deng et al., 2023; Jung et al., 2024). In addition, these climate disasters contribute to increased incidence of injuries and the spread of infectious diseases, and as a result, population migration is observed. Population displacement is particularly prevalent among rural communities dependent on agriculture.

### Current climate change adaptation strategies

Ethiopia has already adopted several climate change adaptation and mitigation measures; however, the importance of these measures differs at the national level, and the search for better adaptation practices is still ongoing (Hirpha et al., 2020). The main adaptation strategies implemented include mixed farming (use of improved and drought-tolerant crop varieties, early and late planting, improved livestock breeds) (Megersa et al., 2014); natural resource management (soil and water conservation, soil fertility management practices, drip irrigation, etc.) (Gebru et al., 2020); and the use of two or more practices (Asfaw et al., 2021; Gemeda et al., 2023).

Activity in adapting to global warming varies within communities and among individual families. Personal and socio-psychological factors can significantly influence individual and societal behaviour and decisions on climate change adaptation (Amare & Simane, 2017). Individual recognition, understanding and attitudes towards climate change largely determine the willingness of each individual to participate in adaptation efforts (Getahun et al., 2021; Ackerl et al., 2023). People's understanding of the risks threatening food security due to global warming in the region and their perception of their severity are crucial to motivating or inhibiting their participation in adaptive actions. Some personal factors, such as education, knowledge, and experience related to climate events, further shape an individual's willingness to adapt (Sinore & Wang, 2024).

In this regard, adaptation measures at the micro level of the farm are needed to obtain the appropriate mechanism. Implementing appropriate adaptation approaches for specific population groups can help overcome the adverse effects of global warming (Füssel, 2007).

More than 80% of Ethiopia's population lives in rural areas and relies heavily on agriculture. Therefore, agri- and cultural adaptation to climate change contributes to the country's sustainable development. This justifies the need to know accurately the type and extent of adaptation practices used by smallholder farmers at the regional (local) level and the need to improve existing adaptation frameworks further. In this regard, it is helpful to understand how smallholder farmers perceive climate change and what factors shape their adaptive behaviour.

According to Abela Abaya Woreda Agricultural Office (AAWAO, 2020/21). Abala Abaya woreda is one of the most vulnerable areas to global warming in the Wolaita Zone. The impacts of climate change seriously affect agriculture and livestock production in the study area. The variability in warming and rainfall reduces the agricultural output of smallholder farmers (AAWAO, 2020/21). Given the above context, the current study aimed to assess the adaptation strategies of smallholder farmers to climate change in Abela Abaya, Wolaita Zone of Southern Ethiopia. Despite the different adaptation strategies adopted by smallholders, there is no systematic and empirical study on what factors influence smallholders' choices and implementation of adaptation strategies. This justifies the need to address the information and knowledge gaps to better plan and promote the most appropriate approach to improve the region's smallholders' livelihoods and economic development efforts. Finding optimal techniques adapted to random extreme events is fundamental for sustainable food production.

In particular, the study attempts to find out the following:

1) the preferences of smallholder farmers in climate change adaptation strategies in the study area;

2) The main factors influencing the choice of climate change adaptation strategies by smallholder farmers in the study area.

Since the current study was conducted at the micro level and therefore seeks to investigate specific adaptation strategies for smallholder farmers, it is assumed that the approach chosen (applied) by smallholder farmers at the regional level may differ from those developed at the national level.

## MATERIALS AND METHODS

### Research area

Abala Abaya is a district in the Wolaita Zone of South Ethiopia Regional State. Its geographical location is defined by the coordinates: 6º32'30" – 6º40'0" N and 37º45'0" – 37º5'0" E. The district's total area is 45,522.2 hectares and is bordered by Humbo woreda to the north, Hobicha woreda to the east, Lake Abaya to the south, and Mirab Abaya to the west. According to Abela Abaya Woreda Agricultural Office (AAWAO, 2020/21), the total forest area is 369.39 hectares.

The district's total population is about 56,812. The total number of households in the district is 27,627, of which 16,981 are male and 10,646 are female (Yesuph et al., 2023). The district consists of 16 kebele administrations, 13 rural and three urban. Crop production is the main economic activity in the study area, and mixed crop-livestock production is also widely practised (Yesuph et al., 2023).

The average annual rainfall and temperature distribution in the area is 760 – 1200 mm and 15 – 20 °C, according to Wolaita Zone Finance and Economic Development (WZFED, 2021). In Abala Abaya, the soil type is mainly black loam. Traditional irrigation is widely used in agricultural production.

Due to the region's climate, there is a division into two agricultural seasons: the long rainy season (June – mid-September) and the short rainy season (March-May). The largest share of the annual harvest is achieved in the short rainy season when more than 90% of farmers work. At the same time, the increase in plant diseases and pests, as a consequence of climate change, contributes to the annual decline in the productivity of crops and livestock of small farmers.

**Study design**

The current study used qualitative and quantitative data in a descriptive research approach to assess potential adaptation strategies of smallholder farmers to climate change. Data on demographic, socio-economic, institutional, physical and psychological factors for smallholder adaptation strategies were collected through specially designed and pre-tested questionnaires, interviews and Focus Group Discussions (FGD).

***Sample definition and data collection***

Purposive sampling was used to select the study area from 16 rural districts of Wolaita Zone. There are 16 kebele administrations in the area, of which 3 kebele administrations were selected using simple random sampling due to the same agroecology, namely Abela Maraka, Abela Faracho, and Abela Gafata. The sample size at 92% confidence level and 8% precision level were calculated by expression (1) (Yamane, 1967):

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

where n is the sample size, N is the population size, and e is the level of precision and corresponds to a value of 0.08.

The study population size is the number of populations in 3 kebele administrations, which is 15,346 people (Abela Abaya Agricultural and NRM office, 2019/20 G.C.).

To proportionally distribute the sample size among the three kebele administrations, the formula was used:

$$n_{ka} = \sum n \frac{N_{ka}}{N}, \quad (2)$$

where $n_{ka}$ is the sample size for a particular kebele administration; $N_{ka}$ is several households surveyed in the particular kebele administration.

Based on the information on the study population, taking into account formulas (1) and (2), the sample size was 155 households. Figure 1 presents the number of households surveyed in each of the selected kebele administrations, where the population and number of households data are based on data from the Abela Abaya agricultural and NRM office, 2019/20 G.C.

Primary qualitative and quantitative household data were collected through questionnaires, focus group discussions with selected farmers and interviews; secondary data were collected from various other sources. The interviews discussed the determinants of farmers' climate change adaptation choices. Fifteen key informants were selected based on their farming experience, indigenous knowledge and climate change expertise to conduct in-depth interviews on the issues raised in the focus group discussions.

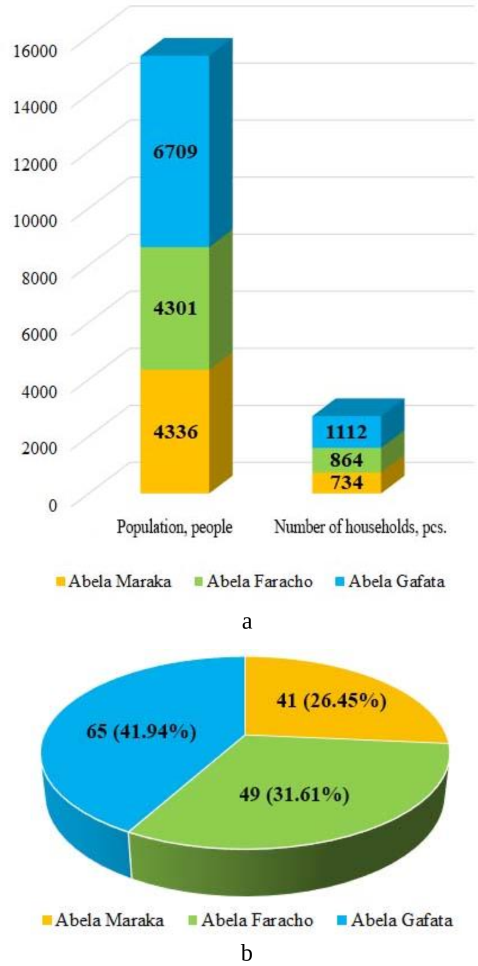


Figure 1. The sample size for a particular kebele administration: a – population and households' number in each of the kebele studied; b – sample size in pcs (%)

This was revealed through the focus group discussions. Primary data on socio-economic, demographic, physical, psychological and institutional factors were collected from smallholder farmers in the study area through a semi-structured questionnaire, and three focus group discussions (FGDs) were conducted in each group with 8 – 10 purposively selected participants. Pre-testing of the questionnaire was done through a pilot study, after which the questionnaire was revised, considering the findings. Secondary data were collected from documents and reports available at district, zonal and other management centres.

***Data analysis technique***

The Multivariate Probit (MVP) model was used because it is a type of correlated binary response regression model that allows for the simultaneous identification and evaluation of the impact of a set of independent factors on each possible approach (Belderbos et al., 2004). The multivariate normal distribution underlies this model, which makes this model recommended in situations of interdependence between irrelevant options (Greene, 2003).

To analyse smallholder farmers' perceptions of climate change, five-level Likert scale measures were used on several climate change attributes, and a household head survey was conducted about their opinions on the direction of global warming in 10 years. The survey participants' results at each level were evaluated in percentage terms. It was assumed that if farmers



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strongly agree and agree, they accept climate change, while in other cases, they do not. Preferences for implementing specific adaptation strategies were also assessed as percentages.

***Working hypothesis and dependent variables***

Five adaptation methods are identified as dependent variables for the Multivariate Probit. These include Soil and Water Conservation (SWC) practices, the use of drought-tolerant varieties, the adjustment of planting dates, the use of agroforestry, and the implementation of water harvesting. The following were selected as independent variables for the current study.

1. Gender of the household head. Since being male positively influences the implementation of SWC practices, tree planting, and the use of different crop varieties, male-headed households are more likely to seek and implement adaptation strategies (Deressa et al., 2009). This variable is expected to affect the choice of adaptation strategy positively.

2. Household head's age (in years). According to some studies, this variable positively influences the introduction of various varieties of crops, irrigation and SWC methods, and planting date adjustment for farming crops and trees (Hadgu et al., 2015; Deressa et al., 2009). Thus, with experience in agriculture, the farmer will choose or develop the best alternative adaptation strategies.

3. The household head's education level is measured in years of schooling completed. Research shows that educated individuals have a better understanding of global warming adaptation, which increases their preference for growing drought-resistant varieties, using water harvesting, and adjusting planting dates (Addisu et al., 2016; Deressa et al., 2009; Adeoti et al., 2016). It is assumed that the influence on the choice of adaptation strategy can be positive or negative.

4. The hectares' cultivated land area measures landholding size. This variable is also continuous, like the previous one. It was found that with increasing landholding area, the likelihood of using water harvesting, SWC practices, adjustment of planting dates and use of drought-resistant varieties will increase (Nhemachena & Hassan, 2007). Also, farmers with more extensive landholdings tend to use more appropriate strategies. Presumably, the effect of this variable will be positive.

5. Land slope (%). The slope of a land plot, namely plain (1), moderate slope (2) and steep slope (3), can be subject to varying degrees of erosion. This erosion is more pronounced on steeper slopes. This variable is discrete. It is hypothesised to positively affect the choice of climate change adaptation strategies, as researchers found that land slope was positively and significantly associated with the decision to implement SWC measures (Asrat et al., 2004).

6. Access to climate information. This is a dummy variable. It is expected that this factor will have a positive impact on the choice of strategy since awareness of climate change and access to information on climate forecasts increases the likelihood of implementation of progressive methods based on adaptation to global warming (Hadgu et al., 2015; Deressa et al., 2009).

The choice of the variables indicated is based on the experience of most reviews of empirical studies.

**Study limitations**

The current study is limited to a geographical area, namely Abela Abaya district of Wolaita Zone (South Ethiopia) and focuses exclusively on smallholder farmers, i.e. farmers managing approximately 2 ha and primarily managed by family labour. In addition, off-farm activities, livestock size and socioeconomic variables (such as access to credit, etc.) were not taken into account based on previous research experience by other authors (Deressa, 2009; Nhemachena & Hassan, 2007). Also, the family size was not taken into account because this factor has many variations,, such as the number of family members, their age, gender, current economic wealth, etc., which can be presented as a separate study.

## RESULTS AND DISCUSSIONS

### Choosing a strategy depending on the household's head

***Gender***

Figure 2 shows the study's results on the dependence of smallholder farmers' strategy choice on the gender of the household head. Of all respondents, 76.2% were men, and 23.3% were women.

The chi-square test's p-value clearly shows a significant difference between male-headed and female-headed households in terms of soil and water conservation, drought-resistant varieties, and agroforestry. This confirms that male household heads are more likely to adopt agricultural adaptation strategies than females.

The current study found a negative and significant effect of the gender of the household head on SWC practices. In contrast, the impact of using drought-tolerant varieties was positive and significant. Male household heads were 0.562 times more likely to use drought-tolerant varieties ($p = 0.001$) as adaptation strategies than female household heads. This could be explained by women's heavier household responsibilities and less access to financial resources, contributing to a lower likelihood of investing in new technologies. Similar observations were made by Deressa et al. (2009), who found that men were more likely to adopt SWC practices and use drought-tolerant varieties.

***Age***

Figure 3 shows the results of the age characteristics of the heads of the studied households. Of all the heads, the oldest was 75 years old, the youngest was 25 years old. The average age was 49.0 years, with a standard deviation of 9.87.

Using one-way ANOVA, a significant mean difference was found – $F = 2.824$ – among adaptation strategies, which suggests a significant relationship between age and adaptation strategies.

The current study demonstrated a negative and significant effect ($p = 0.001$) of the household head's age on the implementation of SWC practices. Older household heads were 0.183 times less likely to implement SWC practices than younger ones. This result contradicts the study conducted by a group of researchers (Hadgu et al., 2015), which found a positive influence of age on the implementation of different crop varieties and irrigation and the implementation of SWC practices.

***Education***

The household head's educational status is one factor influencing the adaptation strategies in each society. Figure 4 shows that soil and water conservation methods, the use of drought-resistant varieties, adjustment of planting dates, and agroforestry were applied by household heads who had a higher level of education than those without it. Therefore, in order to implement strategies in agricultural adaptation, the state should give great attention to increasing the education of heads.

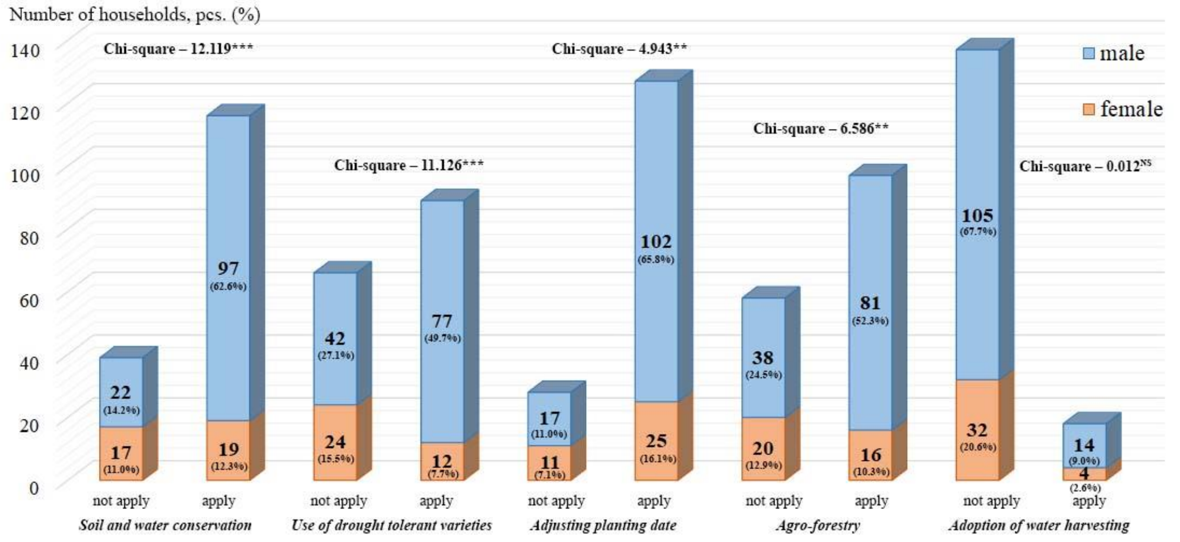


Figure 2. Choice of strategies by smallholder farmers depending on the gender of the household head (own survey, 2021; *** – significant at less than 1%; ** – significant at less than 5%; N.S. – not substantial)

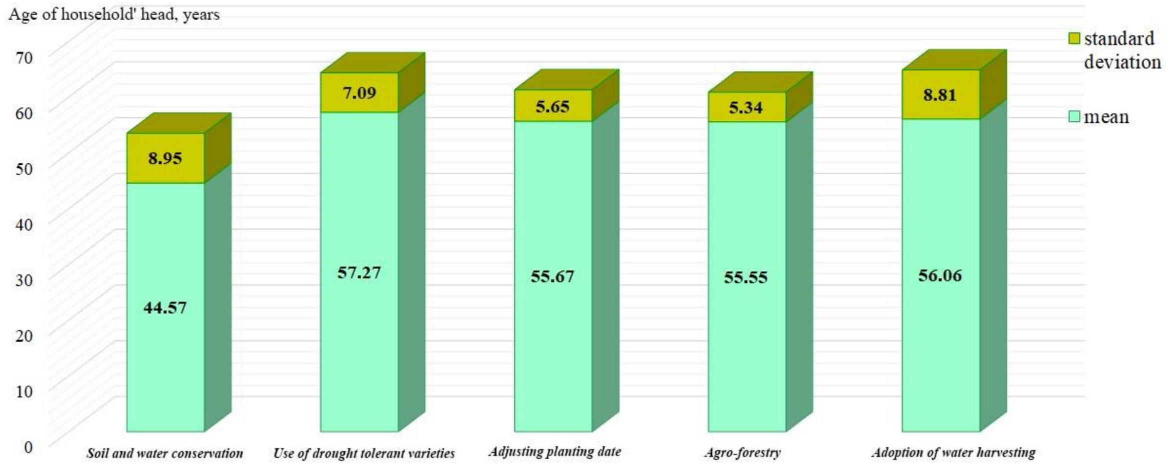


Figure 3. Choice of strategies by smallholder farmers depending on the gender of the head of the household (own survey, 2021; the results are significant at a probability level of less than 1%)

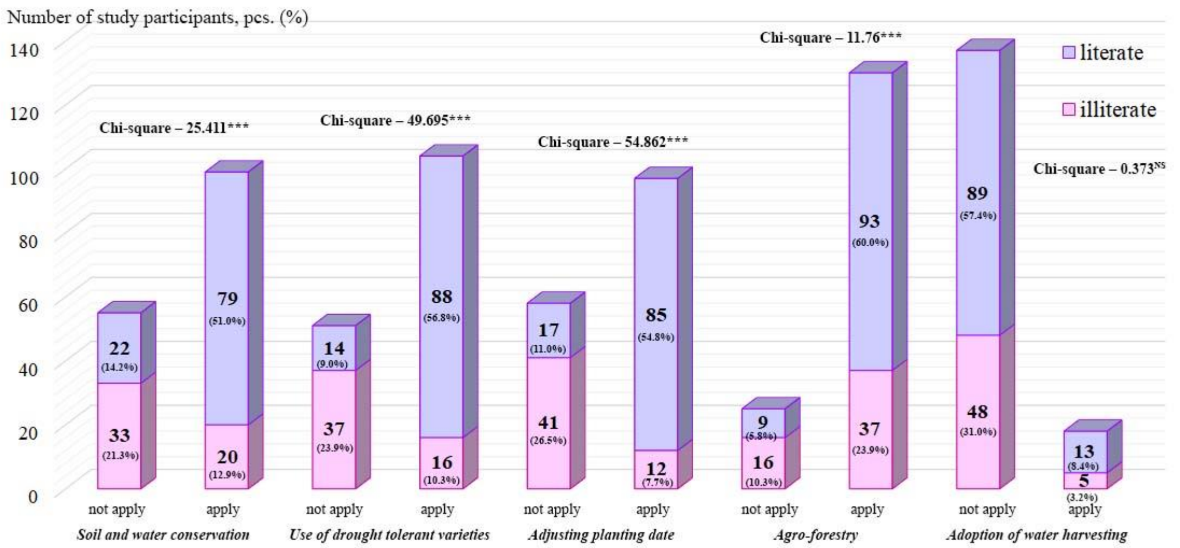


Figure 4. Smallholder farmers' choice of strategies depends on the education of the household head (own survey, 2021; *** – significant at less than 1%; ** – significant at less than 5%; N.S. – not significant)

The current test revealed that the chi-square criterion for the level of education of the applied adaptation strategies has a statistically significant difference at the 1% probability level. This indicates that the educational status of household heads positively affects the adoption of physical soil and water conservation practices, drought-resistant varieties, adjustment of planting dates, and agroforestry practices.

The higher education level of the household head was found to have a significant impact on SWC practices (p = 0.001) with the use of drought-resistant variety (p = 0.001), adjustment of planting date (p = 0.001), and agroforestry (p = 0.01) as adaptation strategies compared to heads with low education. This is justified by a better understanding of the impacts of climate change and a better interpretation and understanding of the benefits of innovative approaches in agriculture. Similar findings have been made in another study in other regions (Gadédjisso-Tossou, 2015; Adeoti et al., 2016), where the authors reported that increasing the education degree of a farmer-head of a small farm increases the understanding degree of the need to adapt to new conditions associated with global warming.

**Physical characteristics of the land plot**

***Land size***

Figure 5 demonstrates a positive relationship between adaptation strategies and the land size owned by the household. The significance was found at less than 1% – F = 2.107. Therefore, this result confirms the hypothesis that adaptation strategies are more likely to be used in the case of large land holdings. Conversely, in the case of small land holdings, farmers have difficulties adjusting planting dates, introducing water harvesting structures, and using drought-resistant plants. Therefore, farmers with small land holdings will need support from the state.

***Land slope***

The slope of the land plot greatly affects farming technologies due to various natural processes such as soil erosion and difficulties with irrigation, which lead to the washing out of the fertile layer. In this regard, it is assumed that the heads of households with sloping plots will be more inclined to adaptation strategies, unlike the owners of flat plots. The current study has revealed such a dependence, and the chi-square test demonstrates the significance of this dependence at levels Figure 6).

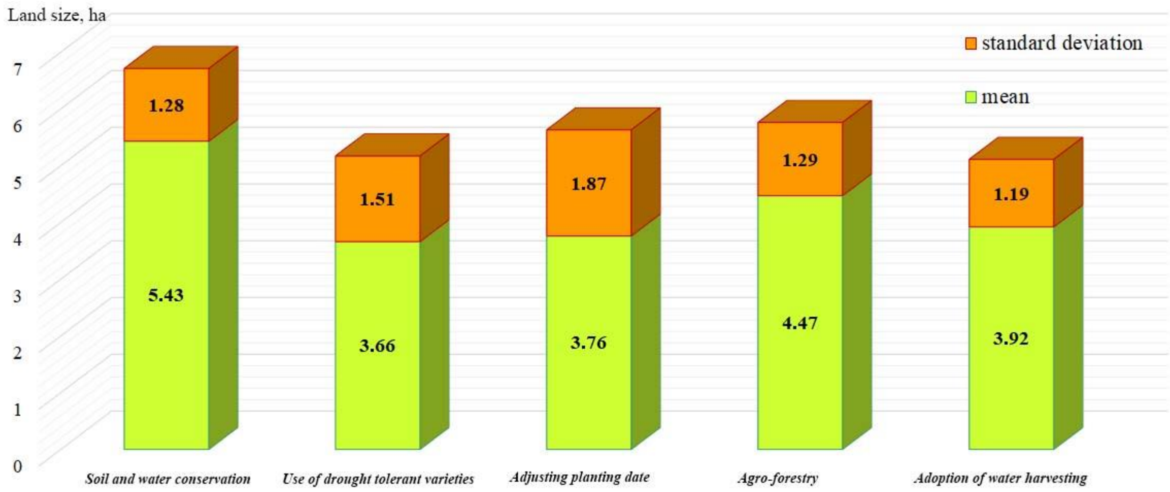


Figure 5. Smallholder farmers' choice of strategies depends on the land size owned by the household (own survey, 2021; the results are significant at a probability level of less than 1%)

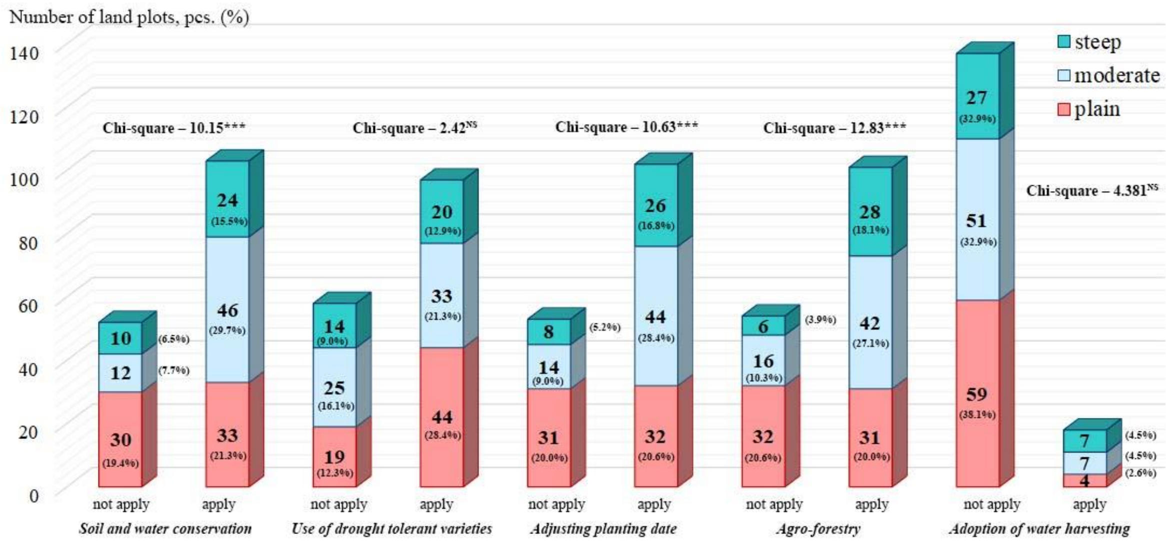


Figure 6. Smallholder farmers' choice of strategies depends on the slope of the land plot (own survey, 2021; *** – significant at less than 1%; ** – significant at less than 5%; N.S. – not substantial)

A negative and significant effect of land slope on SWC practices and a positive impact on planting date adjustment and agroforestry were found. The current study shows that households with gentle slopes are 0.061 less likely to implement SWC, 0.051 more likely to implement planting date adjustment, and 0.627 more likely to implement agroforestry practices than households with steep slopes. This finding is consistent with the conclusions presented in (Paulos et al., 2004), where the authors found a positive and significant effect of site slope on the decision to use SWC measurement practices.

**Awareness of the climate situation and forecasts**

Access to climate information, in this case through meetings with an information agent, significantly increases the likelihood of using adaptation strategies such as water harvesting, drought-resistant varieties, and SWC methods. Figure 7 clearly shows the dependence of specific adaptation strategies on the frequency of meetings. The current study found a positive impact on farmers' agricultural performance in the context of climate warming. It demonstrated statistical significance at a level of less than 1% of information work for the use of adaptation practices by small farmers.

This study's result is a consequence of timely receipt of up-to-date information on climate change and forecasts, as well as on new agricultural technologies. These results are consistent with the findings of similar studies (Deressa et al., 2009; Abid et al., 2015; Hadgu et al., 2015).

**The result of the factor influencing the respondents' choice of adaptation strategies**

Table 1 demonstrates the factors influencing the choice of adaptation strategies.

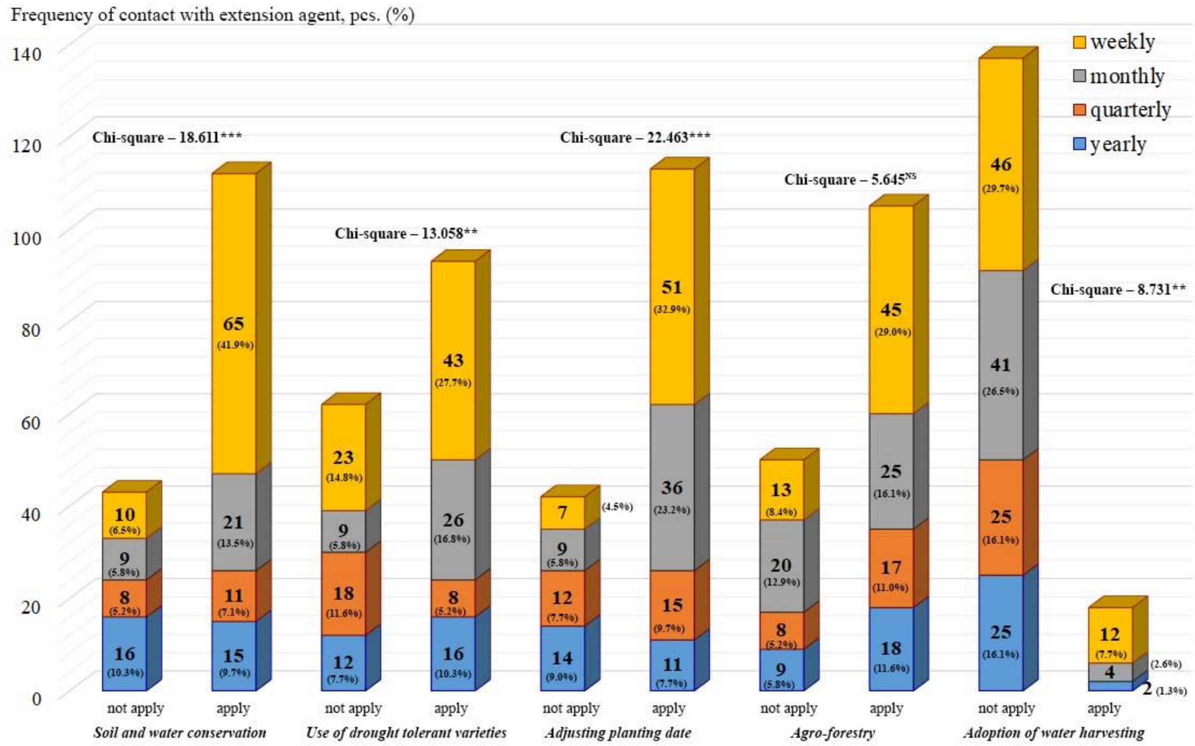


Figure 7. Smallholder farmers' choice of strategies depends on the frequency of contact with a climate change information agent (own survey, 2021; *** – significant at less than 1%; ** – significant at less than 5%; N.S. – not substantial)

Table 1. MVP – the result of factor affecting respondents' choice of updated agricultural approaches

| Updated agricultural approaches | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| Independent variables | Soil and water conservation | | Use of drought-tolerant varieties | | Adjusting planting date | | Agroforestry | | Adopting water harvesting | |
| | Coef.(S.E.) | Sig. | Coef.(S.E.) | Sig. | Coef.(S.E.) | Sig. | Coef.(S.E.) | Sig. | Coef.(S.E.) | Sig. |
| Head gender | -0.256(0.088) | .004 | 0.562(0.081) | .00 | 0.144(0.091) | .115 | 0.053(0.091) | .5 | 0.007(0.061) | .915 |
| Farmer' education | 0.397(0.075) | .000 | 0.561(0.066) | .000 | 0.746(0.068) | .000 | 0.214(0.060) | .001 | 0.033(0.055) | .545 |
| Awareness of the climate situation & forecasts | -0.245(0.080) | .002 | 0.347(0.074) | .000 | 0.201(0.072) | .006 | 0.218(0.074) | .004 | 0.093(0.054) | .086 |
| Land slope | -0.061(0.464) | .023 | 0.120(0.137) | .070 | 0.051(0.142) | .029 | 0.627(0.128) | 0.000 | 0.337(0.192) | .141 |
| Land size | 0.530(0.231) | .021 | 0.011(0.340) | .158 | -0.148(0.260) | .569 | 0.049(0.246) | .842 | 0.45(0.39) | .792 |
| Head age | -0.183(0.040) | .000 | 0.018(0.047) | .702 | -0.006(0.046) | .898 | -0.008(0.041) | .849 | 0.002(0.003) | .481 |

Number of observations – 155 Log likelihood = -305.406; $\chi^2$ = 161.08; P-value = 0.0000
Source: own survey, 2021

To sum up, most farmers (96.7%) acknowledge the ongoing climate change and are concerned that their farming will not suffer in the new conditions. This is justified by the fact that farmers confirm their observations regarding the increase in air temperature, the increase in the frequency of plant diseases and the decrease in precipitation. At the same time, only 36.2% of the surveyed farmers reported that society is aware of the possible risks associated with global warming and is trying to adapt agricultural activities to new climatic conditions (Figure 8).

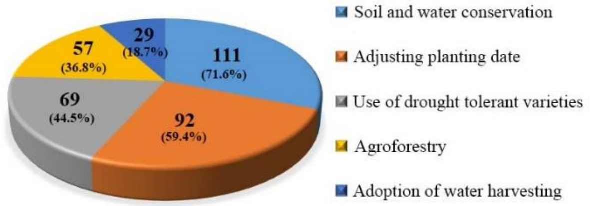


Figure 8. Frequency of implementation of updated agricultural approaches (own survey, 2021)

## CONCLUSION

The current study provides a comprehensive picture of smallholder farms' vulnerability and adaptive capacity in one specific region to changing climate conditions associated with global warming. Namely, the current study made it possible to reveal for the first time that smallholder farmer Abela Abaya primarily prefers such approaches as soil and water conservation (71.6%), adjusting planting date (59.4%), and agroforestry (44.5%). This is justified by their natural reasoning and the best understanding of these approaches. Unfortunately, water collection structures are practically not used (18.7%), probably due to the high labour intensity of the process and its cost.

Multi-Variate Probit analysis allowed us to identify the most influential factors on the use of adapted agricultural techniques in a specific region of Abala Abaya (Wolaita Zone, South Ethiopia) and confirm the results of previous studies. The significant variables were household heads' access to education, frequency of extension visits, access to climate information, and slope of the land plot.

Thus, decision-makers can develop and adopt appropriate programs based on current results to preserve small farms and maintain food security at the national level.

### Author's statements

#### *Contributions*

All authors contributed to the study's conception and design. Conceptualization: M.M., M.T.; Data curation: M.M.; Formal analysis: M.M., M.T., A.B.; Investigation: M.T., D.D.; Methodology: M.T., A.B., B.L.; Project administration: M.T., D.D., B.L.; Supervision: M.T., B.L.; Validation: M.M., M.T.; Visualization: A.B.; Writing – original draft: M.M., A.B.; Writing – review & editing: M.T., A.B., B.L.

#### *Declaration of conflicting interest*

The authors declare no competing interests.

#### *Financial interests*

The authors declare they have no financial interests.


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#### *Data availability statement*

No data were used for the current study.

#### *AI Disclosure*

The authors declare that generative AI was not used to assist in writing this manuscript.

#### *Ethical approval declarations*

All survey participants were over 18 years of age; before the survey, all were informed about the purpose of the survey and the purpose of the study; all gave oral consent for the processing of data and their responses; all gave consent for the publication of the research results based on their data without indicating their names and personal contact information.

### Additional information

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