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# Smallholder farmers' perceptions and adaptation strategies to climate change risks in northwest Ethiopia

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Received 1 January 2022
Revised 28 July 2022
Accepted 4 October 2022

## Abstract

**Purpose** – The purpose of this paper was to examine smallholder farmers' perceptions of climate change risks, adaptation responses and the links between adaptation strategies and perceived/experienced climate change risks in South Gondar, Ethiopia.

**Design/methodology/approach** – This paper used a convergent mixed methods design, which enables us to concurrently collect quantitative and qualitative data. Survey data was collected from 352 households, stratified into Lay Gayint 138 (39%), Tach Gayint 117 (33%) and Simada district 97 (28%). A four-point Likert scale was used to produce a standardised risk perception index for 14 climate events. Moreover, using a one-way analysis of variance, statistical differences in selecting adaptation strategies between the three districts were measured. A post hoc analysis was also carried out to identify the source of the variation. The findings of this paper are supplemented by qualitative data gathered through focus group discussions and key informant interviews of households who were chosen at random.

**Findings** – The standardised climate change risk perception index suggests that persistent drought, delayed onset of rainfall, early termination of rainfall and food insecurity were the major potentially dangerous climate change risks perceived by households in the study area. In response to climate change

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This paper forms part of a special section "Climate change adaptation and mitigation measures at local and national levels for sustainable development", guest edited by Dr Minhaz Farid Ahmed.

The authors would like to thank Dilla University and Addis Ababa University for providing financial support for the data collection and write-up of the manuscript. The authors also extend their sincere thanks to all the data collectors and farmers who took part in the surveys for the study. The authors are also very grateful to the National Meteorological Agency of Ethiopia for providing rainfall and temperature data.

*Disclosure statement*: the authors declare no conflict of interest.

International Journal of Climate Change Strategies and Management
Vol. 15 No. 5, 2023
pp. 599-618
Emerald Publishing Limited
1756-8692
DOI 10.1108/IJCCSM-01-2022-0001

risks, households used several adaptation strategies such as adjusting crop planting dates, crop diversification, terracing, tree planting, cultivating drought-tolerant crop varieties and off-farm activities. A Tukey's post hoc test revealed a significant difference in off-farm activities, crop diversification and planting drought-tolerant crop types among the adaptation strategies in the study area between Lay Gayint and Simada districts ($p < 0.05$). This difference reconfirms that adaptation strategies are location-specific.

**Originality/value** – Although many studies are available on coping and adaptation strategies to climate change, this paper is one of the few studies focusing on the linkages between climate change risk perceptions and adaptation responses of households in the study area. The findings of this paper could be helpful for policymakers and development practitioners in designing locally specific, actual adaptation options that shape adaptation to recent and future climate change risks.

**Keywords** Climate change risk perception, Adaptation strategies, Smallholders, South Gondar, Ethiopia

**Paper type** Research paper

## 1. Introduction

Worldwide climate change risks are increasing, and agriculture remains one of the most vulnerable sectors (Ado *et al.*, 2019; Alves *et al.*, 2020; Getahun *et al.*, 2021) causing stress on food supply systems in different parts of the world (Gebru *et al.*, 2020). Smallholder farmers are particularly vulnerable to climate change impacts (Antwi-Agyei and Nyantakyi-Frimpong, 2021; Berger *et al.*, 2017; Fahad and Wang, 2018; Marie *et al.*, 2020; Mulwa *et al.*, 2017). Climate change has the greatest impact in the developing world because of their low adaptive capacity and lack of access to alternative means of livelihood (Ali and Erenstein, 2017; Fahad and Jing, 2018):

> In the context of the assessment of climate impacts, the term risk is often used to refer to the potential for adverse consequences of a climate-related hazard, or of adaptation or mitigation responses to such a hazard, on lives, livelihoods, health and well-being, ecosystems and species, economic, social, and cultural assets, services (including ecosystem services), and infrastructure. [Intergovernmental Panel for Climate Change (IPCC), 2018]

Ethiopia has been identified as one of the most vulnerable developing countries to climate change risks (Paul *et al.*, 2018). Ethiopia's vulnerability stems from the country's heavy reliance on rainfed agriculture (Paul *et al.*, 2018), and the sector's performance is strongly linked to the rainfall pattern (Gebru *et al.*, 2020). Food shortages and, in the worst-case scenarios, famines result from rainfall shortages or changes in seasonal patterns. Climate-related disasters such as droughts, floods and rainfall variability have contributed to the country's reliance on food aid.

The South Gonder Zone (the present study area) in the northwest highlands of Ethiopia is highly vulnerable to climate change and variability. In contrast to the overall decrease in rainfall, Likinaw *et al.* (2022) noted that the mean seasonal and annual minimum and maximum temperatures in Lay Gayint, Tach Gayint and Simada districts showed a significant increasing trend. A recent study has revealed that climate variability has a considerable negative effect on crop production in this area (Getachew, 2018). Moreover, Bewket and Alemu (2011) observed a considerable reduction in crop production and the length of the growing period because of the late onset and early cessation of rainfall in the Abay and Baro-Akobo River Basins of Ethiopia. Several studies have highlighted on the importance of understanding risk perceptions and adaptation measures used at the household level to facilitate planned adaptation interventions (Abid *et al.*, 2016; Ahmed *et al.*, 2021). Adaptation practices are an important component of farmers' climate risk management strategies and are closely linked to their risk perceptions (Dorward *et al.*, 2020; Khanal *et al.*, 2018, 2021).

The linkage between climate change risk perceptions and adaptation responses is, however, complex, because it involves combining behavioural elements from belief formation with outcome assessments resulting from actions and weather events (Van der Linden, 2017). Understanding and identifying the climatic factors that farmers consider when framing their views on climate change is critical (Tripathi and Mishra, 2017; Zamasiya *et al.*, 2017). A study conducted by Tesfaye and Seifu (2016) identified six major adaptation strategies in the eastern Hararghe Zone (eastern part of Ethiopia) such as adjusting crop planting dates and using drought-tolerant crop types, among others. Another study found that the most common adaptation measures in the central highlands of Ethiopia included adjusting crop planting dates, soil and water conservation, crop diversification, tree planting and soil fertility management (Alemayehu and Bewket, 2017). Gebru *et al.* (2020) found that adaptation strategies in eastern Tigray include soil and water conservation, water harvesting, compost preparation to increase soil fertility, tree planting and changing the quantity of land under cultivation. Likewise, Bewket (2012) revealed that adaptation measures used in crop production comprise diversification of crops, changes in the types and varieties of crops produced and adjusting the agricultural calendar in the central Highlands of Ethiopia. A previous study in Gonder Zuria district, northwest Ethiopia, found that mixed farming, mixed cropping, adjusting crop planting dates, use of drought-resistant crop varieties and application of soil and water conservation measures were the most commonly used adaptation strategies (Marie *et al.*, 2020).

Most of the available studies are focused on coping and adaptation strategies, giving little or no attention to the linkages between climate change risk perceptions and the coping and adaptation responses of farmers. Unlike the previous studies, this study attempts to assess the linkages between climate change risk perceptions and adaptation responses of households in the study area. Also, we used a standardised index-based metric to assess households' views of climate change risk and their adaptation practices. The general objective of this study was to explore climate change risk perceptions and adaptation strategies practiced by smallholder farmers in the northwest highlands of Ethiopia. The specific objectives were to:

- assess climate change risk perceptions of households;
- describe adaptation strategies used by the households; and
- examine the linkage between adaptation strategies and perceived or experienced climate change risks.

In the following section, we present a description of the study area and materials and methods of the study, followed by the results and discussion section. The final section contains the conclusion.

## 2. Methodology

### *2.1 The study area*

The study area covers three districts (*woredas* in Amharic), namely, Lay Gayint, Tach Gayint and Simada in the South Gondar Administration Zone of the Amhara National Regional State of Ethiopia (Figure 1). Lay Gayint is in the *High Dega* (3,200–3,700 m asl) agroecological zone, and Tach Gayint and Simada are in the *Dega* (2,300–3,200 m asl) and *Woyna Dega* (1,500–2,300 m asl) agroecological zones, respectively (Hurni *et al.*, 2016). According to information obtained from the district administration offices, about 32% of the total area of the three districts is mountainous, 53% is rugged topography, 10% is plain land and 5% is dissected valley. Based on the FAO soil classification system, Vertisols, Nitosols and Chernozems cover about 32%, 29% and 28% of the districts, respectively. The remaining 11% is covered by other soil types. The study area is a highly deforested part of the country, which is because of a long history of settlement and cultivation, overgrazing and other socioeconomic and policy-related factors (Getachew, 2018). The current land cover is dominated by extensive cultivation and shrub lands. Simada and Tach Gayint have

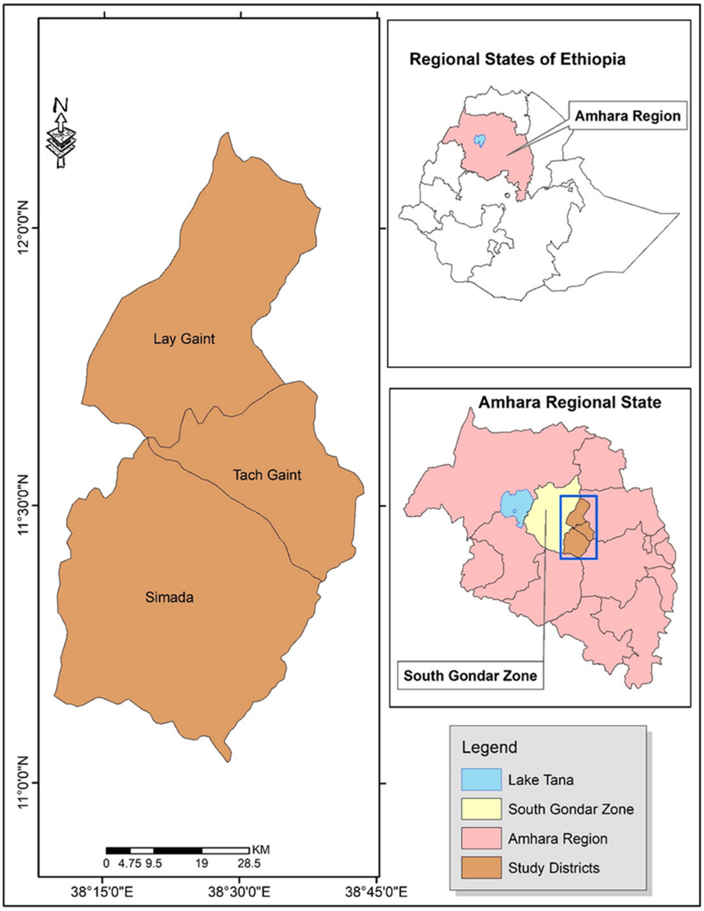

**Figure 1.**
Location map of the study area

annual rainfall averages of 788 and 820 mm, respectively, while Lay Gayint has a rainfall average of 1,096 mm. The average annual temperature in Lay Gayint is 14.4°C, 18.2°C in Simada and 14.7°C in Tach Gayint.

The farming system is mixed crop-livestock, characterised by continuous and intensive cropping. Barley (*Hordium vulgare*), wheat (*Triticum aestivum*), tef (*Eragrostis tef*) and maize (*Zea mays*) are the main cereals grown in the area. Cattle, goats, sheep and equines are the livestock raised. The contribution of livestock to the livelihood of the people is constrained partly by the prevalence of livestock diseases (Getachew, 2018). Agricultural productivity is affected by its dependence on unreliable rainfall among other factors.

### *2.2 Research design*

The study adopted a convergent mixed methods design. The design enables researchers to concurrently collect quantitative and qualitative data, analyse them separately and then compare the findings to determine whether they corroborate or contradict one another (Creswell and Creswell, 2018). The key assumption of this method is that both qualitative and quantitative data provide different types of information-often detailed views of participants qualitatively and scores on instruments quantitatively, and together, they provide results that should be the same. Hence, quantitative research methods were used to collect and analyse households' perceptions of climate change risks and adaptation responses using a household survey. Moreover, perceptions of households related to climate change risks and adaptation responses were also collected and analysed by qualitative research methods using key informant interviews (KIIs) and focus group discussions (FGDs).

### *2.3 Sampling procedure and sample size*

We used a multi-stage sampling technique, where a combination of purposive and random sampling techniques was applied for selecting study area and sample households, respectively. First, Lay Gayint, Tach Gayint and Simada districts were selected purposively from the South Gondar Zone districts. These three districts represent some of the areas most frequently affected by climate extremes in the South Gondar Zone and the Amhara Region at large. They also represent the three important agroecological zones in the country, that is, the *High Dega*, *Dega* and *Woina Dega*.

In the second stage, three *Kebeles* (one from each district and agroecological zone) were selected randomly with the assumption that households in each agroecological zone will have differences in their livelihood assets and strategies, traditional knowledge and skills and that this will result in different perceptions and adaptation responses to climate change and variability. Because climate change will have different effects in different agroecological zones, farmers in different zones often use different adaptation strategies (Belay *et al.*, 2017).

In the third stage, sample households from each sampled *Kebele* were identified. The sampling frame or lists of households were obtained from the sample *Kebele* Administration offices. The sample size of the study was determined following Kothari (2004) as follows:

$$n = \frac{Z^2 * p * q * N}{e^2(N-1) + Z^2 * p * q}$$

where $n$ = sample size; N = total number of households; $p$ = 0.5 the sample proportion reliability and q = 1 − $p$ (0.5); e = 5% the margin of error/acceptable error considered; and Z = 1.96 is the critical value for the 95% confidence interval.

The required sample size (n) from the total 4,203 households (1,644, 1,404 and 1,155 households from Lay Gayint, Tach Gayint and Simada, respectively) was, therefore, 352. Sample size for each *Kebele* was determined to be proportional to the respective population sizes; hence, it was 138, 117 and 97 in Lay Gayint, Tach Gayint and Simada, respectively. Then, households were selected using simple random sampling.

### *2.4 Sources of data and methods of collection*

Data for the study was collected from both primary and secondary sources. Primary data was gathered through household surveys, FGDs and KIIs. The primary data consists of socio-demographic characteristics of households, perceptions of households about climate-related risks and adaptation strategies. The study also used secondary data from Meteorological Stations (rainfall and temperature datasets) from 1981 to 2018 so as to triangulate and compare findings with households' perceptions of climate change risks in the study area. We consider long experience in farming, voluntary participation in the discussion and knowledge about the impact of climate-related risks in the selection of KIIs and FGDs participants. In this regard, two FGDs, each with 8–12 members, and four KIIs were conducted in each kebele. The FGD participants varied in terms of sex and age. Four

KIIs were selected from each kebele purposively. The diversity of households in the FGDs and KIIs was maintained by consulting district experts. They were chosen through a purposive sampling procedure, so they included both males and females aged between 25 and 75 with long-term knowledge of the area. The qualitative information collection from FGDs and KIIs was conducted to supplement the results of the survey. Unstructured interview guide checklists were prepared to frame the interview focused on the objectives of the study and allow flexibility for interviewees to talk freely as they wish. The information gathered comprises households' adaptation strategies against climate change risks in their farming activities.

The FGDs and in-depth interviews were guided by checklists that included topics on:

- How did they describe climate change risk?
- What were their thoughts on the role(s) of climate change risk adaptation responses?

The interview questions were pre-tested with some participants, and minor changes were made to adapt to local circumstances. The interviews were continued until saturation was attained, until topics were conveyed repeatedly and no new information was mentioned (Skovdal and Cornish, 2015). The qualitative data analysis included coding, searching for underlying concepts, developing themes and addressing major themes related to climate change risks and adaptation responses.

### *2.5 Methods of data analysis*

Descriptive statistics such as mean and percentage were used to summarise the socio-economic, demographic characteristics and adaptation strategies of households.

Measurement of climate change risk perception is a complicated process that is influenced by social, cultural, economic and demographic factors (Hasibuan *et al.*, 2020). Households ' climate change risk perceptions are unique in that they allow for a distinction between actual real-world hazards, such as climate change, and intuitive evaluation of those dangers (Lai *et al.*, 2021; Schneiderbauer *et al.*, 2021). In the literature, several methods are used to understand climate change risk perceptions. The climate change risk perception index (SCCRPI) is widely used in studies on climate change risk perceptions (Ahmed *et al.*, 2021; Iqbal *et al.*, 2016; Sullivan-Wiley and Gianotti, 2017). The SCCRPI is a metric or index that is created by combining the probability or likelihood of risk events with the severity of risk event consequences (Aven, 2016; Li *et al.*, 2018). As the risk perception is different from real or objective risk (Ahmed *et al.*, 2021; Sullivan-Wiley and Gianotti, 2017), data in risk perception studies are mainly obtained by asking respondent's perceptions regarding risks using ordered qualitative scales where they can express their subjective views on incidence of climate change risk and, also, their concern regarding magnitude of the gain/loss caused by the risk rather than a detail measurement of probability or consequences (Cullen *et al.*, 2018; Frondel *et al.*, 2017).

The households were asked to give their views on ten climate change risks to gain a thorough understanding of their relative perceptions of the ten chosen climate change risks. Similar methods have been used in the past to assess climate change risk perception (Alam *et al.*, 2017; Sarker *et al.*, 2020). In this study, we used a similar type of Likert scale to assess respondents' risk perceptions of climate change. Hence, a four-point Likert scale was adopted to estimate households' perception levels. Usually, the Likert scales are levelled as odd rather than even (they usually include five- or seven-point scales), but because of limited resources and the household's low educational attainment, we decided to limit the household's responses to a four-point Likert-scale. Furthermore, we included a four-point scale to avoid having too many responses with a neutral response on personal risk assessment. However, our findings can still be used to gain a better understanding of households' views of climate-related risks. Similar studies made use of a four-point Likert scale (Ahmed *et al.*, 2021; Cortés *et al.*, 2021; Ndamani and Watanabe, 2017). The CCRPS and SCCRPI were calculated in this regard to gain a better understanding of how char dwellers perceive climate change risks.

We assigned values to each perception scale in an increasing order for ease of analysis, such as 0 for "no perception," 1 for "low perception," 2 for "medium perception" and 3 for "high perception." Households were asked to rate their opinions on 14 climatic event statements. The following equation was used to calculate a Climate Change Risk Perception Score (CCRPS):

$$\text{Climate Change Risk Perception Score (CCRPS)} = \text{CCRPn}*0 + \text{CCRPl}*1 + \text{CRPm}*2 + \text{CCRPh}*3$$

where CCRPn is the number of households with no risk perception, CCRPl is the number of households with a low-risk perception, CCRPm is the number of households with a medium risk perception and CCRPh is the number of households with a high-risk perception. Low risk perception was assigned to households who expressed little concern for climate change and low perceived exposure to its effects, whereas high risk perception was assigned to households who expressed high concern and high perceived exposure to its impacts. In moderate risk perception, more measured statements about the severity and urgency of climate change were included.

As our sample was 138, 117 and 97 households for Lay Gayint, Tach Gayint and Simada districts, respectively, the CCRPS for any given climatic event could range from 0 to 414, 0 to 351 and 0 to 291; this means the lower boundary would be a minimum of 0, and the higher boundary would be a maximum of 414, 351 and 291 where 0 indicates a minimum level of risk perception and 414, 351 and 291 indicate a maximum level of risk perception. The CCRPS was then converted into a standardised index so that the results could be interpreted more easily. To standardise the CCRPS, we used the following equation:

$$\begin{gathered}\text{Standardized Climate Change Risk Perception Index (SCCRPI)} = \\ (\text{ Total CCRPS Value })/(\text{ Respective Highest CCRPS Value })*100\end{gathered}$$

The total CCRPS value was calculated by multiplying individual perception values by total perception frequency for each climatic event, and the highest CCRPS value was calculated by dividing the total CCRPS value by the highest maximum boundary value and multiplying by 100. SCCRPI is a tool for understanding and categorising climate change risk perceptions (Ahmed *et al.*, 2021). The SCCRPI value can range from 0 to 100, with 0 representing the lowest level of risk perception and 100 representing the highest level of risk perceived by households. Moreover, descriptive statistics were used to summarise information on adaptation responses to climate change risk. A one-way analysis of variance was used to assess if there were statistically significant differences in the selection of adaptation strategies between the districts. Differences between the districts were considered significant if they were statistically significant at the 0.05 level. The one-way analysis of variance test simply reveals the total difference between districts; it does not reveal which districts varied from one another. Hence, a post hoc analysis, Tukey's test, was conducted to identify the location of the difference. The meteorological data (rainfall and temperature) were analysed using linear regression to show the variability of rainfall and temperature data. In addition, Mann–Kendall trend test was computed to test for the presence of a trend in rainfall and temperature data over the period

1981–2018. The Mann–Kendall trend test analysis of the climatic data was performed using R-software version 3.6.1.

## 3. Results and discussion

### *3.1 Characteristics of sample households*

Table 1 presents socio-demographic characteristics of the sample households in terms of sex, age, household size and education. The average age of the households was 43 years (range was 18–76 years). The average household size was 5, which is equal to the national average. Data on education indicated that 43%, 45%, 11% and 1% of households were illiterate in primary education (Grades 1–8), secondary (Grades 9–12) and college level.

### *3.2 Households' perception about climate change*

To assess how households, perceive climate change, we asked them if they believed the temperature and rainfall in the area during the previous years had increased, decreased or

**Table 1.** Socio-demographic characteristics of households in the study area

| Household characteristics (*n* = 352) | Lay Gayint | Tach Gayint | Simada | Mean |
|---|---|---|---|---|
| Household heads proportion (%) | 39 | 33 | 28 | |
| Sex (%) | | | | |
| Male | 93 | 82 | 79 | 85 |
| Female | 7 | 18 | 21 | 15 |
| Average age of respondents (years) | 44 | 44 | 40 | 43 |
| Average household/family (persons) | 5 | 5 | 5 | 5 |
| Education (%) | | | | |
| Illiterate | 29 | 35 | 66 | 43 |
| Primary education (1–8) | 59 | 52 | 23 | 45 |
| Secondary education (9–12) | 12 | 13 | 8 | 11 |
| College and above | – | – | 3 | 1 |

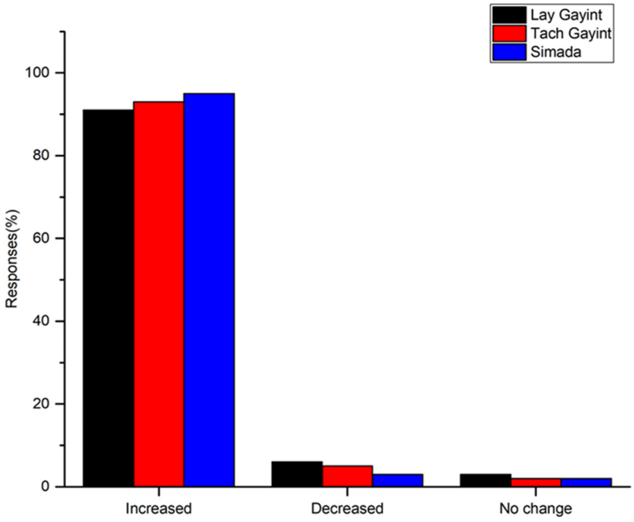

**Figure 2.** Households' perceptions of temperature in the study area

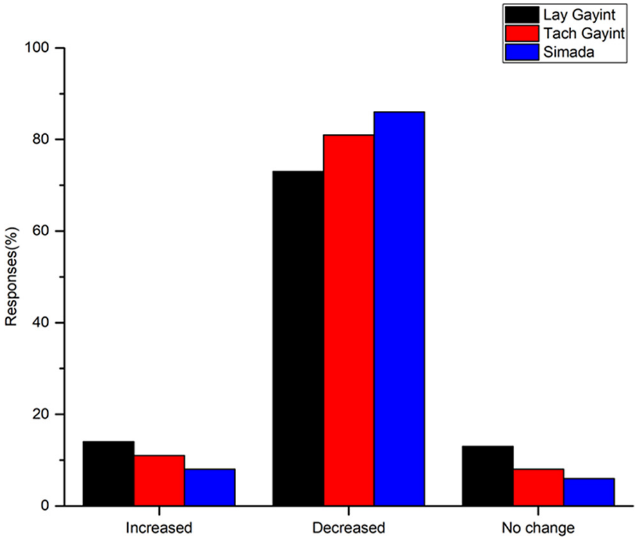

**Figure 3.** Households' perceptions of rainfall in the study area

no change. The result indicates that the majority of households in the study area believed that the temperature and rainfall had increased and decreased, respectively, in the previous years. In Lay Gayint, Tach Gayint and Simada, respectively, 91%, 93% and 95% of households reported an increase in temperature. On the other hand, 73%, 81% and 86% in Lay Gayint, Tach Gayint and Simada, respectively, believed that rainfall was decreasing (Figures 2 and 3).

According to the findings of the FGDs and KIIs, households specifically reported temperature and rainfall variability, an increase in minimum (nighttime) and maximum (daytime) temperatures and a decrease in *Belg* rainfall (the minor rainy season). As a result, it has been found that households' perceptions of climate variability and trends are consistent with variations in minimum and maximum temperatures as well as rainfall in the *Belg* season. The annual and *Kiremt* rainfall (the major rainy season), however, revealed a discrepancy between household perceptions and meteorological analysis. The inconsistency of households' observation and meteorological data analysis is also reported by some studies (Behailu *et al.*, 2021; Mertz *et al.*, 2009; Sofoluwe *et al.*, 2011). In these studies, households observed a decrease in rainfall, while meteorological records showed increasing trends. The discrepancy might be because of the extreme value opinions of households and the constraint of average value analysis in meteorological data.

The observed meteorological data analysis confirmed how the households' perceived changes in temperature and rainfall. As a result, the observed data sets indicated that the minimum and maximum temperatures showed an increasing trend at a rate of 0.04 and 0.05°C/year, respectively, for Lay Gayint at a $p = 0.05$ level. At the $p = 0.05$ level, the regression coefficient in Simada revealed an upward trend at a rate of 0.02 and 0.06°C/year for the minimum and maximum temperatures, respectively. Moreover, the minimum and maximum temperatures showed an increasing trend at a rate of 0.04°C/year in Tach Gayint at a $p = 0.05$ level (Figure 4). The slope of the regression line for the *Belg* rainfall (minor rainy season) declined at a rate of 0.08, 0.11 and 0.13 mm/year for Lay Gayint, Tach Gayint and Simada, respectively, at a $p = 0.05$ level. On the other hand, annual and *Kiremt* rainfall

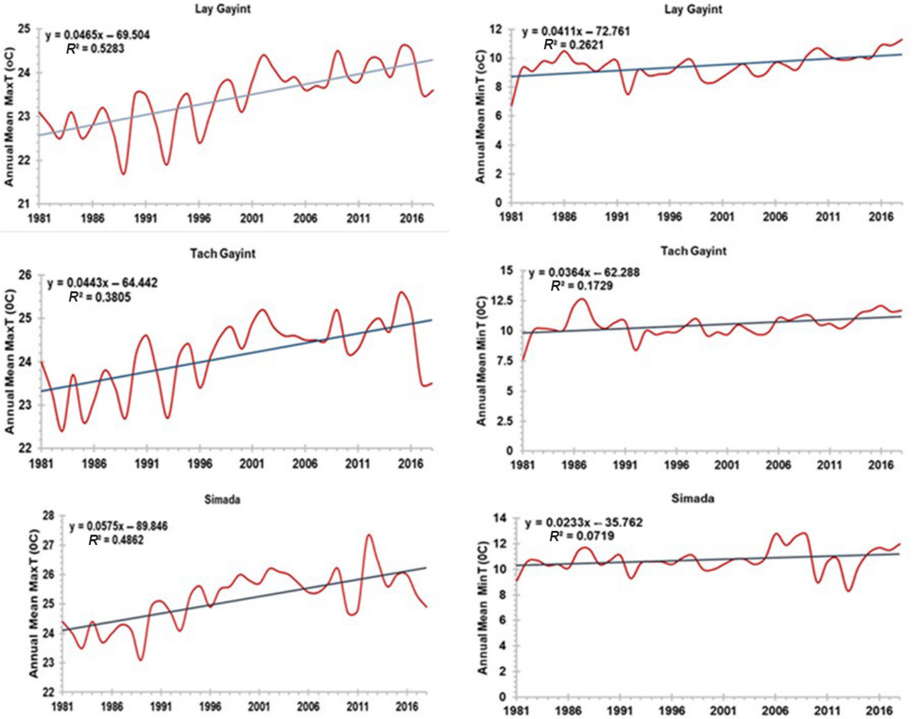

**Figure 4.**
Temperature patterns of maximum (left) and minimum (right) in the study area

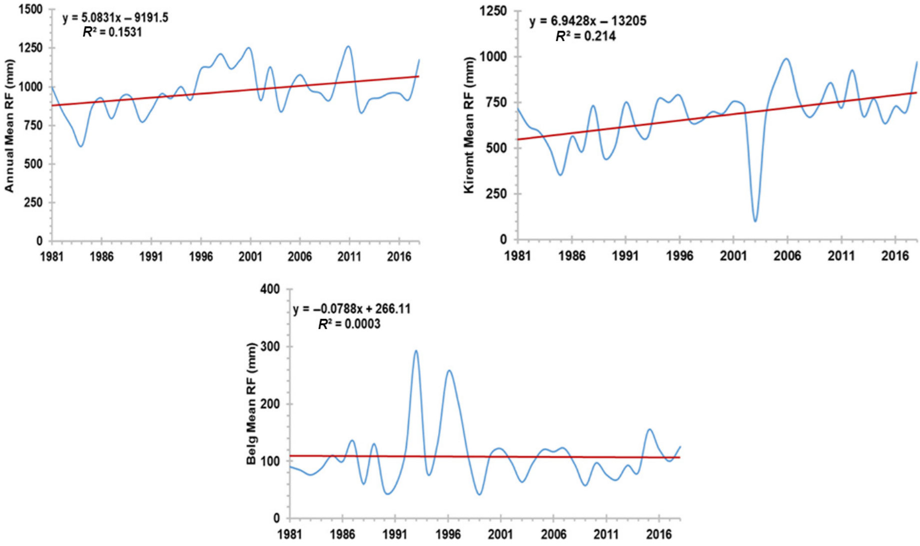

**Figure 5.**
Rainfall patterns of annual, *Kiremt* and *Belg* in Lay Gayint

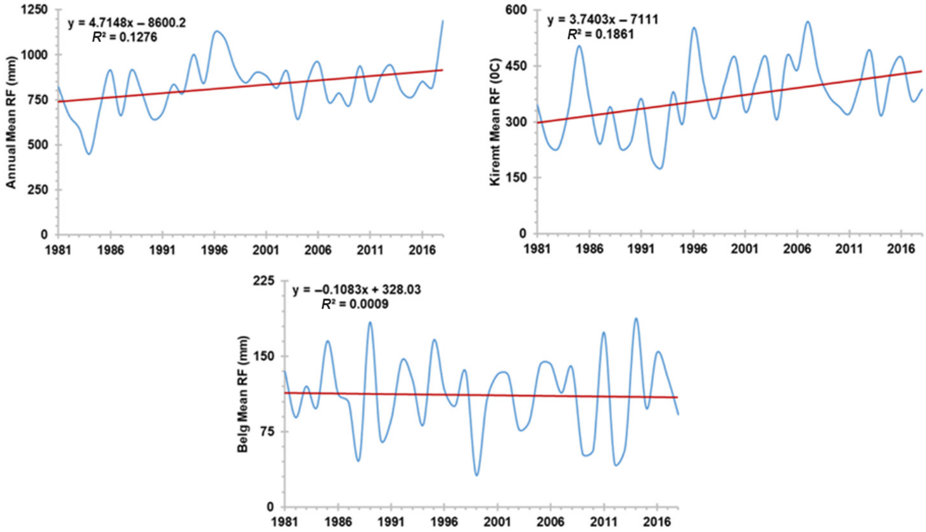

**Figure 6.**
Rainfall patterns of annual, *Kiremt* and *Belg* in Tach Gayint

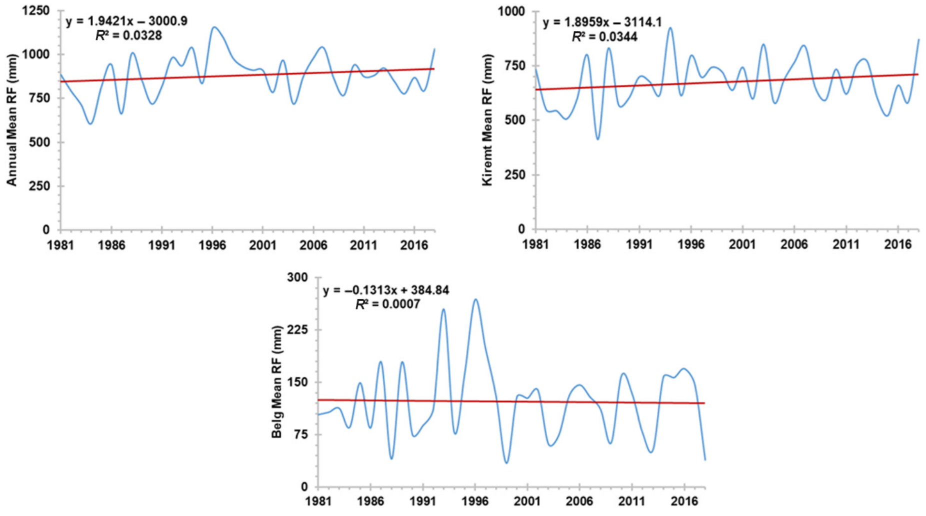

**Figure 7.**
Rainfall patterns of annual, *Kiremt* and *Belg* in Simada

(major rainy season) showed increasing trends in all the study districts, but with high variability (Figures 5–7).

Moreover, seasonal and annual rainfall trends over the study area are examined using the Mann–Kendall trend test (Table 2). On the basis of the Mann–Kendall trend test, annual rainfall exhibited a significant increasing trend (7.89 mm/year) in Lay Gayint at $p = 0.01$ level and an increasing trend (7.00 mm/year) in Tach Gayint at $p = 0.05$ level, but a non-significant downward trend in annual rainfall was observed in Simada. At the seasonal level, *Kiremt* and *Belg* rainfall revealed a non-significant upward trend in Lay Gayint and

Tach Gayint. On the other hand, *Kiremt* and *Belg* rainfall revealed a non-significant downward trend in Simada.

Similar to rainfall trend analysis, mean annual minimum and maximum temperature trends were calculated using Mann–Kendal trend test techniques. The Mann–Kendal trend test showed mean annual minimum temperature exhibited significant warming trends in Simada and Lay Gayint at $p = 0.05$ level but a non-significant increasing trend in Tach Gayint. Similarly, the trend of mean annual maximum temperatures exhibited significant warming trends at a $p = 0.01$ level in the study area (Table 3).

**Table 2.**
The Mann–Kendal trend test values of rainfall at seasonal and annual timescales

| | Lay Gayint | | Tach Gayint | | Simada | |
|---|---|---|---|---|---|---|
| Season and annual rainfall | $Z_{MK}$ | $\beta$ | $Z_{MK}$ | $\beta$ | $Z_{MK}$ | $\beta$ |
| *Belg* | 1.43 | 1.56 | −0.20 | 0.12 | 0.21 | −0.77 |
| *Kiremt* | 1.88 | 7.45 | 1.72 | 0.77 | 1.95 | −0.57 |
| Annual | 2.73 | 7.89*** | 1.02 | 2.47 | 7.00** | 1.13 |

**Notes:** *, ** and *** significant at 0.1, 0.05 and 0.01 alpha levels, respectively. Abbreviations: $Z_{MK}$, standardised statistics of Mann–Kendal trend test; $\beta$, Sen's slope estimator

**Table 3.**
The Mann–Kendal trend test values of mean minimum and maximum annual temperatures

| | Lay Gayint | | Tach Gayint | | Simada | |
|---|---|---|---|---|---|---|
| Temperature | $Z_{MK}$ | $\beta$ | $Z_{MK}$ | $\beta$ | $Z_{MK}$ | $\beta$ |
| Mean minimum annual temperature | 1.56 | 0.01** | 1.19 | 0.01 | 2.01 | 0.02** |
| Mean maximum annual temperature | 4.09 | 0.03*** | 1.56 | 0.01 | 2.31 | 0.02** |

**Notes:** *, ** and *** significant at 0.1, 0.05 and 0.01 alpha levels, respectively. Abbreviations: $Z_{MK}$, standardised statistics of Mann–Kendal trend test; $\beta$, Sen's slope estimator

**Table 4.**
Climate change risk perception of households in Lay Gayint

| Climatic events | 3 | 2 | 1 | 0 | CCRPS | SCCRPI | Rank |
|---|---|---|---|---|---|---|---|
| Recurrent drought | 101 | 33 | 16 | 0 | 385 | 92.99 | 1 |
| Delayed onset of rainfall | 100 | 28 | 17 | 0 | 373 | 90.09 | 2 |
| Early termination of rainfall | 97 | 30 | 12 | 0 | 363 | 87.68 | 3 |
| Food insecurity | 94 | 28 | 13 | 0 | 351 | 84.78 | 4 |
| Flood | 62 | 25 | 13 | 2 | 249 | 60.14 | 5 |
| Soil fertility loss | 61 | 24 | 11 | 1 | 242 | 58.45 | 6 |
| Drinking water scarcity | 57 | 19 | 25 | 4 | 234 | 56.52 | 7 |
| Gulley formation | 59 | 22 | 10 | 0 | 231 | 55.79 | 8 |
| Crop pests | 48 | 4 | 47 | 2 | 199 | 48.06 | 9 |
| Frost | 27 | 4 | 41 | 29 | 130 | 31.40 | 10 |
| Human and livestock diseases | 22 | 5 | 34 | 37 | 110 | 26.57 | 11 |
| Resource based conflict | 18 | 3 | 32 | 36 | 92 | 22.22 | 12 |
| Cultivated and grazing land encroachment | 11 | 2 | 29 | 35 | 66 | 15.94 | 13 |
| Land slide | 1 | 2 | 4 | 76 | 11 | 2.65 | 14 |

**Notes:** 0: No perception; 1: Low perception; 2: Medium perception; and 3: High perception

### *3.3 Climate change risk perception of households*

Tables 4–6 show climate change risk perceptions of households in the study area.

It is shown that in the Lay Gayint district, the likelihood of the occurrence of potentially dangerous climate change risks is most likely to be linked to persistent drought, delayed onset of rainfall, early termination of rainfall and food insecurity as reported by households (Table 4). As shown in Table 5, households in the Tach Gayint district perceived recurrent drought, food insecurity, delayed onset of rainfall and early termination of rainfall as potentially dangerous climate change risks. Moreover, recurrent drought, food insecurity, delayed onset of rainfall and early termination of rainfall were perceived as the major potentially dangerous climate change risks by households in Simada district (Table 6).

The variation of CCRPI for each climate event implies that households have heterogeneous perceptions of risk arising from the different climate events, which could be

| Climatic events | 3 | 2 | 1 | 0 | CCRPS | SCCRPI | Rank |
|---|---|---|---|---|---|---|---|
| Recurrent drought | 91 | 20 | 10 | 0 | 323 | 92.02 | 1 |
| Delayed onset of rainfall | 86 | 19 | 22 | 0 | 318 | 90.59 | 2 |
| Food insecurity | 89 | 19 | 9 | 0 | 314 | 89.46 | 3 |
| Early termination of rainfall | 85 | 16 | 23 | 3 | 310 | 88.31 | 4 |
| Flood | 56 | 14 | 23 | 2 | 219 | 62.39 | 5 |
| Soil fertility loss | 56 | 13 | 21 | 3 | 215 | 61.25 | 6 |
| Drinking water scarcity | 57 | 11 | 17 | 4 | 210 | 59.82 | 7 |
| Gulley formation | 54 | 12 | 21 | 1 | 207 | 58.97 | 8 |
| Resource based conflict | 53 | 12 | 14 | 3 | 197 | 56.13 | 9 |
| Crop pests | 43 | 13 | 16 | 2 | 171 | 48.71 | 10 |
| Cultivated and grazing land encroachment | 41 | 10 | 13 | 2 | 156 | 44.44 | 11 |
| Human and livestock diseases | 30 | 4 | 20 | 5 | 118 | 33.61 | 12 |
| Frost | 31 | 5 | 13 | 2 | 116 | 33.04 | 13 |
| Land slide | 1 | 2 | 5 | 78 | 12 | 3.41 | 14 |

**Notes:** 0: No perception; 1: Low perception; 2: Medium perception; and 3: High perception

**Table 5.** Climate change risk perception of households in Tach Gayint

| Climatic events | 3 | 2 | 1 | 0 | CCRPS | SCCRPI | Rank |
|---|---|---|---|---|---|---|---|
| Recurrent drought | 60 | 40 | 15 | 0 | 275 | 94.50 | 1 |
| Food insecurity | 59 | 39 | 16 | 0 | 271 | 93.13 | 2 |
| Delayed onset of rainfall | 59 | 41 | 9 | 0 | 268 | 92.09 | 3 |
| Early termination of rainfall | 58 | 42 | 2 | 0 | 260 | 89.34 | 4 |
| Cultivated and grazing land encroachment | 56 | 41 | 3 | 0 | 253 | 86.94 | 5 |
| Flood | 27 | 46 | 13 | 2 | 186 | 63.91 | 6 |
| Soil fertility loss | 26 | 45 | 11 | 2 | 179 | 61.51 | 7 |
| Drinking water scarcity | 29 | 38 | 11 | 1 | 174 | 59.79 | 8 |
| Gulley formation | 24 | 41 | 13 | 3 | 167 | 57.39 | 9 |
| Crop pests | 30 | 8 | 37 | 27 | 143 | 49.14 | 10 |
| Resource based conflict | 17 | 9 | 33 | 39 | 102 | 35.05 | 11 |
| Human and livestock diseases | 17 | 7 | 30 | 37 | 95 | 32.64 | 12 |
| Frost | 17 | 4 | 25 | 49 | 84 | 28.86 | 13 |
| Land slide | 1 | 2 | 6 | 90 | 13 | 4.46 | 14 |

**Notes:** 0: No perception; 1: Low perception; 2: Medium perception; and 3: High perception

**Table 6.** Climate change risk perception of households in Simada

associated with the variations in socio-demographic and external factors. This finding is consistent with the literature, which shows that households' perceptions are influenced by individual risk aversion and socio-economic characteristics (Frondel *et al.*, 2017; Sullivan-Wiley and Gianotti, 2017). Accordingly, from the CCRPI, the values varied, ranging from 2.65 to 92.99 (Lay Gayint), 3.41 to 92.02 (Tach Gayint) and 4.46 to 94.50 (Simada), which demonstrates that households' perceptions were heterogeneous. Households living in Simada (*Woyna Dega* agroecology) and Tach Gayint (*Dega* agroecology) perceived more climate change risks than households in Lay Gayint (*High Dega* agroecology). This could be associated with the probability of the incidence of potentially dangerous climate change risks in the area. However, most of the households belonged to medium to high perception index values in Lay Gayint (48.06 to 92.99), in Tach Gayint (48.71 to 92.02) and in Simada (49.14 to 94.50) and fewer belonged to low and medium perception index values (2.65 to 31.40 for Lay Gayint, 3.41 to 44.44 for Tach Gayint and 4.46 to 35.05 for Simada). Moreover, the results of KIIs and FGDs also revealed that the aggregated responses from households matched the estimated index values for each climate change risk.

### *3.4 Households' adaptation strategies*

The study found eight adaptation strategies practiced by households in the study area (Table 7). Adjusting crop planting dates was the most widely used (84% households) adaptation strategy by farmers in the study area. This is perhaps because adjusting crop planting dates is a cheaper practice compared to other adaptation strategies. Similar result was reported by Alemayehu and Bewket (2017), Kahsay *et al.* (2019) and Getahun *et al.* (2021) in different parts of Ethiopia. Terracing was the second most adopted strategy by farmers (82% of households), ranging between 76% in Simada and 83% in Tach Gayint and 87% in Lay Gayint. This is partly a result of the government-led conservation activities in the country as a whole. Crop diversification was the third most (78% of households) adopted strategy by farmers; it was used by 70% of households in Lay Gayint, 77% of households in Tach Gayint and 87% of households in Simada. The other strategies were tree planting (75% of households), use of improved crop seeds (67% of households) and use of drought tolerant crop varieties (51% of households). Off-farm activities (26% of households) and the use of water harvesting/irrigation (12%, of households) were the least used adaptation strategies by households in the study area. Participants in the FGD noted that, despite irrigation being one of the most crucial adaptation measures for managing the risks of climate change, low irrigation potential and a lack of financial resources are two of the major obstacles to adaptation.

**Table 7.** Adaptation strategies used by households in the study area

| Adaptation strategies | Respondents (%) in respective districts | | | | | |
|---|---|---|---|---|---|---|
| | Lay Gayint | Tach Gayint | Simada | Mean | F | Significance |
| Crop diversification | 70 | 77 | 87 | 78 | 4.3 | 0.014* |
| Off-farm activities | 34 | 23 | 21 | 26 | 3.2 | 0.040* |
| Terracing | 87 | 83 | 76 | 82 | 2.3 | 0.104 |
| Improved seed | 65 | 68 | 69 | 67 | 0.2 | 0.820 |
| Tree planting | 76 | 74 | 75 | 75 | 0.6 | 0.545 |
| Adjusting crop planting dates | 84 | 81 | 88 | 84 | 0,8 | 0.443 |
| Water harvesting/Irrigation | 9 | 13 | 13 | 12 | 0.8 | 0.447 |
| Drought tolerant crop | 43 | 50 | 60 | 51 | 3.3 | 0.036* |

**Note:** * Significant at $\alpha$ 0.05 level

A significant difference was found between districts in the following adaptation strategies: off-farm activities [F (2,349) = 3.2 and $p = 0.040$], crop diversification [F (2,349) = 4.3 and $p = 0.014$] and drought tolerant crop [F (2,349) = 3.3 and $p = 0.036$]. A Tukey's post hoc test revealed a statistically significant difference in off-farm activities, crop diversification and planting drought-tolerant crop types among the adaptation strategies in the study area between Lay Gayint and Simada districts ($p < 0.05$) compared to Tach Gayint district. This difference reconfirms the fact that adaptation strategies are location-specific and, thus, differ between localities (Dendir and Simane, 2021).

### *3.5 Links between adaptation strategies and perceived/experienced climate risks*

*3.5.1 Adjusting crop planting dates.* Early sowing dates increase crop production compared to the base line planting dates and a delayed sowing date with rainfed or irrigation (Getachew *et al.*, 2021). However, early sowing dates were more effective when applied with irrigation than when applied with rain. A similar study found that early sowing dates are important for early maturing crops (Akinseye *et al.*, 2020).

According to FGD participants, onset and offset dates for both the main rainy season (June to September, called *Kiremt*) and the short rainy season (March to May, called *Belg*) had become highly variable in recent years, especially with remarkable delays in the onset times. Participants noted that the *Belg* production season had been lost, and the *Kiremt* rainfall had become insufficient for their agricultural production. The *Belg* rains are critical for not only *Belg* season production but also land preparation for the main season crops (also known as *Meher* season). Hence, the decline in *Belg* rains has an impact on both *Belg* and *Meher* season production, especially long-cycle crops. As a result of the changes in rainfall pattern, participants reported that crop planting dates had been adjusted, and land ploughing frequency had been reduced. The reduction of ploughing frequency often leads to increased occurrence of weeds. The timing of farmland preparation and sowing is adjusted to coincide with the arrival of sufficient rainfall. Land preparation for all *Meher* season crops, as well as planting dates for long-cycle crops like maize and sorghum, had been set for May from the earlier usual planting dates of April. Similarly, planting dates for tef (*Eragrotis teff*) had been shifted to late June, from its earlier usual planting date in the study area of early June. However, FGD and KII participants indicated that because the rainy season is unpredictable, adjusting crop planting dates has become more challenging in recent years.

*3.5.2 Terracing.* A study conducted by Alemayehu and Bewket (2017) and Bewket (2012) revealed that soil and water conservation measures are mostly undertaken by the government through its annual community mobilisation for watershed management program, in which each household contributed 30–60 days of free labour in different parts of Ethiopia. In the study area, terracing was found to be the second most important adaptation strategy, as indicated by the number of households who reported to have used it. Terraces provide a variety of ecological services, such as reducing runoff and silt, as well as increasing grain yields and soil moisture content. Furthermore, terracing can help to conserve plant biodiversity on a local scale. Hence, its use mitigates the negative impacts of rainfall variability, which is a growing challenge in the study area because of climate change. However, as terraces age, a variety of drawbacks emerge, including water circulation interference and the development of major environmental problems caused by badly built or unmanaged terraces, where average runoff and soil loss can be one to five times that of well-managed terraces (Deng *et al.*, 2021).

*3.5.3 Crop diversification.* Several studies suggest convincing evidence of how the efficient use of agrobiodiversity can result in improved livelihood outcomes using a variety of strategies that can be used in any combination. For instance, Raseduzzaman and Jensen (2017) confirmed that intercropping lowers the possibility of a complete crop failure, can diversify small-scale farmers' diets and increase their food security and can help crop production adapt to climate change. Moreover, different cultivars of the same crop can be mixed together in a field to reduce pest and disease impacts on crops and increase production both in space and over time (Nankya *et al.*, 2017; Vernooy, 2022).

According to findings from FGDs and KIIs, households in the study area received advice from extension agents to diversify their crops. For instance, farmers in Simada were reportedly encouraged to grow Mung bean (*Vigna radiate*) locally known as *Masho*. Mung bean is a self-pollinated, short-duration diploid legume crop with high nutritional properties and nitrogen-fixing potential and a cash crop that pays better than cereals. Farmers in the area were also encouraged to adopt new varieties of sorghum (known as *Girana-1*) and tef (known as *Cross-37*), both of which are said to be early maturing and adapted to moisture-deficit conditions. *Quncho*, an improved variety of tef that has good tolerance to both drought and waterlogging conditions and suffers relatively little from diseases and pests, has been grown by nearly half of the farmers in Simada. *Quncho* is an improved variety of tef which has a good tolerance for both drought and waterlogging conditions as well as to diseases and pests.

*3.5.4 Tree planting.* Planting trees was, as described above, one of the adaptation strategies used in the study area. Eucalyptus was the most planted tree type, and it is an important cash crop in the area. Besides its climate adaptation benefits, tree planting is preferred for its lower labour demand particularly once it is planted. A study conducted by Alemayehu and Bewket (2018) confirmed that households are transforming their farmlands into eucalyptus tree despite some reservations from local experts that eucalyptus planting may have an impact on future crop production in the central highlands of Ethiopia. Moreover, in the Raya Azebo district of Ethiopia, Sertse *et al.* (2021) noted that households use tree planting as an agroforestry practice and have the option of selling the trees in times of climate change shocks. FGDs and KIIs participants reported that eucalyptus trees offer protection against the negative impacts of climate variability and support them in managing shocks to their way of life.

## 4. Conclusion

This study assessed farmers' perceptions of climate change risks and their adaptation strategies in the northwest highlands of Ethiopia. We found that recurrent drought, delayed onset and early cessation of rainfall and food insecurity were the major climate change risks perceived by households. Adaptation strategies used by the households included adjusting crop planting dates, crop diversification, terracing, tree planting and cultivating drought-tolerant crop varieties, among others. Statistically significant difference was found between the districts in their use of adaptation strategies; the difference being in the use of off-farm activities, crop diversification and planting drought-tolerant crop types between Lay Gayint and Simada compared to Tach Gayint. The results from this study are important for local decision-makers, as they seek to support adaptation strategies that improve livelihoods of households, while the local climate is changing. There is an opportunity to enhance the climate change risk perception and adaptation strategies of households to climate-related issues in the study area. Households with fewer adaptation strategy may be more exposed to climatic threats and require further attention to strengthen their adaptation responses. Our recommendations are that (a) future policy initiatives both by government and non-governmental organisations should be agroecology-specific and incorporate the study area during policy design given the peculiar environmental conditions faced by these households;

(b) decision-makers should integrate households' perceptions of climate change risks and locally used adaptation strategies to facilitate their transition to improve adaptation and sustainability; (c) adaptation plans and risk communication techniques need to be developed to increase the risk perception and adaptation responses of climate change in the study area; and (d) there is a need for further research on climatic change risk perception and adaptation strategies among demographic and socioeconomic characteristics in the study area, such as gender, age, education level and income.

## Notes

1. *Kebele* is the lowest administrative unit in Ethiopia.
2. *Regional* refers to one of the federating states of Ethiopia.

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