Research Square

Preprints are preliminary reports that have not undergone peer review.
They should not be considered conclusive, used to inform clinical practice,
or referenced by the media as validated information.

Community based breeding programs influence climate adaptation strategies among smallholder sheep farmers in Ethiopia

Emna Rekik

r.emnarekik@gmail.com

University of Natural Resources and Life Sciences (BOKU)

Maria Wurzinger

Iowa State University

Hassan Ouerghemmi

International Center for Agricultural Research in the Dry Areas (ICARDA)

Shanbel Besufkad

Debre Birhan Agricultural Research Center

Zelalem Abate

Bonga Agricultural Research Center

Johann Sölkner

University of Natural Resources and Life Sciences (BOKU)

Tesfaye Getachew

International Centre for Agricultural Research in the Dry Areas (ICARDA)

Shigdaf Mekuriaw Zewdu

Unique land use GmbH

Barbara Rischkowsky

International Centre for Agricultural Research in the Dry Areas (ICARDA)

Dawit Solomon

International Livestock Research Institute (ILRI)

Aynalem Haile

International Centre for Agricultural Research in the Dry Areas (ICARDA)

Research Article

Keywords: Climate change, adaptation, livestock systems, perception, Ethiopia

Posted Date: November 11th, 2026

DOI: https://doi.org/10.21203/rs.3.rs-10995953/v1

License: This work is licensed under a Creative Commons Attribution 4.0 International License.
Read Full License

Additional Declarations: No competing interests reported.

Community based breeding programs influence climate adaptation strategies among smallholder sheep farmers in Ethiopia

Emna Rekik[1,6*], Maria Wurzinger[1,2] Hassan Ouerghemmi[3], Shanbel Besufkad[4], Zelalem Abate[5], Johann Sölkner[1], Tesfaye Getachew[6], Shigdaf Mekuriaw Zewdu[7], Barbara Rischkowsky[6], Dawit Solomon[8], Aynalem Haile[6].

[1] Division of Livestock Sciences, Department of Sustainable Agricultural Systems, University of Natural Resources and Life Sciences (BOKU), Vienna, Austria.

[2] Department of Animal Science, Iowa State University, Ames, USA

[3] International Center for Agricultural Research in the Dry Areas (ICARDA), Ariana, Tunisia.

[4] Debre Birhan Agricultural Research Center, Debre Birhan, Ethiopia.

[5] Animal sciences case team, Bonga Agricultural Research Center, Bonga, Ethiopia

[6] International Centre for Agricultural Research in the Dry Areas (ICARDA), Addis Ababa, Ethiopia

[7] Unique land use GmbH, Addis Ababa, Ethiopia

[8] CCAFS Program, International Livestock Research Institute (ILRI), Addis Ababa, Ethiopia

***** Corresponding author

r.emnarekik@gmail.com

Abstract

Climate change poses significant challenges to agricultural systems, particularly in livestock-dependent communities. This study examines farmers' perceptions of climate change, its impacts, and adaptation strategies in two sheep Community-Based Breeding Program (CBBP) sites in Ethiopia: Bonga and Menz. Meteorological data from 1993–2023 were analysed alongside household surveys of 407 farmers. Findings reveal notable differences in farmers' perceptions and adaptation practices between sites. Farmers in Menz reported a higher frequency of droughts and water scarcity, while Bonga farmers highlighted grazing land loss as critical challenges. The analysis of adaptation practices identified key determinants such as geographical location, membership in cooperatives, training attendance, and access to climate-related information. Participation in cooperatives, such as the CBBP, emerged as a key enabler of climate-smart adaptation, with members adopting twice as many adaptation strategies as non-members. While feed improvement and destocking were widely adopted across all farmers regardless of CBBP membership, breeding animals that are more adapted was more common among CBBP members (66.8%) than non-members (14.6%), alongside proactive health management, income diversification, transhumance, and pasture management. Despite the positive role of cooperatives, barriers such as limited access to farm inputs, veterinary services, and microfinance remain common for all surveyed farmers in both sites. This study underscores the importance of farmer cooperatives and organizations in enhancing institutional support to improve the climate resilience and foster climate-smart agricultural practices of small holder livestock systems. The findings offer practical insights for policymakers, and livestock breeding organizations to support their efforts in strengthening climate-resilient smallholder systems.

Keywords: Climate change, adaptation, livestock systems, perception, Ethiopia

Introduction

Climate change has increasingly affected agricultural systems over the past few decades, especially in Africa, where its impacts on livelihoods and food production are among the most severe (Barrios et al. 2008; Adhikari et al. 2015) . Beyond global warming, climate change encompasses altered precipitation patterns, more frequent extreme weather events such as droughts and floods, shifts in temperature regimes, disrupting agricultural production systems and exacerbating natural disasters (Godde et al. 2021).

Farmers, particularly those relying on rain-fed systems, are facing several challenges to implementing adaptation strategies, aiming to mitigate the adverse effects of climate change (Alemayehu and Bewket 2017). The successful implementation of any adaptation strategies such as adjusting feeding practices, protecting livestock, or modifying crop management, largely depends on farmers' perceptions of climate change and variability (Elum et al. 2017). There are several examples from Ethiopia that depict farmers' understanding and perception of climate change and this seems to be greatly influenced by the geographic and the production context. In Jimma, the largest coffee producing zone in Ethiopia, over 70% of surveyed farmers experienced drought and rainfall shortages, with 58.7% expressing significant concern about the future due to climate-related shocks (Eneyew et al. 2019). Climate change-induced disasters have severely impacted livestock production, particularly in fragile ecosystems of the Wolaita region along the Great Rift Valley in the south (Yesuph et al. 2023). Farmers in Ethiopia's semi-

arid and arid lowlands, who heavily rely on rain-fed agriculture and have few assets for diversification, are especially vulnerable to the effects of climate change.

Adaptation to climate change is a global concern (Bryan et al. 2009a) and livestock farmers in Ethiopia are also practicing adaptation measures to cope with climate change (Hameso 2018). Some of these measures relate to diversification of livestock animals (species/breeds) and crops, shifting towards sylvo-agro-pastoral systems (integrated farming systems that combine forestry, crop cultivation, and livestock grazing within the same production landscape), and changing the timing and locations of farm operations. The major climate change adaptation measures adopted by the livestock farmers in Tigray (Ethiopia) included provision of improved animal health care together with the key biosecurity practice to house animals in clean shades, reducing herd size to minimize feed pressure during climate shocks (destocking), use of feeding & watering troughs to reduce wastes and crossbreeding to expand the range of genetic diversity for adaptation (Ruo 2018). Further south in the arid and semi-arid lowlands like Afar and Somali regions, pastoralists frequently resort to mobility and transhumance, that is, moving livestock to areas with better pasture and water availability; however, climate change is gradually changing the transhumance routes and increasing the frequency of herds' movement (Tilahun et al. 2017; Djakpa et al. 2024). Additionally, in regions such as Oromia, farmers adopt practices like integrating crop-livestock systems, using crop residues as supplementary feed, and switching to drought-tolerant livestock breeds (Aklilu and Catley).

Farmers' cooperatives can raise awareness to ensure timely early warning about climate shocks or disasters and can promote mitigation strategies among member farmers. Even

though documented experiences using a scientific approach are difficult to find, evidence from Vietnam describes the critical role of farmer cooperatives in promoting green production, reducing ecological harm, and facilitating environmental protection (Vu et al. 2023). In Mongolia, herders engaged in traditional community-based natural resource management (CBNRM) exhibited a higher adaptive capacity compared to non-CBNRM herders (Fernández-Giménez et al. 2015). This increased capacity is attributed to robust social networks and well-coordinated institutions for managing livestock movements and grassland exchanges. Farmers' cooperatives can also help members embrace less emitting agriculture by reducing their carbon footprints and through access to governments' climate funds (Yi and Gu 2022).

In this context, cooperatives and professional organizations active around livestock Community-Based Breeding Programs (CBBPs) have emerged as a significant innovation to enhance herds' productivity and resilience among their smallholder members (Wurzinger et al. 2021). CBBPs involve the active participation of local communities in the selection and breeding of livestock (Haile et al. 2020a). CBBPs were first introduced in Ethiopia around 2009 and have since expanded to several sheep and goat production systems across the country (Haile et al. 2020a). These programs not only improve genetic resources but also foster greater community involvement and ownership, leading to better adaptation and sustainability. CBBPs are increasingly recognized as a platform that could integrate climate-smart farming approaches that aim to enhance resilience to climate variability while maintaining productivity and potentially reducing greenhouse gas emissions. These may include the selection of animals for adaptive and low-emission traits, the use of improved climate-resilient forages, strengthened herd-health interventions, and serving as an entry point for monitoring and reporting livestock GHG

115 emissions (Tesfa et al. 2025). To do this at scale, we hypothesize that there are still
116 knowledge research gaps of local farmers' perceptions and adaptation strategies to
117 address the impacts of climate change on the livestock enterprise. In addition, there is
118 limited scientific and programmatic understanding of how farmers' cooperatives and
119 community organizations, such as CBBPs, could facilitate climate change adaptation
120 within smallholder livestock systems.

121 Based on the above, this research work intends to investigate mixed crop-sheep farmers'
122 perceptions of climate change in two major sheep CBBP sites in Ethiopia, namely Bonga
123 and Menz regions. It examines how farmers interpret climate impacts on their livestock
124 systems and the adaptation measures they adopt. Specifically, the study addresses four
125 research questions: i) Do farmers' perceptions of climate trends correspond with
126 historical meteorological records of temperature and precipitation in Bonga and Menz?,
127 ii) What are the main climate-related challenges affecting livestock production as
128 perceived by farmers in the two study sites?, iii) Do farmers participating in Community-
129 Based Breeding Programs (CBBPs) adopt different or more climate adaptation strategies
130 compared with non-CBBP farmers?, iv) What are the main barriers preventing
131 smallholder sheep producers, both CBBP and non-CBBP members, from adopting
132 climate change adaptation measures?.

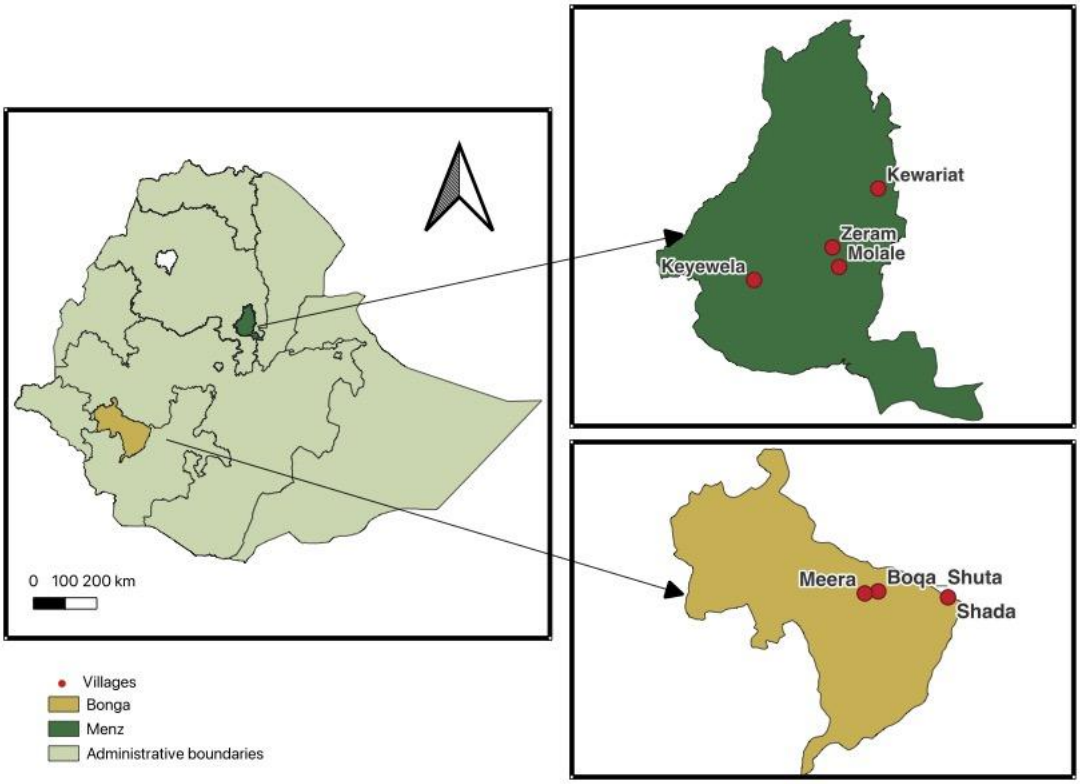


Figure 1: map of the study area

Materials and methods

Ethical statement

This study has been approved by the ethics committee of the University of BOKU (approval number: BOKU-2025/001) and it complies with all relevant ethical regulations of the University of BOKU. Written informed consent was obtained from all participants. Participants were also informed that they could withdraw their consent at any time.

Study Area

This study focused on Menz and Bonga, two sites that have hosted Community-Based Breeding Programs (CBBPs) for over a decade (Figure 1). The Menz area is located in the central northern part of Ethiopia. The region covers around 1,100 km^2, with around 120,000 inhabitants; over 90% of households practice mixed crop–livestock farming. It is characterized as a low-input

146 sheep-barley production system with a bimodal rainfall pattern where the main rainy season is
147 from June to September and a short rainy season commonly occurring in February and March
148 (Sharma 2010). The cool highland parts of Menz are the main habitat of Menz sheep. This breed
149 is adapted to high altitude ranging from 2600 to 3200 meters. At these altitudes, there is a low
150 production of crops and a scarcity of feed due to low temperatures. Animals graze the whole
151 year round on communal pastures and are fed on crop residues during the dry season. In Menz,
152 sheep - with approximately 200,000 heads - is the main livestock species and predominates in
153 smallholder farmers (Sharma 2010).

154 Bonga is a village part of the mountainous highlands west of the Great Rift Valley and is located
155 in southwest Ethiopia (Figure 1), with altitudes ranging from 1,000 to 3,400 meters (Schmitt et
156 al. 2014). The region experiences a warm tropical rainy climate. The rainfall pattern is unimodal,
157 characterized by lower precipitation from November to February and the main rainy season,
158 known as Kiremt, occurring from June to September. During this period, the region receives the
159 heaviest and most consistent rainfall. The dominant farming system is Sylvo-agro-pastoral,
160 where local livelihoods primarily depend on livestock, crop production, and forestry by-
161 products (Tarekegn et al. 2016). The average family size in Bonga is 6.51 (Melaku et al. 2014).
162 The district statistics report over 140,000 head of livestock. Cattle constitute the primary
163 species of livestock in Bonga, comprising 47.5% of the total livestock population, while sheep
164 account for 17.3% (Mamiru et al. 2024) .

165 Sampling procedure and data sources

166 Data collection took place in two stages during this period. Questions for the climate
167 change discussions were fine-tuned through focus group discussions (FGDs) and
168 pretested with a small sample of farmers to ensure clarity and relevance. The pretesting

involved 40 farmers in total, with two focus groups in each study area (one male group and one female group), each consisting of 10 farmers. These open discussions explored their perceptions of climate change, the challenges they face, adaptation strategies, and barriers to implementation. Three kebeles, the smallest administrative units in Ethiopia, were selected from the two districts based on the presence of cooperatives involved in sheep CBBP. Accordingly, one kebele, namely Boka-Shuta, was selected from Bonga district, and two kebeles, Zeram and Molale, were selected from Menz Gera district. Control cooperatives non-involved in sheep CBBP were selected from four kebeles, namely Shada and Meera from Bonga district, and Kewariat, and Keyewela from Menz district.

To determine the appropriate sample size, the methodology outlined in was followed (Areb et al. 2021). A comprehensive list of owners sheep-producing household heads across all selected villages was compiled with the assistance of village leaders. A total of 2,277 sheep owners from Bonga and Menz, each owning more than three ewes, were identified. The sample size for this study was calculated using Yamane's formula (Yamane 1967) with a 95% confidence level, 5% variability, and a precision level of 5%, as outlined below:

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

where n = sample size, N = population size, and e = the desired precision level (margin of error), set at 0.05. The calculation yielded a sample size n = 340. Finally, a total of 407 sheep-producing households were then selected using simple random sampling within each kebele, with 204 from the Bonga district and 203 from the Menz district. In each village, the surveyed households were evenly distributed between CBBP and non-CBBP

192 farmers to ensure balanced representation and robust comparisons between the two
193 groups. The climate questionnaire consisted of both open-ended and closed-ended
194 questions, including ranking and Likert-scale items. The survey was administered in
195 paper format by trained enumerators in the local language.

196 Meteorological assessment

197 The meteorological data for the Bonga and Menz areas were primarily derived from the
198 Google Earth Engine (GEE) (Gorelick et al. 2017) . The Mann-Kendall test was employed
199 to assess trends in temperature and precipitation data for Menz and Bonga between 1993
200 and 2023 (Rustum et al. 2017). This non-parametric test is particularly suited for
201 detecting monotonic trends in environmental time series data, as it does not require the
202 data to conform to a specific distribution (Nyambariga et al. 2023). Sen's slope estimator
203 was used to quantify the rate of change per year in temperature and precipitation,
204 enabling comparison between observed climate trends and farmers' reported
205 perceptions (Kerebo et al. 2024).

206 Data analysis

207 This study employed a mixed-methods approach, integrating both qualitative and
208 quantitative components to provide a comprehensive understanding of farmers'
209 perceptions, adaptation strategies, and the factors influencing them. The data collected
210 from focus group discussions (FGDs) were organized and analyzed using descriptive
211 statistical methods. Quantitative analyses were conducted using SPSS ver. 23.0 software
212 (IBM SPSS Statistics for Windows, IBM Corp., Armonk, By, USA). Descriptive statistics
213 were first calculated to summarize household characteristics, perceived climate trends,
214 climate-related challenges, and adaptation practices. To address the first research

question, Farmers' perceptions of climate change indicators were assessed using a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). The indicators included perceived changes in temperature trends, rainfall variability, drought frequency, water availability, and grazing resource availability. Mean perception scores were calculated for each indicator and compared between the two study areas.

Independent t-tests were applied to compare mean perception scores between Bonga and Menz when the data met normality assumptions, while the Mann–Whitney U test was used for non-normally distributed variables. The first research question was considered supported when farmers' perceptions showed the same direction of change as the meteorological records. For the second research question, the main climate-related livestock challenges were identified as those reported by at least 50% of the total sample. Regional differences in perceived challenges were considered meaningful when chi-square tests of independence indicated a statistically significant difference between Bonga and Menz ($p < 0.05$). The same approach was applied to barriers to adaptation for the 4th research question: group differences between CBBP and non-CBBP farmers were interpreted only when chi-square tests reached significance at $p < 0.05$; where no significant differences were found, barriers were described as common constraints affecting both groups regardless of CBBP membership.

Model specification: Factors Influencing Farmers' Adaptation to Climate Change

To address the third research question, which examines whether farmers participating in CBBPs adopt different or more climate adaptation strategies than non-CBBP farmers, a

237 binary logistic regression model (BLR) was employed to identify the key factors
238 influencing the adoption of strategies in response to the adverse impacts of climate
239 extremes (Bryan et al. 2009b; Kato et al. 2011; Abid et al. 2016). The choice of each
240 adaptation measure available to farmers is a binary decision. The model was
241 independently applied to each of the nine adaptation strategies identified during the
242 FGD. Let *Y* be the binary outcome variable, *Y* is defined as follows:

243 Y_i= 1 if the farmer ticks the given adaptation measure, otherwise Y_i = 0

244 The binary dependent variables were regressed against the X variables as specified in the
245 following equation:

246 $$Yi = \beta 0 + \beta 1X1 + \ldots BnXn$$

247 $\beta 0$ being the intercept, $\beta 1$, $\beta 2$,..., βn the coefficients for the independent variables and
248 $X1$, $X2$,..., Xn the explanatory variables influencing a given adaptation practice. These
249 variables included household characteristics: gender, study area, age group, farming
250 experience, education level, main income source, agricultural training, attendance at
251 climate-related events or training and farmer group membership (Table 1).

252 Prior to the logit regression, we checked for multicollinearity among the explanatory
253 (independent) variables using the Variance Inflation Factor (VIF) and pairwise correlation
254 test (Pearson's correlation coefficient). A VIF value below 10 was used as the accepted
255 threshold for determining the absence of problematic multicollinearity (Gujarati 2003).
256 Given the exploratory nature of this analysis and the estimation of nine separate logistic
257 regression models, no correction for multiple comparisons was applied. Under these
258 conditions, some statistically significant results may represent false positives; findings

259 are therefore interpreted as hypothesis-generating rather than confirmatory, with greater
260 weight placed on effects that are consistent across multiple models.

261 **Table 1:Description of the variables influencing the adaptation of strategies**

Explanatory variables	Description
Study area	Dummy 1= Bonga 0 = Menz
Gender	Dummy 1= Female 0=Male
Age	Categorical
	21-30
	31-40
	41-50
	51 and above
Education	Categorical:
	None
	Primary
	Secondary
	University education
Farming experience	Categorical
	Less than 5 years
	5 – 10 years
	10 – 15 years
	Greater than 15 years
Main income	Categorical
	Crops

	Livestock
	Off Farm Employment (e.g., governmental)
	Business
	Remittances/Monetary Gifts
	OTHER
CBBP	Dummy 1=yes, 0= no
Climate change event/course	Dummy 1=yes, 0= no
Training	Categorical
	None
	Training attendance
	Certificate in Agriculture
	Diploma in Agriculture

Propensity score matching (PSM)

It is possible that farming households that are members of CBBP differ systematically from non-members. To address this issue of selection bias, this study employs a propensity score matching (PSM) method. The PSM technique pairs the treatment group (CBBP members) and the control group (non-members) based on the similarity of observable characteristics as detailed in Table 1 (Ali and Abdulai 2010). This technique helps to adjust for initial differences between CBBP member and non-member groups by matching each member unit to a non-member unit based on similar observable characteristics, conveniently summarizing the conditional probability of membership

given pre-treatment characteristics (Rosenbaum and Rubin 1983). The first step in estimating the CBBP membership effect is to estimate the propensity score.

After obtaining the predicted probability values conditional on the observable covariates, nearest neighbor and Kernel matching was then performed to match each treated unit (CBBP members) with control group (non-members) based on their propensity scores. Covariate balance before and after matching was assessed using standardised mean differences (SMD) for all seven matching covariates. An SMD below 0.10 in absolute value was used as the threshold for adequate balance (Austin 2011). The common support region was identified based on the overlap in propensity score distributions between treated and control group. Matching was conducted using nearest-neighbour matching (1:1, without replacement) with a caliper of 0.05, within the common support region (propensity score range: 0.20–0.87). Full balance diagnostics are reported in Table S 3. Finally, ordinary least squares (OLS) regression analysis was conducted on the matched sample to determine the effect of CBBP membership on the total number of adaptation measures employed by the farmers.

Results

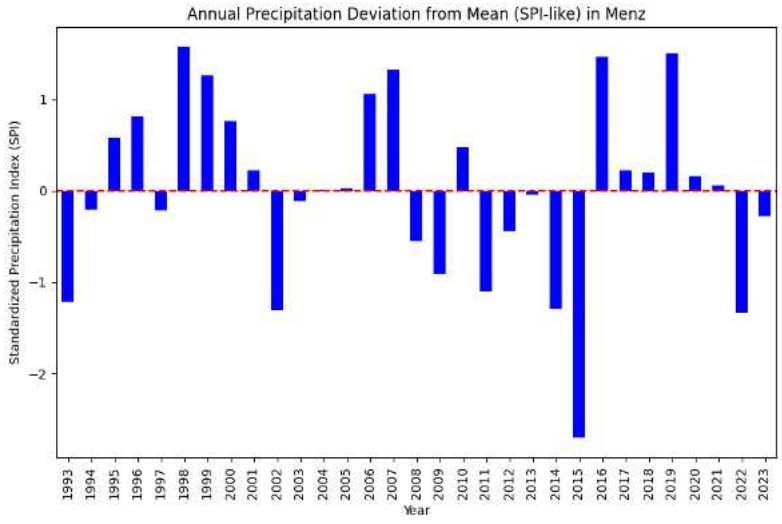
Meteorological data

The meteorological analysis (table 2) revealed an increasing trend in temperature in both Menz and Bonga. The maximum temperature in Bonga increased by 0.42 °C per decade and 0.39°C for Menz. Additionally, the analysis indicated that Menz is experiencing more severe drought conditions compared to Bonga, as evidenced by the precipitation data and the Standardized Precipitation Index (SPI) (Figure 2).

294 **Table 2: Temperature and rainfall trends in the study regions Bonga and Menz**

LOCATION	CLIMATE PARAMETERS	MEAN	STD.DEV	TREND	KENDALL'S TAU	P-VALUE	SEN'S SLOPE
BONGA	Annual Maximum Temperature (°C)	22.3	0.78	increasing	0.37	0.004	0.04
	Annual Minimum Temperature (°C)	15.7	0.48	increasing	0.28	0.03	0.02
	Annual Rainfall (mm)	1793	195.82	increasing	0.24	0.05	6.57
MENZ	Annual Maximum Temperature (°C)	19.9	0.71	increasing	0.25	0.05	0.04
	Annual Minimum Temperature (°C)	12.2	0.53	increasing	0.15	0.26	0.02
	Annual Rainfall (mm)	1111	147.08	decreasing	-0.11	<0.001	-2.47

295



296

297 **Figure 2: Standardized Precipitation Index (SPI) in Menz from 1993-2023**

298 Trends in figure 2 show significant variability in precipitation over the years, with several
299 periods of severe above-average and below-average rainfall. The same figure shows the
300 frequent occurrence of years with SPI < -1, hence indicating that Menz has experienced
301 several periods of potential drought over the last few decades.

302 Farmers perception of climate variability indicators

303 The perception scores of individual climate indicators presented in Table 3 highlight
304 regional differences in how farmers experience and interpret climate change, with Menz
305 generally reporting higher concern levels across most indicators**.** For example, farmers in
306 Menz reported stronger concern about increasing drought frequency (mean score = 4.08)
307 and temperature fluctuations (mean score = 3.89 on a five-point Likert scale, where 1 =
308 strongly disagree and 5 = strongly agree that the change is occurring), consistent with the
309 more arid conditions and pronounced rainfall decline documented in the meteorological
310 analysis. In Bonga, farmers perceived noticeable temperature fluctuations (mean score
311 = 3.28), which aligns with observed climatic data indicating a significant increase in
312 annual maximum temperature (p = 0.004), confirming the experiential knowledge of
313 rising temperatures. During FGD sessions, participants expressed that Bonga's climate
314 no longer feels like a highland climate due to the extreme temperature variations.

315 **Table 3: Mean perception scores of climate variability indicators among farmers in**
316 **Bonga and Menz (Likert scale: 1 = strongly disagree, 5 = strongly agree).**

Item	*Bonga*	*Menz*	*p-value*
Rainfall amount decreases	4.19	4.11	0.49
Rainfall amount increases	1.07	1.48	<0.001
Delayed onset of rainy season	2.89	3.00	0.35

Cessation of rainy season becoming more unpredictable	2.92	3.15	0.07
Irregular rainfall	2.36	2.26	0.44
Temperature fluctuation	3.28	3.47	0.12
Increase in wind intensity	1.89	2.61	<0.001
Increased frequency of droughts	1.01	4.08	<0.001
Increased frequency of floods	1.03	1.32	<0.001

317

318 Table 3 reveals that the majority of farmers perceived a decrease in rainfall in both
319 regions, with this indicator recording the highest mean score among all assessed climate
320 factors. However, in Bonga region, farmers generally perceived that rainfall is decreasing,
321 whereas the meteorological data indicate a slight increasing trend in annual rainfall
322 (approximately 65.7 mm per decade). This discrepancy between instrumental records
323 and farmers' perceptions may arise because farmers tend to recall extreme or recent
324 rainfall events, whereas meteorological analyses reflect long-term average trends. In
325 Menz, the decreasing trend in annual rainfall (Kendall's tau = -0.11, p = <0.000; Sen's
326 slope = -2.47) matches farmers' perceptions of reduced rainfall (mean = 4.11).
327 Additionally, the high mean scores for delayed onset of rains (mean = 3.00) and increased
328 unpredictability (mean = 3.15) are consistent with meteorological observations from
329 GEE, lending support to the farmers' experiential accuracy regarding rainfall challenges.
330 A notable difference in the mean perception of droughts was observed between Menz
331 (mean= 4.08) and Bonga (mean= 1.01). To further explore this, the Standardized
332 Precipitation Index (SPI) was measured and plotted. Figure 2 illustrates that Menz has

been experiencing alternating periods of wetter and drier conditions. Increased drought occurrences, particularly in the last two years, clearly indicate the region's susceptibility to variable rainfall patterns and potential climate impacts.

Principal climate change challenges that farmers encounter in livestock management

Smallholder farmers identified climate change as a significant threat to their livelihood systems. They were asked to assess their vulnerability to the challenges posed by climate change, particularly in relation to livestock management. Table 4 presents the percentage of respondents reporting each challenge, based on their perception of climate-related impacts on livestock production.

Table 4: Percentage of farmers reporting livestock production challenges perceived to be associated with climate variability and change in Bonga and Menz.

Perceived climate challenges	Bonga (n=204) %	Menz (n=203) %	Total %	P-value
Reduced growth performance	74.9	84.3	79.6	0.20
Increased frequency of still birth	51.2	74.5	62.9	<0.000
Livestock morbidity	74.4	72.5	73.5	0.74
Disease outbreak	67	90.2	78.6	<0.000
Extreme weather impacts on livestock health and management	27.1	67.2	47.2	<0.000
Heat stress	35.5	65.7	50.6	<0.000
Water scarcity	23.2	63.2	43.2	<0.000
Loss of grazing land	72.9	44.1	58.5	<0.000
Livestock mortality	95.1	81.4	88.2	<0.000
Forage and pasture scarcity	96.6	94.1	95.3	0.35

The findings, presented in Table 4, reveal notable regional differences in perceptions of climate-related challenges. Respondents from Menz expressed greater concern about issues such as the increased frequency of stillbirths, disease outbreaks, extreme weather events, heat stress, and water scarcity compared to farmers in Bonga. Despite these regional differences, both regions shared similarly high levels of concern regarding livestock morbidity (73.5%) and forage and pasture scarcity (95.3%).

Frequency of Adaptation Strategy Adoption Among CBBP and Non-CBBP Farmers:

354 The findings from Table 5 indicate that certain adaptation strategies are more commonly
355 adopted by CBBP farmers compared to their non-CBBP counterparts. As illustration,
356 proactive livestock health management (51.2% vs. 48.8%), diversifying income sources
357 beyond livestock farming (45.9% vs. 27.7%), breeding animals that are more adapted
358 (66.8% vs. 14.6%), transhumance **(**18.4% vs. 4.9%), and pasture management through
359 plant clearance and forage cropping (24.0% vs. 8.7%) exhibit statistically significant
360 differences between the two groups.

361 **Table 5: Frequency of Adaptation Strategies Among CBBP and Non-CBBP Farmers**

Adaptation strategy	**CBBP farmers % (n= 199)**	**Non CBBP farmers % (n=208)**	**P-value**
Feed improvement	75.5	68.9	0.15
Implementing shelters structures or cooling systems for animals	29.1	31.6	0.66
Efficient water use and conservation for livestock	14.3	8.7	0.09
Proactive livestock health management	51.2	48.8	<.001
Diversifying income sources beyond livestock farming	45.9	27.7	<.001
Breeding animals that are more adapted	66.8	14.6	<.001
Transhumance	18.4	4.9	<.001
Destocking	76	68.4	0.09

Pasture management through plant clearance and forage cropping	24	8.7	<.001

362

363 Determinants of adaptation choice

364 The results from the logit regressions (marginal effects) on the determinants of
365 adaptation are presented in Table 6.

366 The study area was significantly associated with differences in the likelihood of adopting
367 several adaptation strategies (AD). Practices related to feeding and grazing management,
368 including feed improvement (AD1: -1.79***), transhumance (AD7: -2.08***), and pasture
369 management through plant clearance and forage cropping (AD9: -0.72*), were less likely
370 to be adopted by farmers in Menz compared to Bonga. Similarly, diversification and risk
371 management practices, including diversifying income sources (AD5: -2.40***) and
372 destocking (AD8: -0.949**), also showed lower adoption probabilities among farmers in
373 Menz.

374

Table 6: Parameter estimates of the determinants of adaptation practices

Variables	AD1	AD2	AD3	AD4	AD5	AD6	AD7	AD8	AD9
Study area	**-1.78*** **	**3.79*** **	**1.41** **	**0.86** **	**-2.39*** **	-0.19	**-2.08*** **	**-0.95** **	**-0.71***
Gender	0.18	0.38	0.24	-0.38	0.19	-0.37	0.00	0.19	0.09
Education	0.21	-0.20	0.44	0.38	0.16	**0.68***	0.35	0.25	-0.02
Age group	0.11	0.26	0.20	0.07	-0.29	0.03	**1.14***	-0.25	0.06
Experience	0.16	-0.23	-0.40	-0.39	0.48	-0.41	**-1.15***	0.58	0.10
Main income	0.15	-0.68	0.34	1.05	**-0.67** **	-0.15	-0.20	0.02	-0.41
CBBP	0.31	-0.36	0.44	**0.68** **	**1.07*** **	**2.5*** **	**1.22** **	0.30	**1.07*** **
CC event	-0.45	**1.28***	0.49	**0.61***	**1.01*** **	0.49	**0.85***	0.09	0.19
Training	0.12	**0.72***	0.42	0.25	**-0.99** **	0.20	**0.98***	0.18	0.52

AD: Adaptation strategy, AD1= Feed improvement, AD2= Implementing shelter structures or cooling systems for animals, AD3= Efficient water use and conservation for livestock, AD4= Proactive livestock health management, AD5= Diversifying income sources beyond livestock farming, AD6= Breeding animals that are more adapted AD7= Transhumance, AD8= Destocking, AD9= Pasture management through plant clearance and forage cropping

Significance level: $p < 0.001$: ***, $p < 0.01$: **, $p < 0.05$.

Variable definitions, coding, and reference categories are provided in Table 1.

Conversely, practices associated with animal welfare and resource efficiency, such as implementing shelter structures or cooling systems for animals (AD2: 3.794***) and efficient water use and conservation for livestock (AD3: 1.412**), were positively associated with Menz.

Being a male household male-led household or female-led household showed no significant effects across all adaptation practices.

Having an education background was positively associated with the adaptation choice of breeding animals that are more adapted (AD6: 0.685*) but had minimal influence on other practices.

Age showed a positive association with transhumance (AD7: 1.141, $p < 0.05$) while farming experience showed a negative association with the same strategy (AD7: -1.153, $p < 0.05$), suggesting that younger or less experienced farmers may be more likely to adopt transhumance. These are single-model associations at the marginal significance threshold and should be treated as tentative findings pending replication in larger or independent samples.

Farmers participation in CBBP emerged as a strong positive factor, significantly contributing to breeding animals that are more adapted (AD6: 2.499***) and diversifying income sources (AD5: 1.072***), as well as with practices including transhumance (AD7: 1.220**), and pasture management through plant clearance and forage cropping (AD9: 1.073***)

Attending climate change-related events positively influenced several practices, such as shelter structures (AD2: 1.288*) and proactive livestock health management (AD4:

404 0.610*). Training also positively impacted transhumance (AD7: 0.979*) but showed a
405 negative relationship with income diversification (AD5: -0.989**).

406

The Propensity Score Matching (PSM)

Propensity score matching was conducted on a sample of 402 farmers after excluding five observations with missing covariate data. Nearest-neighbour matching (1:1, without replacement, caliper = 0.05) was applied within the common support region, yielding a matched sample of 304 farmers (152 CBBP members and 152 non-CBBP controls). Covariate balance before and after matching is reported in Table A2. Six of seven covariates achieved adequate post-matching balance (|SMD| < 0.10); study site showed marginal residual imbalance (SMD = 0.105), which is acknowledged as a limitation. OLS regression on the matched sample indicated that CBBP members adopted on average 1.3 more adaptation strategies than comparable non-CBBP farmers (ATT = 1.257, SE = 0.138, 95% CI: 0.985–1.528, $p < 0.001$), a finding consistent with kernel matching results (ATT = 1.29, $p < 0.001$; Table A2). In practical terms, this difference represents a meaningful gap in adaptive capacity: while matched non-CBBP farmers adopted on average 2.7 strategies, CBBP members adopted approximately 4, suggesting that cooperative membership is associated with a substantially broader portfolio of climate responses.

The primary barriers hindering the adoption of climate change adaptation strategies

No statistically significant differences were found between CBBP and non-CBBP farmers in the proportion reporting limited access to farm inputs (29% vs. 28%), limited credit and microfinance (25% vs. 22%), knowledge and information gaps (13% vs. 17%), or limited access to veterinary services (26% vs. 20%) as barriers to adoption (all $p > 0.05$), the

results indicate that these constraints are shared across both groups regardless of membership.

Discussion

Climate Trend Analysis Nexus with Farmers' Perceptions.

Overall, farmers' perceptions of increasing temperatures in both Bonga and Menz were consistent with the meteorological records, indicating that local observations broadly align with measured climate trends. The findings indicate a significant increase in temperature over the past three decades in Bonga and Menz. This trend aligns with recent evidence showing upward trends in average annual maximum and minimum temperatures over a 33-year period (Asfaw et al. 2018; KOBE and LIU 2022). Temperature changes in Amhara Region where Menz is located, have been recorded at rates of 0.046 °C, 0.067 °C, and 0.026 °C annually for mean, minimum, and maximum temperatures, respectively(Asfaw et al. 2018). Similarly, in the Amhara region, annual increases of 0.0905 °C and 0.0886 °C have been observed for maximum and minimum temperatures, respectively (Sewagegn 2024). Farmers' perceptions corroborate these findings, with many respondents reporting noticeable increases in temperature in the study areas. This is consistent with other studies in Ethiopia, where temperature rise is a primary indicator of climate change (Deressa et al. 2009a; Kassie et al. 2013a).

The analysis revealed a declining trend in annual rainfall in the Menz region. The results of Menz are in accordance with a meteorological study in Ethiopia that indicated an annual rainfall of 1100-2000 mm in Amhara region (Sewagegn 2024). The analysis revealed a declining trend in annual rainfall in the Menz region, with a reduction of 2.47 mm per year. This decrease is lower than average estimates from broader regional

studies, which range from 1.84 mm to 9.74 mm per year (Birara et al. 2018; Kerebo et al. 2024). The lower value can be attributed to the analysis being focused solely on the Menz region which may have impacted the accuracy and continuity of the dataset. Farmers' perceptions of rainfall changes reflect these trends, with widespread acknowledgment of decreasing rainfall, delayed onset, and earlier cessation of rainy seasons. Similar observations were reported in studies across Ethiopia, highlighting regional convergence in these perceptions (Eneyew et al. 2019). The SPI analysis for Menz further validates these findings, showing alternating wetter and drier conditions in recent decades, with a severe drought in 2015 linked to El Niño (Niño 2016). This drought significantly impacted farming communities, particularly pastoralists, whose livestock was adversely affected. Farmers in Menz also reported the increasing frequency of droughts as a critical concern during FGD, which aligns closely with the SPI results, emphasizing the region's vulnerability to climatic variability. Although Bonga and Menz are both located in Ethiopia, farmers' perceptions of climate change differed between the two regions, reflecting their contrasting agro-ecological and climatic conditions. These differences suggest that farmers' perceptions of climate change are strongly shaped by local environmental conditions and production constraints rather than by national climate narratives alone. In response to the second research question, these findings confirm that climate-related livestock challenges are widespread across both sites but differ significantly in their nature and prevalence: Menz farmers face predominantly drought-related stressors including water scarcity, heat stress, and increased stillbirth frequency, while Bonga farmers are more affected by grazing land loss and livestock mortality, underscoring the need for site-specific rather than uniform adaptation responses.

Climate change challenges

The observed climate challenges in the study reveal critical differences between the two study areas, reflecting the diverse impacts of climate variability on livestock-dependent communities. Menz and Bonga reported a high prevalence of disease outbreaks and increased frequency of stillbirths. These findings are consistent with previous research identifying feed shortages, water scarcity, and reduced productivity as the primary challenges among livestock farmers in Jimma zone (Duguma and Janssens 2021) and in the Southern Nations, Nationalities, and Peoples' Region of Ethiopia (Mengistu et al. 2021). Similarly, the increased frequency of stillbirths in Menz aligns with reports documenting drought-induced reductions in livestock reproductive performance in pastoral areas (Megersa et al. 2014), however, stillbirths can also be associated with factors such as poor maternal nutrition, infectious diseases, and genetic abnormalities (Gurmu et al. 2024). A study conducted in Bonga and Menz reported a low stillbirth rate of 10% at the flock level based on a sample of 40 households in each region ([CSL STYLE ERROR: reference with no printed form.]), suggesting that actual cases may vary depending on the scale and method of data collection. In the present study, farmers frequently attributed stillbirths to drought-related feed shortages and declining forage quality, which may exacerbate depressed reproductive performance in highland systems facing extended dry spells and nutritional limitations.

The proportion of farmers reporting water scarcity as a climate-related challenge was markedly higher in Menz (63.2%) than in Bonga (23.2%), reflecting the more arid conditions and limited water resources characteristic of that highland region. Other studies observed that recurrent droughts and declining rainfall significantly degraded

rangelands in the Fentale district, resulting in more occurring unpalatable species and feed scarcity (Mekuyie and Mulu 2021). In contrast, Bonga reported a higher percentage of loss of grazing land (72.9%) compared to Menz (44.1%). This difference likely reflects the greater pressure of deforestation, urbanisation, and agricultural expansion on grazing lands in Bonga's mid-altitude areas. This pattern is consistent with broader evidence from Ethiopia: in the neighbouring Jimma zone, 93.7% of households reported declining grazing land quantity and quality, a trend further exacerbated by climate variability (Eneyew et al. 2019) . These findings suggest that while farmers in both regions perceive climate change as affecting livestock production, the specific challenges they emphasize differ according to local environmental conditions and production systems. Farmers in Menz tend to associate climate change with drought-related stressors such as water shortages and reproductive challenges, whereas farmers in Bonga more frequently highlight land-use pressures and grazing constraints.

Frequency of Adaptation Strategy Adoption Among CBBP and Non-CBBP Farmers:

Addressing Research Question 3—whether farmers participating in CBBPs are more likely to report engaging in climate adaptation strategies compared with non-CBBP farmers—the results indicate that CBBP farmers adopt more adaptation strategies overall. CBBP members were more likely to report adopting proactive livestock health management, income diversification, breeding of more adapted animals, transhumance, and pasture management practices. This higher adoption rate can be attributed to knowledge dissemination and capacity-building within CBBP programs, which provide

farmers with access to technical expertise, peer learning, and improved resources (Abdulai et al.).

Some strategies, such as feed improvement, shelter structures, water conservation, and destocking, show no significant differences between groups, suggesting that these practices are widely recognized and adopted by all farmers, regardless of CBBP participation. The role of structured cooperatives in promoting adaptation is further supported by a recent study in Ethiopia (Dawid and Boka 2025). Their study reported that cooperative membership increased the probability of adopting improved crop varieties by 42.4%**,** improved livestock breeds by 35.5%**,** and crop-livestock diversification by 37.3**%**, suggesting that collective action and structured programs enhance farmers' adaptive capacity. Taken together, evidence from the descriptive group comparisons, the logistic regression models, and the propensity score matching analysis consistently points in the same direction: in response to the third research question, CBBP membership is positively and significantly associated with higher adoption of climate adaptation strategies, with members adopting on average 1.3 more strategies than observationally comparable non-CBBP farmers (ATT = 1.257, SE = 0.138, $p < 0.001$), satisfying the pre-specified criterion of convergent support across at least two analytical approaches.

Factors of adaptation strategies to climate change

The analysis of the determinants of adaptation practices reveals notable regional variations. The study area emerged as the most influential factor, significantly impacting the adoption of eight out of the nine proposed adaptation measures. A recent review similarly emphasized that determinants of adaptation strategies to climate variability and

543 change vary significantly across different locations within Ethiopia, particularly at the
544 local level (Demem 2023).

545 Some adaptation practices, such as destocking (AD8) and diversifying income sources
546 (AD5), are less likely to be adopted in Menz, as reflected by negative coefficients. This is
547 consistent with other findings (Zelalem 2009), where destocking was not popular among
548 farmers for cultural values and because restocking was challenging because of the
549 limited livelihood alternatives. Conversely, Menz farmers are more likely to implement
550 practices like proactive livestock health management (AD4) and efficient water use and
551 conservation for livestock (AD3), as indicated by the positive coefficients. In other parts
552 of Ethiopia, the importance of water conservation and disease management in areas
553 facing frequent droughts and resource scarcity was emphasised in order to cope with
554 climate change (Bekele 2012). The adoption of these strategies highlights the adaptive
555 capacity of Menz farmers in addressing specific challenges tied to their epidemiological
556 and agroecological conditions.

557 In this study, gender did not appear to significantly influence the adoption of any of the
558 analysed adaptation strategies, and no clear gender differences were observed in
559 adaptation behaviour. This finding contrasts with previous studies reporting that gender
560 plays an important role in households' adoption of climate change adaptation strategies
561 (Mengistu et al. 2015; Tesfaye and Seifu 2016). Some studies documented that male and
562 female-headed households often adopt different strategies based on access to
563 resources, decision-making authority, and roles within the household (Dev and Manalo
564 2023). However, this was not observed in our study and gender did not appear to
565 significantly influence the adoption of any of the analysed adaptation strategies. This may

be partially explained by the implementation of Gender Transformative Approaches (GTA) in both study areas ([CSL STYLE ERROR: reference with no printed form.]), which aim to promote gender equality by challenging traditional roles and empowering both men and women to participate equally in decision-making and resource access. Such initiatives may have contributed to narrowing the gender gap in adaptation behaviour.

Education showed a positive association with the adoption of breeding more adapted animals (AD6). While this is consistent with evidence that higher education enhances farmers' awareness of improved livestock practices (Kassie et al. 2013a), this is a single-model association and should be interpreted cautiously given the exploratory nature of the analysis[45]. Similarly, participation in climate change-related events and training was positively associated with several practices, such as implementing shelter structures (AD2) and efficient water use and conservation for livestock (AD3). These results underscore the role of knowledge dissemination and capacity-building initiatives in fostering climate resilience (Deressa et al. 2009b).

Participation in CBBP emerges as a key determinant, with significant positive impacts on practices like breeding adapted animals (AD6) and diversifying income sources (AD5). These findings are consistent with other studies (Zampaligré and Fuchs 2019; Abegunde et al. 2019; Kangogo et al. 2021; Belay et al. 2022; Dawid and Boka 2025), which highlight the positive role of membership in agricultural associations or groups in promoting the adoption of climate adaptation practices. Such memberships facilitate the creation of robust social networks, strengthen social capital, and provide access to public spheres where experiences and challenges are shared. These platforms enable knowledge exchange, practical problem-solving, and exposure to innovative coping strategies,

589 ultimately fostering the adoption of climate adaptation practices among farmers. The
590 consistency of the CBBP effect across five of nine models, including three at $p < 0.001$,
591 and its corroboration by the PSM analysis, together provide strong convergent evidence
592 for this association and reduce the concern of false positive inflation.

593 Moreover, the negative association between training and diversifying income sources
594 (AD5) is difficult to explain as diversification is commonly regarded as a coping strategy
595 to mitigate climate shocks. One possible explanation may be due to the specialized
596 focus of training programs, particularly in areas like Menz and Bonga, where both training
597 and policy emphasize sheep production, potentially limiting farmers' pursuit of
598 alternative livelihoods. Further data may help clarify this relationship.

599 We are not aware of any studies that specifically examine the role of CBBP in climate
600 change adaptation; however, related research has explored its impact on the well-being
601 of smallholder farmers (Haile et al. 2020b). Participation in CBBP has been shown to
602 significantly improve farmers' livelihoods by enhancing productivity and income levels
603 (Ahmed and Mesfin 2017). Additionally, animals bred through CBBP programs have
604 demonstrated improved resilience and adaptability under varying environmental
605 conditions, highlighting the potential of these programs in fostering climate change
606 resilience (Tesema et al. 2024).

607 In current study, results indicate that CBBP membership positively and significantly
608 influences farmers' adoption of adaptation strategies. CBBP members adopt
609 approximately twice as many adaptation measures compared to their non-member
610 counterparts. This suggests that CBBP participation fosters greater awareness, capacity,
611 and access to resources necessary for implementing climate adaptation measures.

Barriers hindering the adoption of climate adaptation strategies

Addressing Research Question 4, which sought to identify the main barriers hindering the adoption of climate adaptation strategies among smallholder sheep farmers, the findings of this study highlight several key constraints affecting both CBBP and non-CBBP farmers. Limited access to farm inputs and veterinary services emerged as major challenges for both CBBP and non-CBBP farmers. During FGD discussions, farmers reported that these services, which were previously provided by government programs, have become increasingly scarce and discontinued in recent years. Limited availability and restricted access to high-yielding seeds and improved livestock breeds pose significant challenges to the adoption of climate adaptation practices. Many adaptation strategies practices rely on specialized seeds for cover crops or intercrops, which can be difficult to source, especially if they are not traditionally cultivated in the region. Without the development of efficient and reliable input supply chains, these barriers will persist, hindering the widespread implementation of such practices (Barnard et al. 2015). The scarcity of both agricultural inputs and extension services underscores the pivotal role of government support in ensuring the availability of essential agricultural services. Limited access to financial resources is another key factor constraining the adoption of adaptation practices and technologies, particularly among smallholder and marginalized farmers (Imran et al. 2018). Similar challenges have been identified as significant barriers to adopting climate-smart agricultural practices in developing countries (Khatri-Chhetri et al. 2017; Abegaz et al. 2024). Policy interventions, such as subsidies or credit programs, play a crucial role in addressing these financial barriers and

promoting the adoption of climate-smart practices (Kassie et al. 2013b). Farmers from both study areas also reported limited knowledge and awareness of adaptation practices. Ethiopian smallholder farmers either do not have access to appropriate information or are unable to fully utilize existing information. This underscores the need for capacity-building programs and effective knowledge dissemination to enhance adoption and implementation of climate adaptation strategies (Barnard et al. 2015). Physical and social infrastructure are essential as indicated by farmers from both study areas. Adequate infrastructure, such as irrigation systems, water management facilities, roads, and markets play a crucial role in improving agricultural productivity and access to resources. Additionally, strong social support networks, including farmers' organizations and cooperatives, facilitate knowledge sharing, resource access, and collective decision-making(Barnard et al. 2015).

Conclusion

In our study we demonstrated that farmers' perceptions of climate change in two mixed crop–livestock farming systems in Ethiopia are broadly consistent with meteorological trend analyses, particularly regarding increasing temperatures and declining rainfall. Regardless of CBBP membership, climate-related challenges affected livestock production in both Menz and Bonga, with farmers frequently reporting disease outbreaks and increased stillbirth frequency. In response, and again regardless of CBBP membership, feed improvement, shelter structures, water conservation, and destocking were shown to be common adaptation practices widely adopted by farmers in both study sites. Interestingly, the findings revealed that CBBP-member farmers exhibited a higher capacity to adopt more adaptation strategies than non-CBBP farmers, particularly health

management, income diversification, breeding adapted animals, transhumance, and pasture management. This is supported by the increased exposure of CBBP members to knowledge dissemination, access to technical expertise and peer learning. These insights offer clear guidance for policymakers and researchers aiming to design interventions that enhance climate resilience among smallholder livestock producers.

Declarations

Clinical trial number: Not applicable.

Ethics approval and consent to participate:

This study was reviewed and approved by the Ethics Committee of the University of Natural Resources and Life Sciences, Vienna (BOKU), Austria, under reference number BOKU-2025/001.

The study complies with all relevant ethical regulations of the University of Natural Resources and Life Sciences, Vienna (BOKU).

Written informed consent was obtained from all participants before participation. Participation was voluntary, and participants were informed that they could withdraw their consent at any time.

Consent for publication:

Not applicable. The manuscript does not contain identifiable individual-level data, images, or personal details of participants.

Data Availability Statement: The data presented in this study are available on MEL, and the dataset was published through Dataverse. https://hdl.handle.net/20.500.11766.1/FK2/AGBBEK.

Funding: This work was partially funded by the CGIAR Initiative on Sustainable Animal Productivity (SAPLING; grant number 200296) and by the Accelerating the Impact of CGIAR Climate Research in Africa (AICCRA) project. There was no additional external funding received for this study. We would like to thank all funders who support CGIAR through their contributions to the CGIAR Trust Fund. The funders had no role in study design, data collection and analysis, decision to publish, or preparation of the manuscript.

Author Contributions

Conceptualization: Maria Wurzinger, Barbara Rischkowsky, Aynalem Haile.

Data curation: Shanbel Besufkad, Zelalem Abate, Emna Rekik

Formal analysis: Emna Rekik, Hassan Ouerghemmi, Johann Sölkner.

Investigation: Emna Rekik, Aynalem Haile, Tesfaye Getachew , Maria Wurzinger, Johann Sölkner.

Methodology: Emna Rekik, Hassan Ouerghemmi, Maria Wurzinger.

Project administration: Aynalem Haile, Dawit Solomon, Barbara Rischkowsky.

Supervision: Maria Wurzinger, Johann Sölkner, Tesfaye Getachew, Shigdaf Mekuriaw Zewdu, Aynalem Haile

Writing – original draft: Emna Rekik.

Writing – review & editing: Maria Wurzinger, Johann Sölkner, Tesfaye Getachew, Shigdaf Mekuriaw Zewdu, Aynalem Haile.

References

Abdulai A-M, Sulemana M, Ayambila SN Smallholder Farmer Adaptation Strategies to Climate Change in Northern Ghana: Evidence from Gushegu Municipality

Abegaz A, Abera W, Jaquet S, Tamene L (2024) Adoption of climate-smart agricultural practices (CSAPs) in Ethiopia. Clim Risk Manag 45:100628. https://doi.org/10.1016/j.crm.2024.100628

Abegunde VO, Sibanda M, Obi A (2019) Determinants of the Adoption of Climate-Smart Agricultural Practices by Small-Scale Farming Households in King Cetshwayo District Municipality, South Africa. Sustainability 12:195. https://doi.org/10.3390/su12010195

Abid M, Schilling J, Scheffran J, Zulfiqar F (2016) Climate change vulnerability, adaptation and risk perceptions at farm level in Punjab, Pakistan. Science of The Total Environment 547:447–460. https://doi.org/10.1016/j.scitotenv.2015.11.125

Adhikari U, Nejadhashemi AP, Woznicki SA (2015) Climate change and eastern Africa: a review of impact on major crops. Food Energy Secur 4:110–132. https://doi.org/10.1002/fes3.61

Ahmed MH, Mesfin HM (2017) The impact of agricultural cooperatives membership on the wellbeing of smallholder farmers: empirical evidence from eastern Ethiopia. Agricultural and Food Economics 5:6. https://doi.org/10.1186/s40100-017-0075-z

Aklilu Y, Catley A Strengthening the humanity and dignity of people in crisis through knowledge and practice Livestock Exports from the Horn of Africa: An Analysis of Benefits by Pastoralist Wealth Group and Policy Implications

722 Alemayehu A, Bewket W (2017) Determinants of smallholder farmers' choice of coping and
723 adaptation strategies to climate change and variability in the central highlands of
724 Ethiopia. Environ Dev 24:77–85. https://doi.org/10.1016/J.ENVDEV.2017.06.006

725 Ali A, Abdulai A (2010) The Adoption of Genetically Modified Cotton and Poverty Reduction in
726 Pakistan. J Agric Econ 61:175–192. https://doi.org/10.1111/j.1477-9552.2009.00227.x

727 Areb E, Getachew T, Kirmani M, Haile A (2021) Farmers' Perception on the Effect of
728 Community-Based Sheep Breeding Program for Smallholder Production System. A Case
729 of Bonga Sheep in Ethiopia. International Journal of Livestock Research 1.
730 https://doi.org/10.5455/ijlr.20210724080713

731 Asfaw A, Simane B, Hassen A, Bantider A (2018) Variability and time series trend analysis of
732 rainfall and temperature in northcentral Ethiopia: A case study in Woleka sub-basin.
733 Weather Clim Extrem 19:29–41. https://doi.org/10.1016/j.wace.2017.12.002

734 Austin PC (2011) An Introduction to Propensity Score Methods for Reducing the Effects of
735 Confounding in Observational Studies. Multivariate Behav Res 46:399–424.
736 https://doi.org/10.1080/00273171.2011.568786

737 Barnard J, Manyire H, Tambi E, Bangali S (2015) Barriers to scaling up/out climate smart
738 agriculture and strategies to enhance adoption in Africa

739 Barrios S, Ouattara B, Strobl E (2008) The impact of climatic change on agricultural production:
740 Is it different for Africa? Food Policy 33:287–298.
741 https://doi.org/10.1016/J.FOODPOL.2008.01.003

742 Bekele A& AA. (2012) Effects of drought on pastoral household in Fentale Woreda of Oromia
743 Regional State. . J Environ Issues Agri Dev Countries 4 1-19.

744 Belay A, Oludhe C, Mirzabaev A, et al (2022) Knowledge of climate change and adaptation by
745 smallholder farmers: evidence from southern Ethiopia. Heliyon 8:.
746 https://doi.org/10.1016/j.heliyon.2022.e12089

747 Birara H, Pandey RP, Mishra SK (2018) Trend and variability analysis of rainfall and temperature
748 in the Tana basin region, Ethiopia. Journal of Water and Climate Change 9:555–569.
749 https://doi.org/10.2166/wcc.2018.080

750 Bryan E, Deressa TT, Gbetibouo GA, Ringler C (2009a) Adaptation to climate change in Ethiopia
751 and South Africa: options and constraints. Environ Sci Policy 12:413–426.
752 https://doi.org/10.1016/J.ENVSCI.2008.11.002

753 Bryan E, Deressa TT, Gbetibouo GA, Ringler C (2009b) Adaptation to climate change in Ethiopia
754 and South Africa: options and constraints. Environ Sci Policy 12:413–426.
755 https://doi.org/10.1016/j.envsci.2008.11.002

756 Dawid I, Boka E (2025) Farmers' adaptation strategies to climate change on agricultural
757 production in Arsi zone, Oromia National Regional State of Ethiopia. Frontiers in Climate
758 7:. https://doi.org/10.3389/fclim.2025.1447783

759 Demem MS (2023) Impact and adaptation of climate variability and change on small-holders
760 and agriculture in Ethiopia: A review. Heliyon 9:e18972.
761 https://doi.org/10.1016/j.heliyon.2023.e18972

762 Deressa TT, Hassan RM, Ringler C, et al (2009a) Determinants of farmers' choice of adaptation
763 methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change
764 19:248–255. https://doi.org/10.1016/j.gloenvcha.2009.01.002

765 Deressa TT, Hassan RM, Ringler C, et al (2009b) Determinants of farmers' choice of adaptation
766 methods to climate change in the Nile Basin of Ethiopia. Global Environmental Change
767 19:248–255. https://doi.org/10.1016/J.GLOENVCHA.2009.01.002

768 Dev DS, Manalo JA (2023) Gender and adaptive capacity in climate change scholarship of
769 developing countries: a systematic review of literature. Clim Dev 15:829–840.
770 https://doi.org/10.1080/17565529.2023.2166781

771 Djakpa MG, Egah J, Degla P (2024) Adaptation to climate change among transhumant herders:
772 evidences from northern Benin (West Africa). Front Sustain Food Syst 8:.
773 https://doi.org/10.3389/fsufs.2024.1426771

774 Duguma B, Janssens GPJ (2021) Assessment of livestock feed resources and coping strategies
775 with dry season feed scarcity in mixed crop–livestock farming systems around the gilgel
776 gibe catchment, southwest ethiopia. Sustainability (Switzerland) 13:.
777 https://doi.org/10.3390/su131910713

778 Elum ZA, Modise DM, Marr A (2017) Farmer's perception of climate change and responsive
779 strategies in three selected provinces of South Africa. Clim Risk Manag 16:246–257.
780 https://doi.org/10.1016/J.CRM.2016.11.001

781 Eneyew A, Mitiku F, Olemariam TT (2019) Perception of Small Livestock Keepers onthe Effect
782 of Climate Related Risks and Household Food Security: The Case of Mana and Sekoru
783 Woredas, Jimma Zone

784 Fernández-Giménez ME, Batkhishig B, Batbuyan B, Ulambayar T (2015) Lessons from the
785 Dzud: Community-Based Rangeland Management Increases the Adaptive Capacity of

786 Mongolian Herders to Winter Disasters. World Dev 68:48–65.
787 https://doi.org/10.1016/j.worlddev.2014.11.015

788 Godde CM, Mason-D'Croz D, Mayberry DE, et al (2021) Impacts of climate change on the
789 livestock food supply chain; a review of the evidence. Glob Food Sec 28:100488.
790 https://doi.org/10.1016/J.GFS.2020.100488

791 Gorelick N, Hancher M, Dixon M, et al (2017) Google Earth Engine: Planetary-scale geospatial
792 analysis for everyone. Remote Sens Environ 202:18–27.
793 https://doi.org/10.1016/j.rse.2017.06.031

794 Gujarati DN. (2003) Basic econometrics. McGraw Hill

795 Gurmu EB, Bronsvoort B, Cook EAJ, et al (2024) Environmental and food security implications
796 of livestock abortions and calf mortality: a case study in Kenya and Tanzania. Front Sustain
797 Food Syst 8:. https://doi.org/10.3389/fsufs.2024.1390047

798 Haile A, Getachew T, Mirkena T, et al (2020a) Community-based sheep breeding programs
799 generated substantial genetic gains and socioeconomic benefits. Animal 14:1362–1370.
800 https://doi.org/10.1017/S1751731120000269

801 Haile A, Getachew T, Mirkena T, et al (2020b) Community-based sheep breeding programs
802 generated substantial genetic gains and socioeconomic benefits. Animal 14:1362–1370.
803 https://doi.org/10.1017/S1751731120000269

804 Hameso S (2018) Farmers and policy-makers' perceptions of climate change in Ethiopia. Clim
805 Dev 10:347–359. https://doi.org/10.1080/17565529.2017.1291408

Imran MA, Ali A, Ashfaq M, et al (2018) Impact of Climate Smart Agriculture (CSA) practices on cotton production and livelihood of farmers in Punjab, Pakistan. Sustainability (Switzerland) 10:. https://doi.org/10.3390/su10062101

Kangogo D, Dentoni D, Bijman J (2021) Adoption of climate-smart agriculture among smallholder farmers: Does farmer entrepreneurship matter? Land use policy 109:105666. https://doi.org/10.1016/j.landusepol.2021.105666

Kassie BT, Hengsdijk H, Rötter R, et al (2013a) Adapting to Climate Variability and Change: Experiences from Cereal-Based Farming in the Central Rift and Kobo Valleys, Ethiopia. Environ Manage 52:1115–1131. https://doi.org/10.1007/s00267-013-0145-2

Kassie M, Jaleta M, Shiferaw B, et al (2013b) Adoption of interrelated sustainable agricultural practices in smallholder systems: Evidence from rural Tanzania. Technol Forecast Soc Change 80:525–540. https://doi.org/10.1016/j.techfore.2012.08.007

Kato E, Ringler C, Yesuf M, Bryan E (2011) Soil and water conservation technologies: a buffer against production risk in the face of climate change? Insights from the Nile basin in Ethiopia. Agricultural Economics 42:593–604. https://doi.org/10.1111/j.1574-0862.2011.00539.x

Kerebo KA, Bizuneh YK, Mekonnen AG, Mohammed Y (2024) The trends and spatiotemporal variability of temperature and rainfall in Hulbarag district, Silte Zone, Ethiopia. Heliyon 10:e31646. https://doi.org/10.1016/j.heliyon.2024.e31646

Khatri-Chhetri A, Aggarwal PK, Joshi PK, Vyas S (2017) Farmers' prioritization of climate-smart agriculture (CSA) technologies. Agric Syst 151:184–191. https://doi.org/10.1016/j.agsy.2016.10.005

828 KOBE FT, LIU A (2022) ANALYSIS OF SEASONAL AND ANNUAL VARIATIONS OF EXTREME
829 TEMPERATURES AND PRECIPITATION IN ETHIOPIA. International Journal of Big Data
830 Mining for Global Warming 04: https://doi.org/10.1142/S2630534822500024

831 Mamiru M, Melesse A, Haile A, Getachew T (2024) The Multifaceted Contributions of
832 Community-Based Breeding Program of Bonga Sheep to Flock Dynamics, Animal
833 Performance, and Socio-economic Benefits of Beneficiaries in Kafa Zone, Ethiopia.
834 Advances in Agriculture 2024:. https://doi.org/10.1155/2024/2493179

835 Megersa B, Markemann A, Angassa A, et al (2014) Impacts of climate change and variability
836 on cattle production in southern Ethiopia: Perceptions and empirical evidence. Agric Syst
837 130:23–34. https://doi.org/10.1016/j.agsy.2014.06.002

838 Mekuyie M, Mulu D (2021) Perception of Impacts of Climate Variability on Pastoralists and
839 Their Adaptation/Coping Strategies in Fentale District of Oromia Region, Ethiopia.
840 Environmental Systems Research 10:. https://doi.org/10.1186/s40068-020-00212-2

841 Melaku E, Ewnetu Z, Teketay D (2014) Non-timber forest products and household incomes in
842 Bonga forest area, southwestern Ethiopia. J For Res (Harbin) 25:215–223.
843 https://doi.org/10.1007/s11676-014-0447-0

844 Mengistu D, Bewket W, Lal R (2015) Soil Erosion Hazard Under the Current and Potential
845 Climate Change Induced Loss of Soil Organic Matter in the Upper Blue Nile (Abay) River
846 Basin, Ethiopia. In: Sustainable Intensification to Advance Food Security and Enhance
847 Climate Resilience in Africa. Springer International Publishing, Cham, pp 137–163

Mengistu S, Nurfeta A, Tolera A, et al (2021) Livestock Production Challenges and Improved Forage Production Efforts in the Damot Gale District of Wolaita Zone, Ethiopia. Advances in Agriculture 2021:. https://doi.org/10.1155/2021/5553659

Niño E (2016) FAO in Ethiopia

Nyambariga FK, Opere AO, Kituyi E, Amwata DA (2023) Climate change scenario projections and their implications on food systems in Taita Taveta County, Kenya. PLOS Climate 2:e0000114. https://doi.org/10.1371/journal.pclm.0000114

Rosenbaum PR, Rubin DB (1983) The Central Role of the Propensity Score in Observational Studies for Causal Effects. Biometrika 70:41. https://doi.org/10.2307/2335942

Ruo G (2018) Climate Change Adaptation Practices by Ruminant Livestock Producer of in Hintalo Wajerat District Tigray Regional State, Northern Ethiopia. Biomed J Sci Tech Res 11:. https://doi.org/10.26717/bjstr.2018.11.002166

Rustum R, Adeloye AJ, Mwale F (2017) Spatial and temporal Trend Analysis of Long Term rainfall records in data-poor catchments with missing data, a case study of Lower Shire floodplain in Malawi for the Period 1953–2010

Schmitt CB, Denich M, Boehmer HJ (2014) Plant diversity and conservation of Afromontane rainforest with Coffea arabica in the Bonga region (SW Ethiopia). PLANT DIVERSITY AND CONSERVATION OF AFROMONTANE RAINFOREST WITH COFFEA ARABICA IN THE BONGA REGION (SW ETHIOPIA)

Sewagegn T (2024) Analysis of Temporal Variability and Trends of Rainfall and Temperature Over Western Amhara Region, Ethiopia

869 Sharma AK (2010) Herd management and breeding practices of sheep owners in a mixed crop-
870 livestock and a pastoral system of Ethiopia

871 Tarekegn K, Abate Z, Gizaw H (2016) Analysis of Sheep Value Chain in KafaZone, Southern
872 Ethiopia. International Journal of Scientific Footprints 4:12–23.
873 https://doi.org/10.22576/ijsf/SF-2016-59

874 Tesema Z, Getachew T, Belay B, et al (2024) Impact of climate change on the productivity and
875 adaptation of Ethiopia's Bonga and Menz sheep breeds. Livest Sci 105633.
876 https://doi.org/10.1016/j.livsci.2024.105633

877 Tesfa A, Taye M, Haile A, et al (2025) Systematic review on the impacts of community-based
878 sheep breeding programs on animal productivity, food security, women's empowerment,
879 and identification of interventions for climate-smart systems under the extensive
880 production system in Ethiopia. Small Ruminant Research 253

881 Tesfaye W, Seifu L (2016) Climate change perception and choice of adaptation strategies. Int J
882 Clim Chang Strateg Manag 8:253–270. https://doi.org/10.1108/IJCCSM-01-2014-0017

883 Tilahun M, Angassa A, Abebe A (2017) Community-based knowledge towards rangeland
884 condition, climate change, and adaptation strategies: the case of Afar pastoralists. Ecol
885 Process 6:. https://doi.org/10.1186/s13717-017-0094-4

886 Vu TH, Phi TDH, Nguyen DH, Tran QT (2023) Agricultural cooperatives and climate change
887 adaptation - Case study in Son La, Vietnam. Ministry of Science and Technology, Vietnam
888 65:41–53. https://doi.org/10.31276/VMOSTJOSSH.65(1).41-53

889 Wurzinger M, Gutiérrez GA, Sölkner J, Probst L (2021) Community-Based Livestock Breeding:
890 Coordinated Action or Relational Process? Front Vet Sci 8:.
891 https://doi.org/10.3389/fvets.2021.613505

892 Yamane T (1967) Yamane formula. Statistics: An Introductory Analysis 2nd Edition:

893 Yesuph DS, Bedeke SB, Didana HL (2023) Assessing climate change-induced poverty of mixed
894 crop-livestock smallholders in Wolaita zone. Research in Globalization 7:100158.
895 https://doi.org/10.1016/J.RESGLO.2023.100158

896 Yi Y, Gu C (2022) Impact of structure and organization of smallholders on agricultural carbon
897 emissions. Front Environ Sci 10:. https://doi.org/10.3389/fenvs.2022.1032863

898 Zampaligré N, Fuchs LE (2019) Determinants of Adoption of Multiple Climate-Smart
899 Adaptation Practices in Sudano-Sahelian Pastoral and Agro-Pastoral Production Systems.
900 Sustainability 11:4831. https://doi.org/10.3390/su11184831

901 Zelalem (2009) Effects of climate change on livestock production and livelihood of pastoralists
902 in selected pastoral areas of Borana, Ethiopia. https://doi.org/10.13140/2.1.4475.9044

903 GTA-Ethiopia-Brief

904

Supplementary Files

This is a list of supplementary files associated with this preprint. Click to download.

- Supplementarymaterial.docx