sustainability

MDPI

Article

Climate Change Perceptions, Impacts, and Adaptation Strategies in Mixed Crop–Livestock Systems of Ethiopia's Lowlands

Sintayehu Alemayehu [1,2,3,*], Daniel Olago [1], Opere Alfred [1] and Sintayehu W. Dejene [2,4]

[1] Department of Earth and Climate Sciences, University of Nairobi, Nairobi P.O. Box 30197-00100, Kenya
[2] International Center for Tropical Agriculture, Addis Ababa P.O. Box 5689, Ethiopia
[3] International Center for Tropical Agriculture (CIAT), Nairobi P.O. Box 823-00621, Kenya
[4] Institute of Geophysics, Space Science and Astronomy, Addis Ababa University, Addis Ababa P.O. Box 1176, Ethiopia
* Correspondence: sintayehu1@gmail.com or s.alemayehu@cgiar.org

Abstract

Climate change and variables pose a significant risk for agro-pastoral production systems, where mixed crop–livestock production is a primary livelihood strategy. Therefore, this study aims to analyze agro-pastoralists' perceptions of climate change, the perceived impacts on their production systems, and the adaptation strategies used by mixed crop–livestock producers in the lowland areas of Ethiopia. Data was collected using household surveys, focus group discussions (FGDs), and key informant interviews. A survey was conducted in three major mixed crop–livestock producer woredas (Teltale, Yabello, and Gomole) with a total of 396 respondents. A multi-stage sampling approach was used for selecting the sample household for the study. The data were analyzed using descriptive statistics and a chi-square test. The study found that agro-pastoralists perceive climate change as a significant threat to their livelihoods. The results revealed that 95.9% and 91.4% of respondents across the three woredas perceived a decline in rainfall and increased temperatures, respectively. The most widely adopted adaptation strategies were livelihood diversification (96.4%), livestock diversification (89.3%), and crop diversification (70.4%). Notably, Teltale had the highest adoption rate of crop diversification, while Yabello exhibited a higher prevalence of non-farming activities. The findings highlight the need for targeted interventions to enhance adaptive capacity, improve access to climate-smart technologies, and strengthen capacity for climate adaptation in mixed crop–livestock systems. This study contributes to climate risks, their impacts on their production systems, and the adaptation strategies for designing targeted interventions that enhance the resilience of mixed crop–livestock production systems in the face of climate change.

Keywords: climate change; adaptation strategies; agro-pastoral resilience; mixed crop-livestock systems

check for updates

Academic Editor: Primo Proietti

Received: 20 October 2025
Revised: 7 November 2025
Accepted: 17 November 2025
Published: 20 November 2025

Citation: Alemayehu, S.; Olago, D.; Alfred, O.; Dejene, S.W. Climate Change Perceptions, Impacts, and Adaptation Strategies in Mixed Crop–Livestock Systems of Ethiopia's Lowlands. *Sustainability* **2025**, *17*, 10428. https://doi.org/10.3390/su172210428

Copyright: © 2025 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

1. Introduction

Climate change is one of the most pressing global challenges of the 21st century, with profound and far-reaching implications for agriculture, livelihood, economic stability, and food security. Agriculture is particularly highly vulnerable to climate change, as it is directly linked to the livelihood of billions of people globally [1,2]. Africa, especially Sub-Saharan Africa, is more susceptible to the changing climate, as the sector plays a critical role in providing income, livelihoods, and food for rural populations [3]. It is witnessed that shifts in climate patterns, such as changes in rainfall distribution, rising temperatures, prolonged

droughts, and the increasing frequency of extreme weather events, have already impacted the agricultural sector, particularly in areas where agriculture is mainly dependent on seasonal rainfall [4,5]. Thus, efforts to build climate resilience are critical for addressing these challenges.

Mixed crop–livestock systems, where both crop cultivation and livestock farming are integrated into the same farming system, are a dominant agricultural practice in Sub-Saharan Africa. The systems are highly vulnerable to climate change and variability, as they are mainly dependent on consistent rainfall patterns for both crop and livestock production [6]. They face the compounded challenges of erratic rainfall, heat stress, floods, prolonged droughts, and extreme weather events, which can lead to crop failures and reduced fodder and water availability for livestock [7,8]. This, in turn, reduced agricultural productivity, increased livelihood and economic vulnerability, and heightened food insecurity [9–11]. Disruptions in one component of the mixed crop–livestock system often led to cascading effects on the other, intensifying the vulnerability of rural households that depend on both for their livelihood [2,4]. Understanding how climate change impacts these systems is crucial for developing actionable adaptation strategies that can help reduce vulnerabilities and strengthen resilience.

Ethiopia, located in the Horn of Africa, is one of the countries most vulnerable to the impacts of climate change and variabilities [12,13]. Agriculture is the main sector of Ethiopia's economy, with a large proportion of the rural communities relying on mixed crop–livestock systems for income, livelihood, and food security [13,14]. However, climate change and variability have heightened the vulnerability of these agricultural systems, with erratic rainfall patterns, high temperature and heat stress, prolonged droughts, and floods negatively affecting crop yields and livestock productivity [5,7,13]. As a rainfall dependent sector, reduced rainfall and water scarcity affect both crop and livestock productivity [1,15]. Thus, the interdependence between crops and livestock exacerbates these challenges, making it harder for rural communities to adapt to the changing climate. Therefore, understanding and enhancing the adaptive capacity of mixed crop–livestock systems is crucial to building climate resilience at both household and community levels.

Previous studies have identified several adaptation strategies used by mixed crop–livestock producers such as crop diversification, livestock diversification, supplementary irrigation, and livelihood diversification [6,7,13,14,16]. For example, in response to erratic rainfall, many farmers have shifted planting dates or introduced drought-resistant crop varieties [5,14,17]. Most previous studies, however, have been focused on highland areas of Ethiopia, despite the importance of lowland mixed crop–livestock systems. Studies in the lowland areas have primarily examined pastoral systems, highlighting livestock mobility as a key strategy for managing water and pasture scarcity [18–22]. Additionally, livelihood diversification, such as charcoal production or small businesses, has emerged as a key strategy to mitigate climate-related risks [21,23]. Despite these contributions, important gaps remain. First, most research has focused on highland areas, leaving limited understanding of mixed crop–livestock systems in lowland regions. Second, lowland studies have concentrated on pastoral systems, largely overlooking the integrated dynamics of crops and livestock in agro-pastoral livelihoods. Third, there is limited empirical evidence on how agro-pastoralists perceive climate change, its impacts on their production systems, and the locally developed adaptation strategies they employ. Thus, this study aims to address these gaps by (1) exploring perceptions of climate change and its impacts on mixed crop–livestock production in Ethiopia's lowlands and (2) examining the adaptation strategies employed by agro-pastoralists to mitigate these impacts. By combining these two objectives, the study examines how agro-pastoralists in Ethiopia's lowlands perceive climate change, the effects of climate variability on mixed crop–livestock production sys-

tems, and the adaptation strategies they implement to mitigate these impacts. Additionally, by examining the unique dynamics of these lowland systems, the study contributes to the literature in the field by integrating perceptions, impacts, and strategy mixes that have previously been underexplored. This research is particularly relevant for policymakers and development practitioners as it provides empirical insights that can inform tailored climate adaptation strategies for local contexts. Ultimately, the findings will enhance our understanding of resilience in the face of climate variability and offer valuable lessons for similar regions in Sub-Saharan Africa, thereby contributing to broader strategies aimed at improving the resilience of vulnerable agricultural communities.

2. Methods

2.1. Study Area Description

The study was conducted in three woredas (districts) within the Borana zone of southern Ethiopia, namely, Teltale, Yabello, and Gomole (Figure 1). These areas are situated in the lowland agro-pastoral areas, characterized by a mix of crop–livestock production systems [24]. Yabello Woreda spans approximately 9327 km^2, with altitudes ranging between 1200 and 1800 m above sea level (m.a.s.l). Teltele Woreda covers an area of about 10,620 km^2, with its elevations ranging from 500 to 1500 m.a.s.l. Moreover, Gomole Woreda covers an area of 8500 km^2, featuring elevations that lie between 1000 and 1500 m.a.s.l. These selected areas showcase a diverse topography that reflects the unique geographical characteristics of the Borana zone. Moreover, these areas are largely classified as semi-arid and lowland, which significantly influences their agricultural and pastoral activities [21]. Temperature ranges from 20 °C to 30 °C throughout the year but can reach over 35 °C during the dry seasons [25]. The economy of Yabello is primarily based on the rearing of livestock, such as cattle, goats, sheep, and camels. Crop productions are also commonly practiced, producing crops like maize, sorghum, and beans [26]. The annual average rainfall of the study areas varies between 400 and 700 mm [27,28], with the rainy season concentrated between March and May and from September to November. Rainfall is bimodal, with the main rainy seasons occurring between March and May (long rains) and from September to November (short rain), though variability often leads to prolonged drought periods [28,29]. Livestock production is the primary source of livelihood in the study areas, but crop production is practiced, producing crops such as maize, sorghum, and teff, though rainfed [27,28].

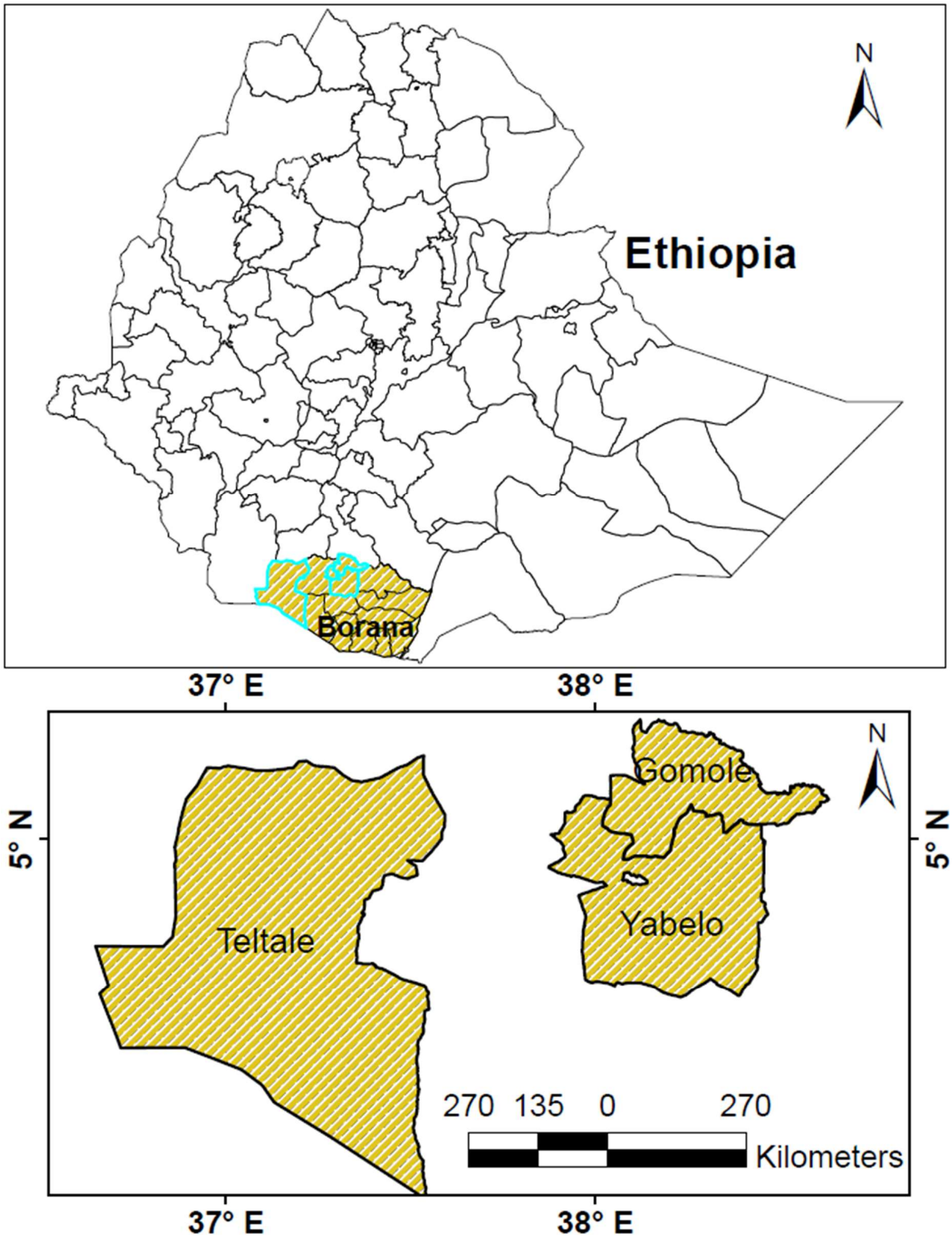

Figure 1. Map of the study area, southern Ethiopia.

2.2. Sampling Procedure and Sample Size

A multi-stage sampling method was used to select the study household for the study area. From the lowlands of Ethiopia, the Borana zone was purposively selected because it represents the country's lowland mixed crop–livestock systems, where crop cultivation

and livestock production are closely integrated. The zone is ecologically representative of semi-arid environments in Ethiopia's lowlands and is among the regions most affected by recurrent droughts, rainfall variability, and other climate-induced stresses. Its selection was therefore based on both ecological relevance and contextual importance for analyzing climate change perceptions, impacts, and adaptation strategies within integrated agro-pastoral production systems. From the zone, three woredas (districts), specifically Teltale, Yabello, and Gomole, were selected purposively. These woredas were selected as key mixed crop–livestock production areas, representative of lowland agro-pastoral systems where livestock production and crop cultivation are undertaken in an integrated manner. Additionally, these areas experience considerable climate change-induced impacts, making them well-suited for analyzing the effects of climate variability on mixed crop–livestock production systems. From each of the selected woredas, three kebeles (the smallest administrative units in Ethiopia) were chosen, resulting in a total of nine kebeles. The kebeles were selected due to their predominant mixed crop–livestock production practices in lowland areas. The selection process was carried out in collaboration with the Woreda Agricultural Offices. This approach ensured that the study areas represent a diverse range of communities affected by climate variability under mixed crop–livestock production systems. The total sample consisted of 396 farmers, drawn from a list of 39,201 households. Sample size was determined following the procedure outlined by [30], ensuring that the sample was representative of the larger population (Equation (1)).

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

where n = sample size; N = population size; and e = level of precision at 0.05.

The margin of error (e) represents the range within which the true population parameter is expected to lie. A common choice for the margin of error is 0.05 (5%), meaning that the study is willing to accept a 5% error in the estimate. The margin of error directly influences the sample size; a smaller margin of error results in a larger sample size. The number of respondents from each kebele was determined proportionally to reflect the distribution of agro-pastoral households in the area. To ensure that each member of the population has an equal chance of being selected, random sampling methods are employed. This method ensured that each household had an equal chance of being selected, minimizing selection bias and enhancing the reliability and validity of the study's findings. The use of the Yamane formula ensures that the sample is not only statistically valid but also representative of the population. This is crucial for generalizing findings to the entire population.

2.3. Data Collection

2.3.1. Household Survey

A structured questionnaire was developed in alignment with the objectives of the study to gather primary data from mixed crop–livestock producers. To ensure clarity and ease of understanding among respondents, the questionnaire was carefully translated into the local language (Oromiffa). The questionnaire included both open- and close-ended questions, allowing for quantitative and qualitative data collection. Prior to the actual survey, the questionnaire was pre-tested to evaluate its reliability, validity, and effectiveness in collecting relevant information. Feedback from the pre-test was used to refine the questionnaire, ensuring its appropriateness for the target respondents.

The questionnaire covered five key thematic areas: (1) farmers' perceptions of climate change, including observed changes in temperature, rainfall patterns, and extreme weather events; (2) perceived impacts of climate change on mixed crop–livestock production, such as changes in crop yield, livestock productivity, water availability, and pasture conditions;

(3) adaptation strategies practiced by mixed crop–livestock producers to adapt to climate change and variability, as well as the associated risks; (4) factors influencing farmers' adaptation decisions, such as access to climate information, availability of financial resources, institutional support, and traditional knowledge; and (5) specific support needed from governmental and non-governmental organizations to overcome adaptation barriers and enhance their resilience to climate change.

To complement the household survey and enrich the findings, qualitative data were also collected using key informant interviews (KIIs) and focus group discussions (FGDs). KIIs were conducted with agricultural extension workers and local government officials to gain expert insights into climate change impacts and adaptation measures. The FGDs followed a structured guide that encouraged discussions on collective experiences, adaptation practices, and shared perceptions of climate change. A total of nine FGDs, three per district, were conducted with groups of eight to ten participants, selected randomly from the study area. These discussions allowed for capturing collective experiences, adaptation practices, and shared perceptions of climate change, as well as the effectiveness of various adaptation strategies. Each session was designed to achieve sample saturation, ensuring that diverse perspectives were captured. Coding procedures for the qualitative data involved systematic analysis of the transcripts from KIIs and FGDs. Initial codes were developed based on the themes outlined in the interview guides, followed by open coding to identify emerging patterns. Thematic analysis was then employed to synthesize the findings and for a holistic understanding of climate change adaptation in mixed crop–livestock systems. These qualitative methods provided deeper contextual understanding and validation of the quantitative survey findings, ensuring a holistic analysis of climate change adaptation in mixed crop–livestock systems.

Some key survey questions from the thematic area of farmers' perceptions of climate change include the following: (1) How has the climate in your area changed over the past decade? (2) Have you noticed a decline in annual rainfall in recent years? (3) Do you believe that temperatures have increased in your region? In the second thematic area on the perceived impacts of climate change, key questions include the following: (1) Have you experienced a decline in livestock productivity due to climate change? (2) How often do you face crop failures that you attribute to climate change? (3) How has climate change affected your access to water for irrigation or livestock? For the thematic area of adaptation strategies, the important questions are as follows: (1) Have you altered your planting dates in response to climate variability? (2) Have you diversified your crops to cope with climate change? (3) Have you diversified your livestock to enhance resilience against climate impacts? (4) What non-farming activities have you adopted as part of your adaptation strategy? For the thematic area of the factors influencing adaptation decisions, key questions include the following: (1) How accessible is climate information to you? (2) How often do you interact with agricultural extension personnel? (3) How aware are you of new agricultural practices that could assist you in adapting to climate change? Finally, in the thematic area of support needs, the survey questions encompass the following: (1) What specific financial assistance would be most helpful for you to implement adaptation strategies? (2) What resources do you believe you need access to in order to better adapt to climate challenges? (3) What additional types of support or services would you like to see offered in your community to help you adapt to the impacts of climate change?

Data collection was conducted by trained agricultural extension experts who were well-acquainted with the local context and fluent in the local language. The enumerators employed a face-to-face interview. They visited households within the selected kebeles and carried out interviews with household heads or other informed members. Typically, one respondent was selected from each household, usually the head of the household. However, if the head was unavailable, the spouse or an older child was interviewed instead.

2.3.2. Data Analysis

Then, the collected data were carefully checked for consistency and accuracy. The data were entered into a statistical software program (R version 4.4.1) for analysis. Quantitative data analysis methods such as descriptive statistics, including frequencies, percentages, and means, were used. The chi-square test was used to compare perceptions of climate change and variability, perceived impacts, and adaptation strategies across the different woredas. For the qualitative data, which were gathered from open-ended responses, KII and FGD thematic analyses were used. This approach helped to identify recurring themes and patterns in the responses, offering a deeper understanding of the local context and the factors influencing adaptation practices within the agro-pastoral communities.

2.3.3. Ethical Consideration

Verbal consent was obtained from all participants before the interviews commenced. The enumerators clearly explained the purpose of the study, emphasizing that participation in the interview was for research purposes.

3. Results and Discussion

3.1. Demographic and Socioeconomic Characteristics

Out of the 396 households surveyed, 94.7% were male-headed, while 5.3% were female-headed (Figure 2). The significantly lower proportion of female-headed households may be attributed to cultural norms that traditionally place men in leadership roles, particularly in agricultural decision-making. Regarding marital status, 97.4% of households were headed by married individuals, emphasizing the central role of family-based labor in farming activities such as land preparation, livestock rearing, and water management. Only 2.6% of the households were headed by widowed individuals. The age distribution of household heads revealed that the majority (62.3%) were between 35 and 55 years, representing the most economically active farming group. About 36.4% were over 55 years, while the remaining 1.3% were below 35 years. This age distribution suggests that a significant proportion of farming and livestock rearing households are led by individuals in their prime working years. In terms of farming experience, all households reported having more than 20 years of farming and livestock rearing experience. The farming and livestock rearing experience of the household head was closely linked to their age, with older household heads having longer years of farming experience.

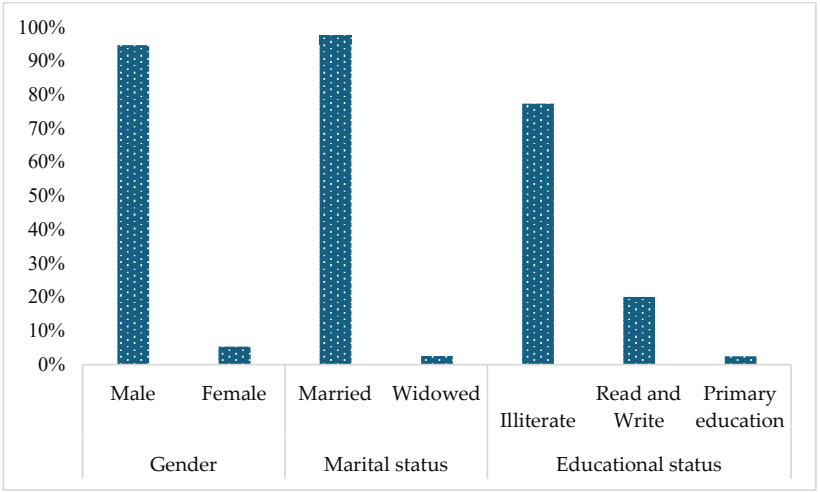

Figure 2. Demographic and socioeconomic characteristics of the respondents in three woredas of Borana zone, southern Ethiopia.

The education level of the respondents revealed that a significant proportion of respondents had low levels of formal education. Specifically, 77.4% of household heads were illiterate. About 20.1% could read and write, while only 2.5% had attended primary education. This low level of education may hinder the adoption of modern climate adaptation practices.

3.2. Agro-Pastoralists' Perceptions of Climate Change

All sampled households in the study woredas perceived at least one aspect of temperature and rainfall change. Understanding this widespread perception is crucial, as it highlights the urgency for adaptive measures in agricultural policies and community resilience strategies. The study revealed that the majority (93.6%) of the respondents in Teltale, Yabello, and Gomole Woredas had perceived a long-term change in climate through their observations on changes in temperature and rainfall over the last 30 years (Table 1). This perception reflects not only the reality of climatic alterations but also the potential for these communities to adapt based on their historical observations. It suggests that there is a foundational knowledge among the farmers that can be leveraged to inform local adaptation strategies and educational initiatives. The χ^2 test results indicated no significant differences ($p > 0.05$) in the perceptions of climate change between the three woredas. Although respondents for Teltale and Gomole perceived high declines in rainfall compared to Yabello, the findings suggested a generally shared perception of climate change across the three woredas. About 99.5% of respondents in Teltale Woreda reported a decline in rainfall, while 89.8% and 98.3% of respondents from Yabello and Gomole experienced a rainfall decline, respectively. Similarly, nearly 97.1%, 87.4%, and 89.9% of respondents perceived an increase in temperature in Teltale, Yabello, and Gomole Woredas, respectively. The overall trend pointed toward reduced precipitation and increased temperature. This finding suggests that climate change is a pressing issue that affects all members of the community equally, which could facilitate collaborative strategies for adaptation.

Table 1. Agro-pastoralists' perceptions of climate change across Teltale, Yabello, and Gomole Woredas of Borana zone, southern Ethiopia.

Climate Change and Variabilities	Teltale Woreda (%)	Yabello Woreda (%)	Gomole Woreda (%)	Overall (%)	χ^2 (*p*-Value)
Perception of long-term climate variability	98.3%	88.6%	94.1%	93.6%	1.734 ($p > 0.05$)
Rainfall decline perception	99.5%	89.8%	98.3%	95.9%	0.536 ($p > 0.05$)
Temperature increase perception	97.1%	87.4%	89.9%	91.4%	0.632 ($p > 0.05$)
Male-headed households (Perception of long-term climate variability)	99.2%	86.7%	93.6%	93.2%	1.134 ($p > 0.05$)
Female-headed households (Perception of long-term climate variability)	97.4%	90.5%	94.6%	94.1%	1.063 ($p > 0.05$)

χ^2 (*p*-value) indicates the chi-square statistic and the corresponding *p*-value for each comparison. A *p*-value greater than 0.05 suggests no statistically significant difference in perceptions among the woredas or between male- and female-headed households. All percentages represent the proportion of respondents from each woreda who reported the given perception regarding climate change and variability.

Regarding the perceptions of respondents by gender, it was found that both male-headed households and female-headed households had similar perceptions of rainfall and temperature changes ($p > 0.05$). Specifically, 93.2% of male-headed households perceived a long-term climate variability, compared to 94.1% of female-headed households. The findings from the focus group discussions (FGDs) and key informant interviews (KIIs) also highlighted the widespread recognition of changing rainfall patterns and rising temperatures. Participants highlighted the unpredictability of rainfall patterns, noting that the rainy season now often arrives late or concludes prematurely, complicating agricultural planning.

The increasing temperatures were also reported to accelerate the drying of pasture and water sources, intensifying challenges in both crop and livestock production.

The climatic changes have made crop and livestock production activities increasingly challenging, with unpredictable rainy seasons and prolonged dry spells affecting productivity. Moreover, the qualitative insights emphasized the differential impacts of climate change on household dynamics. While both male- and female-headed households face increased difficulties due to drought and water scarcity, women in female-headed households bear additional responsibilities, such as spending more time fetching water and ensuring food security. This added burden heightens their vulnerability in the face of climate-induced challenges. The findings of this study were aligned with other previous studies [8,9,14,22,31–34], which also highlighted the widespread perception of climate change among agro-pastoral communities in drylands of Ethiopia. The widespread perception of changing rainfall patterns and increasing temperatures underscores a growing climate-induced vulnerability, signaling future challenges in water security, food production, and livelihood sustainability.

3.3. Perceived Impacts of Climate Change

Crop and livestock producers across the three woredas Teltale, Yabello, and Gomole have observed significant shifts in climate patterns, particularly declining rainfall and increasing temperatures, which have severely impacted their agricultural activities. Water scarcity is perceived as the most critical challenge, with 97.4% of respondents in Teltale, 96.1% in Yabello, and 97.0% in Gomole reporting a drastic reduction in water availability (Table 2). Several respondents noted that prolonged droughts have led to the depletion of traditional water sources, forcing them to travel longer distances in search of water for domestic, livestock, and irrigation needs. Similarly, previous studies [18,35] reported that agro-pastoral communities in southern Ethiopia were negatively impacted by climate change-induced water scarcity. This insight points to a need for urgent adaptive practices to mitigate the negative impacts on food production and livestock health. The implications of these observations could inform both local agricultural practices and broader policy decisions aimed at enhancing food security in the face of climate variability.

Table 2. Perceived impacts of climate change in Teltale, Yabello, and Gomole Woredas of Borana zone, southern Ethiopia.

Perceived Impacts of Climate Change	Teltale (%)	Yabello (%)	Gomole (%)	Overall (%)	χ^2 (*p*-Value)
Livestock productivity decline	96.50%	95.20%	96.00%	95.90%	0.98 ($p > 0.05$)
Crop failure	88.10%	86.50%	87.30%	87.30%	0.72 ($p > 0.05$)
Water scarcity	97.40%	96.10%	97.00%	96.80%	0.74 ($p > 0.05$)
Pasture shortages	87.50%	86.20%	87.00%	86.90%	1.36($p > 0.05$)
Soil fertility loss	76.80%	75.20%	76.00%	76.00%	0.64 ($p > 0.05$)
Increased pests and disease	81.50%	80.10%	81.00%	80.90%	0.69 ($p > 0.05$)

Note: The chi-square (χ^2) test results show no statistically significant differences ($p > 0.05$) among the three woredas, indicating that perceptions of climate change impacts are consistent across Teltale, Yabello, and Gomole.

Soil degradation and declining fertility were also widely perceived impacts of climate change reported, with 76.8% of respondents in Teltale, 75.2% in Yabello, and 76.0% in Gomole. Participants in focus groups highlighted that soil erosion, loss of organic matter, and reduced moisture retention have all contributed to lower agricultural productivity. This deterioration has exacerbated food insecurity, with frequent crop failures reported by 88.1% of respondents in Teltale, 86.5% in Yabello, and 87.3% in Gomole. Prolonged dry spells have further hindered farmers' ability to sustain crop yields, leading to increased reliance on food aid and alternative income sources. Additionally, previous studies [22,36,37] identified that soil degradation was intensified in agro-pastoral areas, particularly where shifting rainfall patterns and prolonged dry spells limit soil regeneration. These studies support

local perceptions that deteriorating soil conditions are leading to lower crops and feed productivity and increased food insecurity.

Shortages of pasture were another commonly perceived impact, with 87.5% of respondents in Teltale and 86.2% and 87.0% in Yabello and Gomole, respectively, highlighting a problem in finding adequate grazing land for their livestock during the dry season. This decline in forage availability has contributed to increased livestock malnutrition, reduced milk production, and higher mortality rates. Over 95% of respondents across all three woredas reported declining livestock productivity, primarily due to water scarcity, feed shortages, and worsening climatic conditions. Additionally, traditional livestock migration patterns have been disrupted by increasing competition over grazing lands, leading to heightened tensions among communities. These observations align with findings from other studies [21,24,38,39], which found that diminishing grazing lands in lowlands of southern Ethiopia are a primary driver of agro-pastoralists' vulnerability.

The rising incidence of pests and livestock diseases was another major concern, with 81.5% of respondents in Teltale, 80.1% in Yabello, and 81.0% in Gomole perceiving an increase in disease outbreaks. This trend has been attributed to warmer temperatures and shifting rainfall patterns, which create favorable conditions for pests and vector-borne diseases. The increase in tick infestations and other livestock diseases, which were previously uncommon, has further strained agro-pastoral livelihoods. This finding is consistent with the existing literature [35,40], which suggests that rising temperatures have expanded the habitat ranges of pests and disease vectors, exacerbating health issues within livestock populations.

The perceived impacts of climate change including water scarcity, soil degradation, crop failure, pasture shortages, and increased livestock diseases are strongly supported by existing research on climate variability in the lowlands of Ethiopia [22,32,40–42]. These findings reinforce the urgent need for climate adaptation strategies in order to enhance resilience among agro-pastoral communities.

Ref. [43] highlighted significant seasonal spatiotemporal climate variability in Ethiopia's Borana zone, revealing distinct patterns in rainfall, temperature, and drought indices. Their findings align with the climate variability observed by local communities. Additionally, the study evaluated the effects of these climate changes on crop yields, particularly wheat and livestock production, offering crucial insights for formulating effective adaptation strategies and policies aimed at enhancing food security and economic stability in the region. Understanding these dynamics is essential for creating resilient adaptation strategies that cater to the unique ecological and economic contexts of the Borana zone. Furthermore, ref. [43] emphasized the necessity for strong adaptation strategies to address the impacts of climate variability within Ethiopia's mixed crop–livestock systems.

3.4. Adaptation Strategies Used by Mixed Crop–Livestock Producers

The study identified various adaptation strategies employed by mixed crop–livestock producers across the three woredas (Teltale, Yabello, and Gomole), with differences in the adoption rates of these strategies (Table 3). The study identified various adaptation strategies employed by mixed crop–livestock producers across the three woredas (Teltale, Yabello, and Gomole), with varying adoption rates (Table 3). Adjusting planting dates in response to changing rainfall patterns was a commonly used adaptation strategy across all woredas. The adoption rates were 55.3%, 59.4%, and 54.2% in Teltale, Yabello, and Gomole, respectively, with no significant difference between the woredas ($\chi^2 = 0.38$, $p = 0.83$). The adjustment of planting dates allows farmers to align their activities with favorable seasonal conditions, thereby mitigating the risk of crop failure due to unexpected rainfall variability. This finding aligns with the study by [21], which highlighted how timing adjustments can

enhance agricultural resilience to erratic weather conditions. By doing so, farmers optimize crop growth and reduce the likelihood of crop failure, ultimately improving yields.

Table 3. Adoption of climate change adaptation strategies across Teltale, Yabello, and Gomole woredas of Borana zone, southern Ethiopia.

Adaptation Strategy	Teltale (%)	Yabello (%)	Gomole (%)	Overall (%)	χ2 (p-Value)
Change in planting date	55.3	59.4	54.2	56.3	$\chi^2 = 0.38$ ($p = 0.83$)
Crop diversification	78.5	67.5	65.1	70.4	$\chi^2 = 7.25$ ($p < 0.05$)
Livestock diversification	89.2	90.1	88.7	89.3	$\chi^2 = 0.15$ ($p = 0.93$)
Livelihood diversification	96.1	97	96.2	96.4	$\chi^2 = 0.11$ ($p = 0.95$)
Livestock mobility	75.6	78.5	82.3	78.8	$\chi^2 = 5.34$ ($p < 0.05$)
Destocking	44.9	46.5	44	45.1	$\chi^2 = 0.15$ ($p = 0.93$)
Soil and water conservation	56.7	58.2	54.3	56.4	$\chi^2 = 0.52$ ($p = 0.77$)
Supplementary irrigation	31.2	33.6	31.5	32.1	$\chi^2 = 8.11$ ($p < 0.05$)
Non-farming activities	40.3	47	41.2	42.8	$\chi^2 = 7.65$ ($p < 0.05$)

Agro-pastoralists widely practiced livestock diversification, particularly through integrating goats into their livestock systems, with adoption rates of 89.2% in Teltale, 90.1% in Yabello, and 88.7% in Gomole ($\chi^2 = 0.15$, $p = 0.93$). The inclusion of multiple livestock species, particularly goats, was found to enhance resilience against water and pasture scarcity. This shift from traditional cattle-based systems to more diversified livestock production reflects a growing preference for drought-tolerant species, which can withstand harsher conditions and provide alternative income sources during periods of scarcity. This transition from cattle-based to mixed livestock production aligns with previous findings [22,26], which report a growing preference for drought-tolerant livestock species in lowlands of Ethiopia.

Crop diversification emerged as a significant adaptation strategy, with Teltale showing the highest adoption rate (78.5%) compared to Yabello (67.5%) and Gomole (65.1%). The chi-square test revealed a significant difference ($\chi^2 = 7.25$, $p < 0.05$), indicating that farmers in Teltale were more likely to diversify their crops. Participants of FGDs and KIIs also highlighted the benefits of crop diversification. Since different crops have varying climate requirements and tolerances, the failure of one crop due to climate-related stresses (such as drought or pest outbreaks) does not necessarily affect all other crops. This approach not only supports food security but also provides multiple income sources, contributing to a more stable livelihood for farmers. This approach aligns with studies by [21] which emphasize the importance of crop diversification in ensuring food security and stable incomes in climate-vulnerable regions.

Livelihood diversification was another commonly used adaptation strategy across all woredas, with no significant difference found in the adoption rates (Teltale 96.1%, Yabello 97.0%, Gomole 96.2%) ($\chi^2 = 0.11$, $p = 0.95$). Expanding income sources beyond agriculture was another key point raised during the FGDs. Non-farming livelihoods, such as small-scale businesses, trade, or handicrafts, provide additional income that helps to buffer against poor crop harvests or livestock productivity or fluctuating market prices. Focus group discussion participants also noted that diversification reduces households' vulnerability to climate-related disruptions in agriculture and helps ensure financial stability during difficult periods. This aligns with findings by [38,39], which show that non-farm income sources reduce climate vulnerability and improve financial stability.

Livestock mobility for searching for better pasture and water was most commonly practiced in Gomole, with 82.3% adoption. The chi-square results showed a significant difference across the woredas ($\chi^2 = 5.34$, $p < 0.05$), indicating that Gomole had the highest adoption rate. Participants of FGD and KII also stressed the importance of livestock mobility, particularly in areas prone to variable rainfall and drought. Seasonal movement

of livestock based on water and pasture availability is vital for maintaining the health of livestock. During the FGDs and KIIs, participants highlighted the importance of destocking as a climate adaptation strategy. When facing prolonged droughts or market instability, reducing the number of livestock helps prevent overgrazing and ensures that remaining animals receive sufficient food and water. Destocking also provides an opportunity for farmers to sell animals before they lose value due to poor health or market conditions. This practice allows households to generate income and reduce the burden of maintaining animals during difficult climatic conditions, while also conserving resources for the remaining livestock. Similarly, other findings are reported by [26,44], highlighting the importance of seasonal mobility and destocking in reducing drought impacts. Supplementary irrigation, which helps maintain crop yields during dry spells, was more widely adopted in Yabello (33.6%) compared to the other regions. The chi-square analysis showed a significant difference in adoption rates across the woredas ($\chi^2 = 8.11$, $p < 0.05$). FGD participants noted that supplementary irrigation plays a critical role in adapting to erratic rainfall patterns. In areas where rainfall is insufficient or poorly distributed, supplementary irrigation helps ensure that crops receive the necessary water for growth.

Regarding non-farming activities, which include local business involvement and charcoal production, Yabello had the highest adoption rate (47.0%), followed by Gomole (41.2%) and Teltale (40.3%). In the FGDs and KIIs, participants emphasized the role of non-farming activities in improving resilience to climate change. Engaging in non-farming livelihoods, such as small-scale trading, handicrafts, or services like transportation, provides additional income streams that reduce dependence on agriculture alone. A significant difference was found in the adoption rates across the woredas ($\chi^2 = 7.65$, $p < 0.05$), with Yabello again showing the highest participation. This might be due to the presence of Yabello town, which offers various job opportunities. In general, crop and livestock producers in Teltale, Yabello, and Gomole woredas used diverse adaptation strategies to enhance their resilience to climate change. While many strategies are universally adopted, variations exist due to ecological and economic factors. These findings underscore the need for targeted interventions that enhance climate adaptation, ensuring long-term sustainability for mixed crop–livestock farming systems.

The findings of this study underscore the urgent need for targeted interventions to enhance the adaptive capacity of agro-pastoralists. Additionally, these insights can assist policymakers in crafting effective strategies tailored to the specific needs of agro-pastoral communities. The study's results can also be incorporated into educational programs for agricultural extension workers and university curricula. Moreover, it highlights the interconnectedness of climate change, food security, and social dynamics, stressing the importance of initiatives aimed at strengthening the resilience of pastoral and agro-pastoral communities while promoting sustainable development in similar contexts. This understanding is vital for building community resilience and garnering broader societal support for climate adaptation efforts.

3.5. Factors Affecting Adoption of Adaptation Strategies

The findings reveal that limited access to climate information and agro-climate advisory services is a major barrier, with 88.4% of respondents in Teltale, 90.5% in Yabello, and 85.2% in Gomole reporting this challenge. The chi-square test results ($\chi^2 = 2.51$, $p = 0.476$) indicate no significant differences among the woredas in this regard (Table 4). The lack of reliable climate information hampers farmers' ability to make informed decisions about planting times and crop varieties, leading to reliance on traditional practices that may not be effective under changing climatic conditions. Improved access to weather forecasts could facilitate more effective adjustments in planting dates.

Table 4. Constraints affecting adoption of climate adaptation strategies in Teltale, Yabello, and Gomole Woredas of Borana zone, south Ethiopia.

Constraints	Teltale (%)	Yabello (%)	Gomole (%)	χ^2 (*p*-Value)
Limited climate information and agro-climate advisory services	88.40%	90.50%	85.20%	$\chi^2 = 2.51$ ($p = 0.476$)
Poor potential for irrigation and infrastructure	75.20%	72.80%	78.40%	$\chi^2 = 1.75$ ($p = 0.630$)
Limited contact with extension personnel	62.40%	65.70%	59.80%	$\chi^2 = 0.94$ ($p = 0.817$)
Limited awareness of the practices	91.60%	89.20%	92.10%	$\chi^2 = 0.82$ ($p = 0.845$)
Shortage of labor for implementing adaptation strategies	77.20%	79.50%	74.80%	$\chi^2 = 1.10$ ($p = 0.777$)
Shortage of necessary farm inputs	83.70%	82.30%	85.10%	$\chi^2 = 0.32$ ($p = 0.857$)
Shortage of money and limited credit	85.60%	88.90%	82.40%	$\chi^2 = 1.57$ ($p = 0.661$)

Poor irrigation potential and inadequate infrastructure also pose significant challenges, affecting 75.2% of respondents in Teltale, 72.8% in Yabello, and 78.4% in Gomole. The lack of well-developed irrigation systems restricts water availability, making it difficult for farmers to sustain crop and livestock production during dry spells. Having limited irrigation systems restricts water availability, making it challenging for farmers to sustain crop and livestock production during dry spells. This dependence on rainfall places farmers in a vulnerable position, particularly during drought conditions, discouraging investment in improved farming techniques such as drought-resistant crops or water-efficient irrigation systems. Thus, investment in irrigation infrastructure is essential for enhancing resilience among farmers. Policymakers should prioritize the development of water management systems that support sustainable agricultural practices, especially in drought-prone areas.

Similarly, limited access to agricultural extension services was reported by 62.4% of respondents in Teltale, 65.7% in Yabello, and 59.8% in Gomole. The chi-square test results for both constraints ($\chi^2 = 1.75$, $p = 0.630$ and $\chi^2 = 0.94$, $p = 0.817$, respectively) suggest that these challenges are widespread across the study areas. Agricultural extension services play a crucial role in promoting climate adaptation strategies. However, limited access to extension personnel prevents farmers from receiving necessary training and guidance, which slows the adoption of climate adaptation practices. Strengthening agricultural extension services should be a priority for policymakers. This includes training extension personnel to provide localized advice on climate adaptation strategies and ensuring that farmers have access to information relevant to their specific conditions.

Another significant barrier to adaptation is the limited awareness of climate adaptation practices, with 91.6% of respondents in Teltale, 89.2% in Yabello, and 92.1% in Gomole acknowledging this constraint. The chi-square test ($\chi^2 = 0.82$, $p = 0.845$) shows no statistically significant differences between the woredas, highlighting a general knowledge gap that affects climate adaptation efforts. Without this knowledge, agro-pastoralists are unlikely to implement strategies that could reduce their vulnerability to climate risks. Thus, educational initiatives aimed at raising awareness of climate adaptation practices are essential. Campaigns to disseminate information about successful adaptation strategies can empower farmers to make informed decisions.

Labor shortages for implementing adaptation strategies were also commonly reported, with 77.2% of households in Teltale, 79.5% in Yabello, and 74.8% in Gomole struggling to find sufficient labor to adopt climate-resilient farming practices ($\chi^2 = 1.10$, $p = 0.777$). The analysis also showed that the migration of young people to urban areas for work has left elderly individuals and children to manage the farms, which limits households' ability to adopt labor-intensive adaptation measures such as soil conservation and water harvesting.

Additionally, shortages of necessary farm inputs (reported by 83.7% in Teltale, 82.3% in Yabello, and 85.1% in Gomole) and financial constraints such as limited credit access (85.6%, 88.9%, and 82.4%, respectively) further restrict farmers' ability to implement adaptation

measures. The chi-square results ($\chi^2 = 0.32$, $p = 0.857$ and $\chi^2 = 1.57$, $p = 0.661$, respectively) confirm that these challenges are consistent across all three woredas. Many adaptation measures, such as irrigation infrastructure, drought-resistant seeds, and improved livestock management, require financial investment. However, most households lack the necessary resources to make these investments. This financial barrier delays the transition to more resilient farming systems. Thus, enhancing access to credit for farmers is crucial for enabling investment in adaptation measures. Financial institutions should explore tailored lending solutions that address the specific needs of agro-pastoralists, facilitating their ability to adopt sustainable practices.

4. Conclusions

This study underscores the significant challenges faced by agro-pastoralists practicing mixed crop–livestock production systems in the lowland regions of Ethiopia due to climate change, as well as the various adaptation strategies they have adopted in response. The findings reveal that while agro-pastoralists are aware of climate change and its impact on their livelihoods, the effectiveness of their adaptation strategies varies depending on local conditions, resources, and support systems. Livelihood diversification, livestock mobility, crop diversification, and soil and water conservation were the most common strategies, though their adoption was not uniform across the three woredas.

This study provides a comprehensive understanding of the perceptions and experiences of agro-pastoral communities in Teltale, Yabello, and Gomole Woredas, revealing the increasing vulnerability of these populations to climate change. The findings demonstrate that changes in temperature and rainfall patterns, which have led to reduced rainfall and higher temperatures, are having severe impacts on agricultural and pastoral activities. As a result, these communities are facing challenges such as water scarcity, soil fertility loss, pasture shortages, and declining livestock productivity, further deepening their vulnerability to climate-related stress.

The study highlights that agro-pastoralists in the region have developed various adaptation strategies, such as adjusting planting dates, diversifying crops and livestock, engaging in supplementary irrigation, and exploring livelihood diversification. These strategies, though helpful at the household level, are not yet sufficient to address the full scope of challenges posed by climate change. Constraints related to resource access, inadequate support systems, and limited knowledge of advanced climate-smart practices suggest that additional support and systemic changes are necessary to scale up these efforts.

From a broader perspective, the findings from this study help fill significant knowledge gaps related to the intersection of climate change, agriculture, and pastoralism in Ethiopia's lowlands. They contribute to a deeper understanding of how climate change affects livelihoods, food security, and social dynamics in such vulnerable regions. These insights can inform more targeted and context-specific interventions that strengthen the adaptive capacities of agro-pastoral communities, not only in Ethiopia but across similar environments in Sub-Saharan Africa and other regions facing comparable climate challenges. Moreover, the findings of this study have significant implications for various stakeholders, including policymakers, agricultural extension services, and non-governmental organizations. The findings are relevant for policy by offering actionable strategies that local authorities, development practitioners, and decision-makers can implement to enhance resilience, improve adaptive capacity, and support sustainable livelihoods in mixed crop–livestock systems. Furthermore, the insights gained can inform the design of climate-smart agricultural practices and support systems that align with the unique ecological and socioeconomic conditions of the region. As climate change impacts continue to evolve, it is essential to further explore and document the adaptive practices of these communities

and use these insights to build more robust, long-term resilience strategies. In summary, the study reveals the urgent need for strengthened climate adaptation strategies in agro-pastoral communities, with a focus on improving livelihoods, food security, and ecosystem sustainability. The challenges highlighted in the research point to the importance of a multi-faceted approach that includes both top–down and bottom–up solutions, building on community strengths and addressing systemic barriers to resilience. By supporting these efforts, Ethiopia and similar regions can enhance their resilience to future climate impacts, fostering sustainable development and improved well-being for vulnerable populations.

5. Limitations of the Study and Future Research Directions

The study was conducted in the Borana zone as a representative area for lowland mixed crop–livestock systems, and further research using data from other regions is recommended to enhance broader generalizability. Future research should also focus on exploring the long-term effectiveness of these strategies and identifying ways to overcome the constraints limiting their adoption, particularly in vulnerable agro-pastoral communities. Moreover, future studies should consider the analysis of gender differences by employing statistical models that assess how gender influences access to resources, decision-making, and the adoption of agricultural practices.

Author Contributions: Conceptualization, S.A.; Methodology, S.A.; Software, S.A.; Validation, S.A., D.O., O.A. and S.W.D.; Formal analysis, S.A.; Investigation, S.A., D.O., O.A. and S.W.D.; Resources, S.A.; Data curation, S.A., D.O., O.A. and S.W.D.; Writing—original draft, S.A., D.O., O.A. and S.W.D.; Writing—review & editing, S.A., D.O., O.A. and S.W.D.; Visualization, S.A., D.O., O.A. and S.W.D.; Supervision, S.A., D.O., O.A. and S.W.D.; Project administration, S.A.; Funding acquisition, S.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: The study was approved by the Institutional Review Board of the Alliance of Bioversity International and International Center for Tropical Agriculture (2025-IRB22, 22 April 2025). Confidentiality and anonymity were maintained throughout the study by using assigned codes, instead of personal identifiers, and secure data management practices.

Informed Consent Statement: Stakeholders' participation was voluntary, and all participants provided verbal consent.

Data Availability Statement: The data used for this research are available from the corresponding author upon request (email: s.alemayehu@cgiar.org).

Acknowledgments: Our special thanks go to the data collectors and study participants for their time and cooperation.

Conflicts of Interest: The authors declare no conflicts of interest.

References

1. Cohn, A.S.; VanWey, L.K.; Spera, S.A.; Mustard, J.F. Cropping frequency and area response to climate variability can exceed yield response. *Nat. Clim. Change* **2016**, *6*, 601–604. [CrossRef]
2. Fanzo, J.; Davis, C.; McLaren, R.; Choufani, J. The effect of climate change across food systems: Implications for nutrition outcomes. *Glob. Food Secur.* **2018**, *18*, 12–19. [CrossRef]
3. Lee, H.; Calvin, K.; Dasgupta, D.; Krinner, G.; Mukherji, A.; Thorne, P.; Trisos, C.; Romero, J.; Aldunce, P.; Barret, K. *IPCC, 2023: Climate Change 2023: Synthesis Report, Summary for Policymakers. Contribution of Working Groups i, II and III to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change*; Lee, H., Romero, J., Eds.; IPCC: Geneva, Switzerland, 2023.
4. Jones, P.G.; Thornton, P.K. Croppers to livestock keepers: Livelihood transitions to 2050 in Africa due to climate change. *Environ. Sci. Policy* **2009**, *12*, 427–437. [CrossRef]
5. Thornton, P.K.; Herrero, M. Adapting to climate change in the mixed crop and livestock farming systems in sub-Saharan Africa. *Nat. Clim. Change* **2015**, *5*, 830–836. [CrossRef]

6. Thornton, P.K.; Herrero, M. Climate change adaptation in mixed crop–livestock systems in developing countries. *Glob. Food Secur.* **2014**, *3*, 99–107. [CrossRef]
7. Baker, E.; Kerr, R.B.; Deryng, D.; Farrell, A.; Gurney-Smith, H.; Thornton, P. Mixed farming systems: Potentials and barriers for climate change adaptation in food systems. *Curr. Opin. Environ. Sustain.* **2023**, *62*, 101270. [CrossRef]
8. Danso-Abbeam, G.; Dagunga, G.; Ehiakpor, D.S.; Ogundeji, A.A.; Setsoafia, E.D.; Awuni, J.A. Crop–livestock diversification in the mixed farming systems: Implication on food security in Northern Ghana. *Agric. Food Secur.* **2021**, *10*, 35. [CrossRef]
9. Ackerl, T.; Weldemariam, L.F.; Nyasimi, M.; Ayanlade, A. Climate change risk, resilience, and adaptation among rural farmers in East Africa: A literature review. *Reg. Sustain.* **2023**, *4*, 185–193. [CrossRef]
10. Aryal, J.P.; Sapkota, T.B.; Rahut, D.B.; Marenya, P.; Stirling, C.M. Climate risks and adaptation strategies of farmers in East Africa and South Asia. *Sci. Rep.* **2021**, *11*, 10489. [CrossRef] [PubMed]
11. Hassan, R.M.; Nhemachena, C. Determinants of African farmers' strategies for adapting to climate change: Multinomial choice analysis. *Afr. J. Agric. Resour. Econ.* **2008**, *2*, 83–104.
12. Mogess, Y.K.; Ayen, D.D. The effects of climate change adaptation strategies on the welfare of rural farm households in Ethiopia. *Food Energy Secur.* **2023**, *12*, e451. [CrossRef]
13. Wakeyo, M.B.; Elias, H. Mixed farming system for crop yield improvement and adaptation to climate change: Evidence from smallholder farmers in Ethiopia. *Ethiop. J. Econ.* **2023**, *32*, 37–73.
14. Duguma, B.; Janssens, G.P. Assessment of livestock feed resources and coping strategies with dry season feed scarcity in mixed crop–livestock farming systems around the gilgel gibe catchment, Southwest Ethiopia. *Sustainability* **2021**, *13*, 10713. [CrossRef]
15. Adhikari, U.; Nejadhashemi, A.P.; Woznicki, S.A. Climate change and eastern Africa: A review of impact on major crops. *Food Energy Secur.* **2015**, *4*, 110–132. [CrossRef]
16. Shibru, M.; Opere, A.; Omondi, P.; Gichaba, M. Understanding physical climate risks and their implication for community adaptation in the borana zone of southern Ethiopia using mixed-methods research. *Sci. Rep.* **2023**, *13*, 6916. [CrossRef] [PubMed]
17. Chekole, F.C.; Ahmed, A.M. Future climate implication on maize (*Zea mays*) productivity with adaptive options at Harbu district, Ethiopia. *J. Agric. Food Res.* **2023**, *11*, 100480. [CrossRef]
18. Debela, N.; Mohammed, C.; Bridle, K.; Corkrey, R.; McNeil, D. Perception of climate change and its impact by smallholders in pastoral/agropastoral systems of Borana, South Ethiopia. *SpringerPlus* **2015**, *4*, 236. [CrossRef] [PubMed]
19. Headey, D.; Taffesse, A.S.; You, L. Diversification and development in pastoralist Ethiopia. *World Dev.* **2014**, *56*, 200–213. [CrossRef]
20. Menghistu, H.T.; Abraha, A.Z.; Tesfay, G.; Mawcha, G.T. Determinant factors of climate change adaptation by pastoral/agro-pastoral communities and smallholder farmers in sub-Saharan Africa: A systematic review. *Int. J. Clim. Change Strateg. Manag.* **2020**, *12*, 305–321. [CrossRef]
21. Tamene, H.; Ayal, D.Y.; Zeleke, T.T.; Ture, K. Determinants of the choice of adaptation strategies to climate variability and extremes among pastoralist and agro-pastoralist households in Yabello and Arero Districts, Southeast Ethiopia. *Clim. Serv.* **2023**, *30*, 100381. [CrossRef]
22. Tofu, D.A.; Fana, C.; Dilbato, T.; Dirbaba, N.B.; Tesso, G. Pastoralists' and agro-pastoralists' livelihood resilience to climate change-induced risks in the Borana zone, south Ethiopia: Using resilience index measurement approach. *Pastoralism* **2023**, *13*, 4. [CrossRef]
23. Kemal, A.W.; Mohammed, A.A.; Lelamo, L.L. Pastoralists' adaptation strategies to climate change and determinant factors in Korahey Zone, Ethiopia. *Am. J. Clim. Change* **2022**, *11*, 79–102. [CrossRef]
24. Debela, N.; McNeil, D.; Bridle, K.; Mohammed, C. Adaptation to climate change in the pastoral and agropastoral systems of Borana, South Ethiopia: Options and barriers. *Am. J. Clim. Change* **2019**, *8*, 40. [CrossRef]
25. Worku, M.A.; Feyisa, G.L.; Beketie, K.T. Climate trend analysis for a semi-arid Borana zone in southern Ethiopia during 1981–2018. *Environ. Syst. Res.* **2022**, *11*, 2. [CrossRef]
26. Birhanu, Z.; Ambelu, A.; Berhanu, N.; Tesfaye, A.; Woldemichael, K. Understanding resilience dimensions and adaptive strategies to the impact of recurrent droughts in Borana Zone, Oromia Region, Ethiopia: A grounded theory approach. *Int. J. Environ. Res. Public Health* **2017**, *14*, 118. [CrossRef]
27. Amare, G.; Seyoum, C.; Sileshi, M. Pastoralists' perception towards climate change and meteorological evidences: A case of Teltele District, Oromia Region, Ethiopia. *Sustain. Environ.* **2025**, *11*, 2489189. [CrossRef]
28. Dejene, T.; Dalle, G.; Woldeamanuel, T.; Mekuyie, M. Temporal climate conditions and spatial drought patterns across rangelands in pastoral areas of West Guji and Borana zones, Southern Ethiopia. *Pastoralism* **2023**, *13*, 18. [CrossRef]
29. Teshome, Y.; Jilo, K.; Kararsa, N.; Zegeye, Z.; Guyo, Z.; Duba, T. Prevalence of camel mange mite and associated risk factors in Gomole district, Borana zone, Southern Ethiopia. *Anim. Vet. Sci.* **2021**, *9*, 88–92. [CrossRef]
30. Bixley, B. Statistics: An Introductory Analysis, by Taro Yamane (New York: Harper & Row, 1964, pp. xvi, 734, $8.75). *Can. J. Econ. Political Sci.* **1964**, *31*, 163.

31. Belay, A.; Recha, J.W.; Woldeamanuel, T.; Morton, J.F. Smallholder farmers' adaptation to climate change and determinants of their adaptation decisions in the Central Rift Valley of Ethiopia. *Agric. Food Secur.* **2017**, *6*, 24. [CrossRef]
32. Gebeyehu, A.K.; Snelder, D.; Sonneveld, B.; Abbink, J. How do agro-pastoralists cope with climate change? The case of the Nyangatom in the Lower Omo Valley of Ethiopia. *J. Arid Environ.* **2021**, *189*, 104485. [CrossRef]
33. Tilahun, M.; Angassa, A.; Abebe, A. Community-based knowledge towards rangeland condition, climate change, and adaptation strategies: The case of Afar pastoralists. *Ecol. Process.* **2017**, *6*, 29. [CrossRef]
34. Tui, S.H.-K.; Descheemaeker, K.; Valdivia, R.O.; Masikati, P.; Sisito, G.; Moyo, E.N.; Crespo, O.; Ruane, A.C.; Rosenzweig, C. Climate change impacts and adaptation for dryland farming systems in Zimbabwe: A stakeholder-driven integrated multi-model assessment. *Clim. Change* **2021**, *168*, 10. [CrossRef]
35. Mengistu, D. Impacts of drought and conventional coping strategies of Borana community, southern Ethiopia. *Res. Humanit. Soc. Sci.* **2016**, *6*, 29–37.
36. Silvestri, S.; Bryan, E.; Ringler, C.; Herrero, M.; Okoba, B. Climate change perception and adaptation of agro-pastoral communities in Kenya. *Reg. Environ. Change* **2012**, *12*, 791–802. [CrossRef]
37. Zampaligré, N.; Dossa, L.H.; Schlecht, E. Climate change and variability: Perception and adaptation strategies of pastoralists and agro-pastoralists across different zones of Burkina Faso. *Reg. Environ. Change* **2014**, *14*, 769–783. [CrossRef]
38. Beyene, F. Determinants of food security under changing land-use systems among pastoral and agro-pastoral households in eastern Ethiopia. *Environ. Dev. Sustain.* **2015**, *17*, 1163–1182. [CrossRef]
39. Tofu, D.A.; Dilbato, T.; Fana, C.; Dirbaba, N.B.; Tesso, G. Analysis of vulnerability, its drivers, and strategies applied towards reducing the pastoral and agro-pastoral livelihood vulnerability to climatic shocks. *Sci. Rep.* **2025**, *15*, 2567. [CrossRef]
40. Adane, B.; Bayissa, B.; Tuffa, S.; Tola, T.; Mekonnen, S. Participatory impact assessment of ticks on cattle milk production in pastoral and agro-pastoral production systems of Borana Zone, Oromia Regional State, Southern Ethiopia. *Ethiop. Vet. J.* **2012**, *16*, 1–13. [CrossRef]
41. Ifejika Speranza, C. Drought coping and adaptation strategies: Understanding adaptations to climate change in agro-pastoral livestock production in Makueni district, Kenya. *Eur. J. Dev. Res.* **2010**, *22*, 623–642. [CrossRef]
42. Kima, S.A.; Okhimamhe, A.; Kiema, A.; Zampaligre, N.; Sule, I. Adapting to the impacts of climate change in the sub-humid zone of Burkina Faso, West Africa: Perceptions of agro-pastoralists. *Pastoralism* **2015**, *5*, 16. [CrossRef]
43. Alemayehu, S.; Olago, D.; Alfred, O.; Zeleke, T.T.; Dejene, S.W. Spatiotemporal analysis of rainfall and temperature variability and trends for a mixed crop-livestock production system: Its implications for developing adaptation strategies. *Int. J. Clim. Change Strateg.* **2025**, *17*, 268–290. [CrossRef]
44. Tolera, T.; Senbeta, F. Pastoral system in the face of climate variability: Household adaptation strategies in Borana Rangelands, Southern Ethiopia. *Environ. Dev. Sustain.* **2020**, *22*, 3133–3157. [CrossRef]

Disclaimer/Publisher's Note: The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.