Vulnerability and Adaptation Strategies of Pastoral and Agro-pastoral Households to Climate Change and Variability in the Lowlands of Ethiopia: Evidence from Six Regions

Ali Hassen[1], Tesfaye Zeleke[2], Meskerem Abi[3], Dilu Shaleka[4]

Abstract

In recent decades, climate change has increasingly impacted rural and urban livelihood systems, heightening communities' vulnerability to climate variability and shocks. Reducing this vulnerability requires a locally contextualized understanding of community perceptions, exposure, sensitivity, and adaptive capacity. Understanding households' perceptions of climate change and their capacities is essential for developing adaptation strategies. This study analyzes the vulnerability of pastoral and agro-pastoral (PAP) households and their responses, reflected in livelihoods that combine capitals, assets, and activities, as well as their perceptions of climate change and efforts to reduce its effects. The article examines exposure, sensitivity, and adaptive capacity to measure climate-induced vulnerability. A total of 1,332 randomly selected households,490 pastoralists and 842 agro-pastoralists, were interviewed across 12 Kebeles in six Woredas from six regions. Of these, 27% were female-headed and 72% male-headed. Focus group discussions, key informant interviews and in-depth interviews were also conducted. Most households perceived rising temperatures (78%), unreliable rainfall (60%), and increasing climate hazards, with 73% reporting droughts and 39% floods consistent with observed trends. Droughts, floods, economic shocks, food crises, and disease outbreaks were identified as major challenges. In the year preceding the field work of study, droughts and floods adversely affected livestock (71%) and crop production (70%). The exposure and sensitivity of livelihood activities to climate-induced hazards were found to be higher ranging from a score of (0.37–0.74) and (0.38–0.80) respectively.

[1] Asst. Prof., School of Development Studies, AAU. P.O. Box 1176; email: ali.hassen@aau.edu.et; Tel: +251 0941264921.

[2] Assot. Prof., School of Development Studies, AAU, P.O. Box 1176; email: tesfaye.zeleke@aau.edu.et; Tel: +251973168681.

[3] Asst. Prof., School of Development Studies, AAU. P.O. Box 1176, email: meskerem.abi@aau.edu.et; Tel: +25190771743.

[4] Asst. Prof., School of Development Studies, AAU. P.O. Box 1176, email: dilu.shaleka@aau.edu.et; Tel: +251911244962

Households responded by adjusting livestock and crop practices, building assets, practicing mobility and adopting food-shortage coping strategies. While these measures support long-term livelihood adaptation, overall adaptive capacity of the surveyed households was found to be low. Future programs and projects should mainstream existing adaptive strategies and strengthen community-driven efforts with government support to enhance resilience and long-term sustainability.

Keywords: Climate change, exposure, livelihoods, pastoralism, sensitivity, lowland regions.

1. BACKGROUND

The global climate is changing and will continue to do so in the coming century (Badar and Farha, 2011). This change primarily manifests in the form of temperature increases, alterations in precipitation patterns, and occurrences of extreme weather events such as severe and prolonged droughts and floods (Kevin, 2005). These changes have significant impacts on human livelihoods, health, natural resources, and ecosystems (Adger et al., 2003; IPCC, 2007). Therefore, climate change and its impacts on livelihood systems have become increasingly severe, affecting rural and urban communities spatially and temporally. This has heightened their vulnerability to climate variability and shocks, especially in developing countries, that rely on natural resources for their livelihoods (Lokuthula and Geoffrey, 2022).

Ethiopia is highly vulnerable to various shocks and disasters, including drought, floods, landslides, pests, earthquakes, and forest fires (Samuel, 2020). The arid, semi-arid, and dry sub-humid areas of the country are most susceptible to these hazards (Lemma, et al., 2013). Pastoral and agro-pastoral (PAP) communities living in these areas face significant risks due to their reliance on climate-sensitive livelihoods and limited asset bases. Additionally, these communities are exposed to recurrent droughts, livestock diseases, economic shocks, violent conflicts, and political instabilities, which further increase their vulnerability (Ayele et al., 2020).

Previous studies have extensively documented the predicaments faced by pastoralists in Ethiopia. These challenges include environmental degradation, ineffective implementation of policies and strategies, poor coverage of basic services and infrastructure, and recurrent conflict (Samuel, 2020). Environmental challenges, such as recurrent drought and floods, have led to the degradation of rangelands, reduced livestock productivity and livelihoods ((Lokuthula and Geoffrey, 2022). Flood hazards often result in disasters, and climate change has led to unfavorable weather patterns. Policy and strategy challenges include the lack of recognition of customary land tenure and increasing land demands for alternative uses, further constraining the pastoral system (UNDP, 2010; Pavanello, 2009). Moreover, basic services and infrastructural challenges including road and communication networks, markets, education, healthcare, and other social services, are underdeveloped. These pitfalls undermine the adaptive capacity of these communities (Fareh, 2011; MoFPDA, 2018).

Recent empirical evidence indicates that PAP households are increasingly vulnerable to climate change and climate variability (Tatek and Tadele, 2024). PAP households face a range of challenges including competition over water and pasture, ethnic-based conflicts, chronic poverty, persistent food insecurity, as well extreme natural events like recurrent droughts and other climate-related shocks (Mohammed, 2019).

Melka et al., (2019) reported that pastoral households in southern Afar region are particularly vulnerable to climate variability-induced stresses, which undermine livestock productivity and livelihood stability. Similarly, researches in Borana document substantial exposure to climate-related risks, with pastoral systems facing heightened sensitivity to rainfall variability and prolonged dry spells (Shetie and Nura, 2024; Tofu et al., 2023).

In the Somali region, pastoralists have experienced repeated droughts, livestock disease outbreaks, and conflict-driven disruptions, all of which have severely threatened food security and livelihood resilience (Devereux, 2006; David, 2009). Moreover, rising temperatures and pronounced inter-annual and seasonal rainfall variability have further

exacerbated crop and livestock losses, intensifying vulnerability across pastoral production systems (Tigist and Muluken, 2022).

Evidence from southwestern Ethiopia further indicates the multidimensional vulnerability of pastoral systems. In Gambella, recurrent conflict, flooding, drought, widespread livestock diseases, cattle raiding, and the conversion of grazing land to large-scale agricultural investments constitute the principal threats to pastoral livelihoods (Wondwosen, 2017; Abraham, 2002; Chayot, 2023). These pressures have progressively undermined access to key productive resources and weakened livelihood security. In South Omo (former SNNPR), the pastoral production system is constrained by chronic feed shortages, livestock diseases, declining and erratic rainfall, flooding, shrinking grazing areas, predation, animal raiding, land disputes, and competition over water and pasture resources (Mekete, 2023; Asmare, 2024). The convergence of climatic and socio-political stressors has intensified resource scarcity and heightened exposure to shocks.

In Ethiopia, semi-arid areas such as Afar and Somali, as well as low-lying lowland areas in Oromia, the former SNNPR, Benishangul-Gumuz and Gambella are highly vulnerable to climate change and the resulting hazards such as droughts and floods. Climate-induced shocks and stresses, including droughts, rising temperatures, irregular rainfall, and the shrinking size of pastoral lands, have had negative impacts on pasture and water availability. This has led to livestock deaths and food insecurity (Degfie and Sintayehu, 2024), necessitating programmatic-level interventions.

In the past two decades, various external programs have been implemented in these regions with the goal of reducing vulnerability and enhancing adaptive capacity to recover from the impacts of climate-induced changes and shocks. These interventions include institutional capacity building, infrastructure development, early warning system, livelihood resilience building, and irrigation. The main programs implemented in pastoral areas of the country are the Pastoral Community Development Programs (PCDP), the Productive Safety Net Program (PSNP), and the Lowland Livelihood Resilience Program (LLRP) (Ministry of Peace, 2019).

Given the extreme natural events and the increasing frequencies and severity of climate-induced risks on one hand, and interventions implemented with the goal of reducing vulnerability and enhancing adaptive capacity on the other hand, it is paramount to understand how PAP households have responded to climate-induced risks and the interventions aimed at adjusting their livelihood activities to reduce their vulnerability. However, there is limited research on how pastoral communities have been responding to climate-induced risks and external interventions aimed at reducing risks and enhancing their adaptive capacity. Furthermore, localized household-level studies are crucial for designing effective adaptation strategies. Therefore, this study aims to address this issue by focusing on six selected Woredas across Ethiopia's six regions, all located in the lowlands.

2. Conceptual and Methodological Underpinnings

2.1 The Concept of Vulnerability

Studies often focus on examining the factors that make communities living in semi-arid and low-lying lowland areas vulnerable (Workneh et al., 2011; Esmael, 2019; Meskrem et al., 2023). These studies suggest that the extent of vulnerability and the capacity of communities and households to adapt vary across space and time. In essence, vulnerability is a dynamic concept that includes exposure, sensitivity, and adaptive capacity (IPCC, 2007). Exposure refers to the extent to which a system is exposed to climate-related hazards, while sensitivity refers to how much a system is impacted by these hazards. Adaptive capacity, on the other hand, refers to the extent of a system's ability to adapt to climate change, reduce potential damage, and capitalize on opportunities (Gallopin, 2006). The idea of the system here largely refers to pastoral and agro-pastoral livelihoods.

Different analyses of vulnerability show that its definitions have two common parts: (i) negative impacts or losses experienced by systems or social groups, and (ii) the ability to recover or cope with these effects. Therefore, affected or exposed systems or groups are not passive recipients of impacts or losses. They also have some capacity to cope with and reduce risk, recover, and adapt through learning from experience and previous practices, living with changes and uncertainties, and utilizing existing opportunities. In other words, the

other side of vulnerability is “adaptive capacity" - the ability to absorb stresses and disasters and avoid unacceptable consequences (Thomalla et al., 2006). These discussions of vulnerability include external environmental factors such as shock or stress, thereby suggesting the need to consider the magnitude and frequency of hazard events in assessing vulnerability to climate change (IPCC, 2007).

Hazards are potentially harmful events, such as droughts, floods, pest infestations, and others, that negatively affect lives, property, or activities. In Ethiopia, these hazards often result from natural processes or human activities and recur, posing serious risks to livelihoods (FDRE, 2013; Lautze et al., 2003). Conversely, shocks are events that immediately and substantially affect the well-being of households and communities (Constas et al., 2022; WB, 2005). These events may include droughts, floods, epidemics, crops and livestock losses, food crises, and price hikes, which frequently lead to food insecurity and asset loss (FAO, 2020).

2.2 Exposure and Sensitivity

Vulnerability relates to the conditions of exposure and sensitivity within communities. Exposure refers to the likelihood that a system or location will be impacted by a shock, representing a negative change rather than the result of change (Faulkner et al., 2020). It can be assessed by the frequency and intensity of climate-related hazards, such as drought, decreased rainfall, rising temperatures, increased number of hot days, and frequency of floods. Therefore, higher frequencies and increases in these factors indicate an increased exposure to climate-related hazards and extreme weather events in pastoral and agro-pastoral areas (Faulkner et al., 2020).

Similarly, sensitivity refers to the extent to which hazards affect livelihoods, such as crop failure, livestock death, and food shortages (Faulkner et al., 2020; Gallopin, 2006). In this study, exposure and sensitivity are measured using indicators such as drought frequency, changes in rainfall patterns, and the impacts of these hazards on crop and livestock production (Table 2).

2.3 Adaptive Capacity, Adaption and Coping Strategies

Adaptive capacity refers to households' and communities' ability to cope with and adapt to climate-induced shocks and stressors that affect livelihoods and food security (Amusa, Esheya, and Efedua, 2023). This capacity is influenced by factors such as income, savings, social capital, and access to resources (Vollenweider, 2015). Households with greater adaptive capacity are better able to recover from shocks and implement feasible, practical adaptation strategies. Some key actions that can help households build adaptive capacity and, therefore, resilience to the effects of climate change include: (i) maintaining productive assets, (ii) access to irrigation, (iii) investing in farmland, (iv) improving soil fertility through the use of organic inputs, (v) using improved production technologies and practices, (vi) planting drought resistant varieties, (vii) diversifying income sources, (viii) building a stronger saving culture and social capital, and (ix) local institutional support (Mengistu et al., 2019).

Adaptive capacity, adaptation, and coping strategies are key concepts in temporary climate vulnerability assessment frameworks (IPCC, 2022). Although they are closely related, they also have distinctions. Adaptive capacity includes access to assets, institutional support, livelihood diversification, governance quality, knowledge systems, and social capital (Singh et al., 2021; Magnan et al., 2022). It reflects a proactive aspect of resilience that influences the potential for long-term risk reduction (IPCC, 2022). In contrast, adaptation refers to specific actions and strategies implemented to address climate change or its effects (Araos et al., 2021; Magnan et al., 2022). It involves permanent, structural adjustments to the system aimed at sustainability. Coping strategies are the actions and responses individuals use to handle immediate stressors or crises (IPCC, 2022). These are immediate, reactive measures focused on survival and managing crisis impacts.

Higher adaptive capacity enables more effective, timely adaptation actions, implying learning and lasting change. Coping strategies, on the other hand, are short-term survival strategies that entail temporary measures to mitigate the impacts of crises. Households and communities have used coping mechanisms for generations to deal with the impacts of crises, but climate change-induced effects have become severe, overwhelming coping strategies, and making them less effective at surviving shocks. The current emphasis is on dealing with the effects

of extreme climate events through adaptive capacity and adaptation strategies.

2.4 Approaches to Vulnerability Analysis

The literature on vulnerability tends to be associated with strategies to reduce risk and the negative impacts of shocks, while that on resilience tends to emphasize strategies used to absorb shocks or disturbances at longer-term scales (Miller et al., 2010). A more holistic approach is required to understand how systems and units respond to changes, both positively and negatively (Faulkner et al., 2020). Faulkner et al. further noted that a holistic approach is presented in the Vulnerability-Resilience Model, which conceptualizes vulnerability and resilience through four components: (1) exposure, (2) sensitivity, (3) capacity of response, and (4) adaptive capacity.

Other methods used to analyze vulnerability include socio-economic, biophysical, and integrated approaches (IPCC, 2022). The socio-economic approach evaluates vulnerability based on characteristics of individuals, groups, and communities such as education, gender, age, health status, access to social capital, information, credit, facilities, infrastructure, political power, and more (Adger and Kelly, 1999). While this approach effectively identifies the inherent capacities of subjects, it often underrepresents environmental resources (natural capital) and climate-change-induced shocks such as droughts and floods, which vary across space and time (Tschakert et al., 2023). Focusing predominantly on socio-economic characteristics may overlook the dynamic interaction between hazard intensity, ecosystem conditions, and temporal variability that jointly shape climate risk (IPCC, 2022; Magnan et al., 2022). Hence, the limitations of the socio-economic approach are addressed by adopting a biophysical approach that captures environmental and resource conditions and processes within the coupled social and natural systems. These conditions include social and biophysical capital, which influences coping strategies (Turner, 2003).

The biophysical approach helps assess the extent of impacts or damage resulting from environmental stressors on both ecological and socio-economic systems. This approach evaluates how climate hazards, including temperature increases, rainfall variability, droughts, and

floods, affect agricultural production, crop yields, pasture availability, and related biophysical resources (IPCC, 2022). It also enables the assessment of impacts on livelihood-dependent assets, including livestock and other income-generating resources closely tied to environmental conditions (Ranasinghe et al., 2021). By quantifying exposure and sensitivity to climatic stressors, the biophysical framework provides spatially explicit evaluations of risk to natural capital and production systems (Tschakert et al., 2023). However, this approach has the limitation of neglecting structural factors and human actors/agencies in its analysis of vulnerability.

The integrated approach combines socio-economic and biophysical methods to analyze vulnerability. While it aims to provide a broader understanding of the multilayered and dynamic nature of vulnerability in coupled biophysical and social systems by merging concepts from different perspectives, there is no standard method for combining biophysical and socio-economic factors (Newell et al., 2005). It can be problematic because it requires merging different ways of framing and conducting vulnerability analysis (Soares et al., 2012). Nevertheless, the integrated approach has merit, particularly in policy-driven assessments that offer guidance on measures to inform adaptation policies (Füssel and Klein, 2006). In this study, an integrated approach is adopted that considers social and environmental factors, including the internal and external dimensions of vulnerability.

2.5 Conceptual Framework

This study utilized an integrated approach to analyze vulnerability within a regionally-based context. The assumption is that pastoral and agro-pastoral households with higher adaptive capacity are less sensitive to the impacts of climate-induced stresses than those that rely on coping strategies as short-term responses. The vulnerability index is computed using the Intergovernmental Panel on Climate Change (IPCC) guidelines from 2012 to assess vulnerability. It is hypothesized that PAP households are particularly exposed to the impacts of rising temperatures, rainfall variability, and extreme climate events such as drought and floods. The pastoral areas of Ethiopia are particularly susceptible to the effects of temperature and rainfall variability, as well as extreme climate events such as droughts and floods. The degree of

vulnerability to these risks is strongly tied to adaptive capacity, as higher capacity can help reduce potential harm. The frequency and intensity of these climate risks significantly impact socioeconomic vulnerability. Sensitivity and adaptive capacity are interrelated, as adaptive capacity can affect sensitivity at a given level of exposure. Thus, vulnerability is determined by the combination of adaptive capacity, sensitivity, and exposure. This relationship among determinants of vulnerability is illustrated in Figure 1 below.

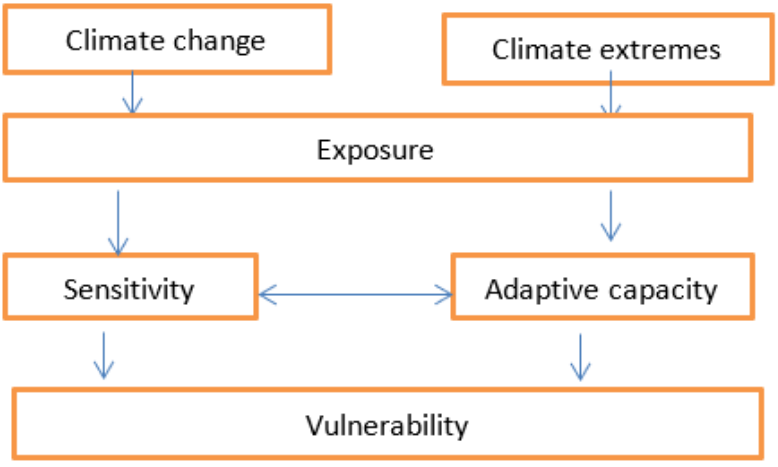
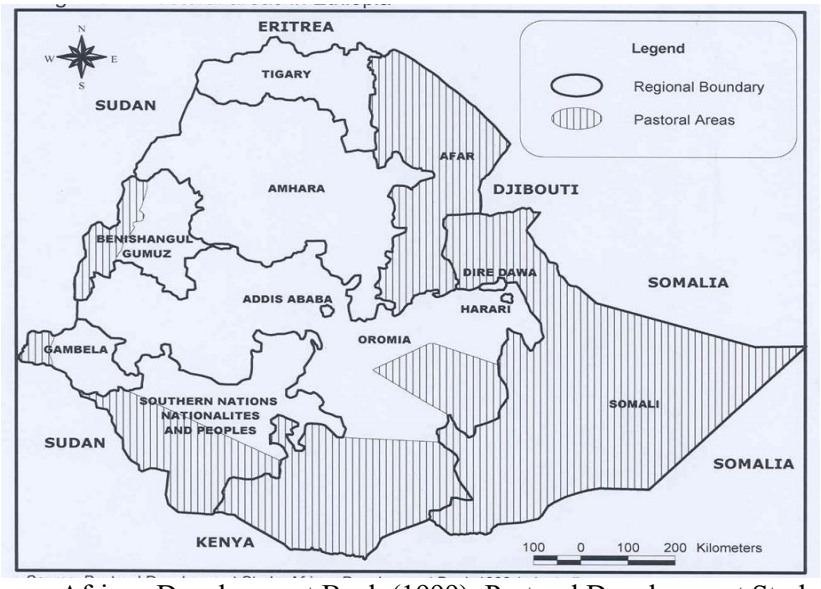


Figure 1: Conceptual Framework of Study
Source: Adopted from Deressa, et al., 2008

3. Methodology

3.1 Description of Study Area

Pastoralists and agro-pastoralists in Ethiopia primarily inhabit lowland regions such as Afar, Somali, Oromia, and former SNNPR. They also reside in pastoral areas of Gambella and Benishangul-Gumuz Regions (Figure 1). These pastoralists are spread across 122 Woredas within these regions. More than 97% of the pastoral population resides in Somali, Oromia, Afar, and former SNNPR (UNDP, 2010). The main livelihood systems of these groups include pastoralism, farming, and small income-generating activities for those who have transitioned out of pastoralism (Behnke et al., 2007).



Source: African Development Bank (1999): Pastoral Development Study
Figure 2: Location of Pastoral Areas in Ethiopia

This study was conducted in six pastoral and agro-pastoral regions of Ethiopia: Afar, Somali, Benishangul Gumuz, Gambella, Oromia, and former SNNPR. The main criteria considered in selecting the study Woredas and Kebeles include the dominant livelihood systems (pastoral and agro-pastoral), available resources, and the security status of the respective Woredas. Data were collected from six Woredas (districts) and two Kebeles (villages) within each Woreda (refer to Table 1). A detailed description of the process used to select the Woredas and Kebeles is presented below.

3.2 Selection of Study Woredas and Kebeles

Multi-stage sampling procedures were utilized to select Woredas, Kebeles, and sample households for this study. Initially, six sample Woredas were purposively selected based on their livelihood systems (i.e., pastoral and agro-pastoral). Factors such as stability, accessibility, and the presence of both PAP livelihoods in some Kebeles were considered in the selection process. In the next stage, two Kebeles were selected from each Woreda, with one being pastoral and the other agro-pastoral. This resulted in 12 Kebeles being selected using purposive sampling. Lastly, sample households were selected randomly from a list

of households. A total of 1,332 PAP households were surveyed, with 37% being pastoralists and 63% being agro-pastoralists (see Table 1). This sampling proportionality illustrates the increasing prevalence of agro-pastoralism in most lowlands of Ethiopia.

3.3 Sample Size Determination

The total number of households from each Kebele was obtained from the Kebele administration. For each selected Kebele, the appropriate sample size calculation formula was used to determine the number of respondents for the specific Woredas. The formula below was used to calculate the sample size (Cochran, 1977).

$$n = \frac{Z^2}{4e^2 + \frac{Z^2}{N}}$$

Where:

- n= is the required and adjusted sample size,
- N= the total population from which the samples are drawn,
- Z= is the confidence level, i.e., 1.96. The confidence level is the amount of uncertainty that the researcher can tolerate. A higher confidence level requires a larger sample size, and
- e= margin error i.e. (0.05), the margin error is often described as the 5% error, which is the amount of error that can be tolerated in such research.

Based on the formula, Table 1 below shows the total population and sample size for each Kebele.

Table 1 Sample Size by Region, Woreda and Kebele

Region	Woreda	Kebele	No. of Households	Sample Size		
				Agro-pastoralist	Pastoralist	Total
Afar	Amibara	Bedulale	683	149	2	151
		Halaydegy	292	0	89	89
Benishangulgumuz	Kurmuk	Agobela	137	40	0	40
		Ogendu	200	102	0	102
Gambella	Itang	Pulkot	783	137	18	155
		Acwaa	425	72	38	110
Oromia	Fentalle	Gelcha	570	0	127	127
		Gola	613	60	53	113
SNNPR (the former)	Benatsemay	Goldiya	201	0	75	75
		Shala	403	73	32	105
Somali	Shabelay	Hadow	472	209	1	210
		Lafmadhedhley	236	0	55	55
Total	**6**	**12**	**5,015**	**842 (63%)**	**490 (28%)**	**1332**

Source: CDS, 2023:28

3.4 Research Design and Data Collection Methods

A mixed-methods research design combining quantitative and qualitative approaches was adopted to guide the research process, achieve a comprehensive understanding of the research issues, explore diverse perspectives, and gain deeper insights into the research questions, while also triangulating the data in the analysis of results. A cross-sectional research design was used to collect data from targeted households in February and March 2022. Primary data were collected through a structured questionnaire, focus group discussions, and key informant interviews. Household surveys were carried out with a sample of 1,332 households, consisting of 490 pastoralists and 842 agro-pastoralists. Among the households surveyed, 28% were female-headed households, and 72% were male-headed households.

Fifteen focus group discussions were conducted with representatives of pastoral communities, and twenty-one key informant interviews were conducted with members of both pastoralist and agro-pastoral communities. Additionally, seventeen in-depth interviews were held with experts from government offices and Kebele councils in the surveyed Woredas. Furthermore, a desk review was conducted to gather secondary data from program documents, case reports, and existing literature.

3.5 Data Analysis

Descriptive statistics were used to analyze the quantitative data, and vulnerability indices were computed using the IPCC-LVI approach. The vulnerability index was calculated based on exposure, sensitivity, and adaptive capacity indicators (refer to Table 2 for a list of indicators). Additionally, the qualitative data were analyzed through thematic analysis to complement and triangulate the quantitative findings.

3.5.1. Variables and Hypothesized Signs for Potential Relationships

The initial step in any livelihood vulnerability assessment would be to define variables within the analysis context. In this article, the context pertains to livelihood vulnerability in pastoral and agro-pastoral areas. Variables that define exposure, sensitivity, and adaptive capacity were identified from the literature and applied accordingly (see Table 2). Plus

(+) or minus (-) signs were included to indicate the relationship between the variable and the elements of vulnerability.

Table 2 Selected livelihood vulnerability variables in the pastoral and agro-pastoral context

Vulnerability attributes	**Indicator variables**	**Measures and explanations**	**Relationship (+ or −) to Attribute**
Exposure [9 indicators]	Hot days	Number of hot days increased	+
	Warm nights	Number of warm nights increased	+
	Coldness	Degree of coldness of cold seasons increased	+
	Rainfall onset	Onset of rainfall becomes more unpredictable	+
	Rainfall cessation	Cessation of rainfall becomes more unpredictable	+
	Rainy days	Number of rainy days decreased	+
	Untimely rainfall	Occurrence of untimely rainfall increased	+
	Drought frequency	Frequency of drought occurrence has increased	+
	Flood frequency	Frequency of flooding occurrence has increased	+
Sensitivity [5 indicators]	Livestock death	Death of livestock encountered due to climate-induced hazards in the last five years	+
	Crop loss	Crop loss/damage encountered due to climate-induced hazards in the last five years	+
	Livestock disease	Diseases that have affected livestock during climatic extremes (low rainfall, high rainfall and high temperature from the normal range)	+
	Famine	Absence of any kind of food to eat any kind in the household due to lack of money or other resources the past four weeks	+
	Shock	Market shocks, illness and death encountered by the household member/s associated with climate-induced shocks during the surveyed period	+
	Crop diversification	Crop diversification (growing different varieties of food and cash crops, etc.)	+
	Resilient crops	Planting drought-resistant crop varieties along with high-yield crops	+
	Improved varieties	Using improved crop and livestock varieties	+

Vulnerability attributes	**Indicator variables**	**Measures and explanations**	**Relationship (+ or −) to Attribute**
Adaptive capacity [23 indicators]	Cropping calendar	Changing cropping calendar/changing planting and harvesting dates	+
	Feed purchase	Purchase and provide supplementary feed (fodder, crop residues)	+
	Preserving	Preserving/managing pasture and storing animal feed	+
	Shifting	Shift from livestock to non-farm activities	+
	Feed diversification	Diversifying, changing or supplementing livestock feed	+
	Species diversification	Diversify livestock species/types	+
	Herd composition	Change herd composition/shifting to camel/small ruminants/poultry/beekeeping	+
	Planting trees	Planting trees	+
	Fodder crop diversification	Fodder crops diversification and development /planting drought tolerant fodder trees	+
	Livelihood diversification	Diversify livelihood activities (labour, charcoal/firewood selling, petty trade,)	+
	Herd destocking	Herd destocking	+
	WHTs	Employing water harvesting technologies	+
	Shifting to crop	Shift from livestock to crop production	+
	Enclosure	Enclosure/controlled grazing/rotational grazing	+
	Herd mobility	Increased herd mobility/migration	+
	Aid	Dependence on aid (government/NGOs), remittance	+
	Human capital	Health post, animal veterinary service and special knowledge and skill	+
	Physical capital	TV, Radio, cell phone, Tape/CD player, motor pump, motorbike, bicycle, horse cart, and hand cart	+
	Natural capital	Cropping land, grazing land, water sources	+
	Financial capital	Saving and credit access, total annual income	+

Source: Authors' own construction based on a review of the literature.

The livelihood vulnerability indices were calculated in the first stage based on their relationship with each sub-component. Next, the indices for each sub-component were calculated using the values of the individual indicators that comprise the sub-component and their respective weights. This step was done for the exposure, sensitivity, and adaptive capacity of the livelihood vulnerability index (LVI) based on the following equation (Hahn et al., 2009).

$$C_j = \frac{\sum_{i=1}^{N} K_m X_i}{n}$$

where, C_j is the index value of the sub − component, K_m is the weight and X_i is the individual indicator's value, and n is the number of indicators in the sub-component. Finally, the livelihood vulnerability index was calculated based on the following equation (Hahn et al., 2009).

$$LVI = s * (e - a)$$

where $\boldsymbol{LVI}$ is the livelihood vulnerability index, $\boldsymbol{s}$ and $\boldsymbol{e}$ are the sensitivity and exposure to the impacts of climate change, respectively, and $\boldsymbol{a}$ is adaptive capacity at the regional level.

4. Results and Discussions

4.1 Demographic and Socio-Economic Characteristics of Respondents

Regarding respondents' birthplace, 98% of agro-pastoral households and 97% of pastoral households were born in their respective study localities. The study also revealed that 72% of households were headed by males, while 8% were headed by females. Within sub-groups of agro-pastoral households, 26% were female-headed, and 74% were male-headed. In pastoral subsystems, 31% households were female-headed, and 69% were male-headed.

A significant portion of households (54%) were found to be unable to read and write, with only 29% having attended formal education. Around 17% had received informal education, enabling them to read and write. The results revealed that a higher percentage of pastoral households were unable to read and write compared to agro-pastoral

households (59% vs. 51%). A smaller percentage of PAP households attended formal education (30% vs 27%) and informal education (19% vs. 14%). The chi-square test results also indicated a statistically significant difference in means between household groups at the 5% significance level.

The results show that approximately 50% of agro-pastoral households and 78% of pastoral households are Muslims, while around 40% of agro-pastoral households and 12% of pastoral households are Protestant. The remaining 10% of agro-pastoral households adhere to Orthodox, Catholic, or other religions, including customary practices (Table 3). Regarding resource ownership, the results show that about 13% of respondents own private grazing land, while around 45% own private farming land. Regarding housing, approximately 29% of respondents live in homes with corrugated iron roofs.

Table 3 Demographic and socio-economic characteristics of study households

No	Variables		Agro-pastoralist (N= 842)	Pastoralist (N= 490)	Total (N=1332)	Chi-square test
			N (%)	N (%)	N (%)	
1.	Sex	Female	221 (26.2)	150 (30.6)	371 (27.9)	0.087
		Male	621 (73.8)	340 (69.4)	961 (72.1)	
2.	Education status	Unable to read and write	433 (51.4)	289 (59.0)	722 (54.2)	0.017*
		Informal education	158 (18.8)	69 (14.1)	227 (17.0)	
		Formal education	251 (29.8)	132 (26.9)	383 (28.8)	
3.	Households born within the study village	Yes	822(97.6)	477 (97.3)	1299(97.5)	0.753
		No	20(2.4)	13 (2.7)	33(2.5)	
		No	737 (87.5)	444(90.6)	1181(88.7)	
4.	Religion	Muslim	424 (50.4)	376 (76.7)	800 (60.1)	0.000***
		Protestant	333 (39.5)	58 (11.8)	391 (29.40)	
		Orthodox	49 (5.8)	0	49(3.7)	
		Catholic	17(2.0)	9(1.8)	26(2.0)	
		Other	19(2.3)	47(9.6)	66(5.0)	

5.	Owns private grazing land	Yes	142(16.9)	35(7.1)	177(13.3)	0.000***
		No	700(83.1)	455(92.9)	1155(86.7)	
6.	Owns private farmland	Yes	494(58.7)	102(20.8)	596(44.7)	0.000***
		No	348(41.3)	388(79.2)	736(55.3)	
7.	Live in a corrugated house	Yes	320(38.0)	68(13.9)	388(29.1)	0.000***
		No	522(62.0)	422(86.1)	944(70.9)	

Source: Computed from the survey data collected, February-March, 2022.

4.2 Pastoral and Agro-pastoral Households' Perceptions of Climate-Induced Hazards

The study revealed that PAP households reported higher temperatures and more unpredictable rainfall. Specifically, over 60% of respondents noted unpredictable rainfall patterns, while 75% reported fewer rainy days. Additionally, 31% reported an increasing trend in rainfall intensity. About 43% of the respondents also mentioned an increase in untimely rainfall (see Table 4). Overall, the survey results indicated that trends in the onset and cessation dates, timing, and intensity of rainfall have become more unpredictable. Furthermore, both daytime and nighttime temperatures were observed to be rising in the surveyed communities.

Table 4 Rainfall variability indicators in PAP communities

Respondents	Statement	Agree	Strongly agree	Neutral	Disagree	Strongly disagree
PAP households (n=1332)	Unpredictable onset of rainfall	47.6%	12.5%	14.4%	21.2%	4.3%
	unpredictable cessation of rainfall	44.9%	11.9%	15.4%	21.7%	6.2%
	Rainy days decreased.	51.8%	23.1%	11.7%	10.1%	3.3%
	Intensity of rainfall increased.	24.8%	5.9%	17.2%	36.8%	15.5%
	Untimely rainfall increased.	34.8%	8.3%	15.2%	33.1%	8.5%

Source: Survey, February to March, 2022

Respondents noted a rise in temperature, evident through more hot days and warm nights. Therefore, 78% of respondents expressed agreement with the rise in daytime temperatures, while 10.5% disagreed (Table 5). A similar percentage of respondents also observed an increase in the number of warm nights.

Table 5 PAP households' perceptions of temperature

Respondents	Temperature indicators	Responses (%)				
		Agree	Strongly agree	Neutral	Disagree	Strongly disagree
PAP Households (N=1332)	Number of hot days increased.	48.7	29.3	11.5	7.5%	3.0
	Number of warm nights increased.	43.5	15.2	12.4	22.2	6.2
	Degree of coldness in cold seasons increased.	20.8	6.8	16.5	41.1	15.8

Source: Survey, February to March., 2022

Both pastoralists and agro-pastoralists viewed climate change, along with all its consequences, as a common issue affecting them. Changing rainfall patterns influence annual cropping decisions and the movement of pastoral herds to access pasture and browse plants, as well as patchy pasture resources. The unpredictability of rainfall trends would affect pastoral communities' decisions on the feasibility of implementing suitable adaptive measures. A focus group discussion held in the Afar region highlights the impact of frequent droughts and climate change on local resources and mobility patterns, which are the key strategies of pastoralists. The excerpt of the FGD is narrated as follows:

> Mobility has increased compared to 10 years ago. Two or three decades ago, there was adequate grazing land and relatively enough water. We used to move together in groups over short distances. However, nowadays, mobility is increasing, but the patterns and distances of movement are different and changing. Factors contributing to these changes include frequent droughts, limited water resources and reserves, and the invasive tree Prosopis Juliflora, which undermines

> grazing resources. As a result, we now travel to distant areas, but we no longer move together as a family like we used to. We leave our children, women, and elders in the village. Our children go to school, which is why we leave them behind. Sometimes, we cross into other communities' territories, where conflicts are possible, making us cautious and leading us to leave women and elders in the base village. (FGD, Halydege Kebele, Afar Region, February-March 2022).

In the household survey, respondents were asked to identify human-climate-induced hazards and shocks they had faced in the past five years. As shown in Table 6, the most common hazards in the surveyed communities were drought and flood. The shocks affecting PAP households included economic shocks, diseases/epidemics, food crises, and conflicts (Table 6).

4.3 Perceived Hazard Occurrences/ Trends and Shocks in the study Areas

Scientific evidence and empirical studies have shown that climate-induced changes and frequent extreme weather events are happening and posing threats to people's livelihoods and environmental goods and services (IPCC 2007). These threats and impacts are more severe for communities that heavily rely on natural resources for their livelihoods and have limited assets to cope with climate-induced shocks. The extreme dependence on natural resources and extreme poverty have exposed PAP households to the impacts of climate change and extreme weather events. In this regard, a key informant interviewed from the Afar community described his community's dependence on natural resources for livelihoods and its vulnerability to extreme weather events and human-induced risks. He said:

> As you know, we are facing numerous challenges. These include drought, the spread of the invasive alien plant (Prosopis Juliflora), flooding and conflicts within our community. We are completely dependent on nature, so if something happens to the rain, river or weather, we are always in danger *(In-depth interview in Bedulale Kebele, Afar Region, February- March, 2022)*

In the household survey, respondents were asked to identify human-climate induced hazards and shocks they had faced in the past five years. As shown in Table 6, the most common hazards in the surveyed communities were drought and flood. The shocks affecting PAP households included economic shocks, diseases/epidemics, food crises, and conflicts (Table 6).

Table 6 Hazards and shocks that occurred in the last five years

Hazards/shocks	Agro-pastoralist (N=842)	Pastoralist (N=490)	Both (N=1332)
	Yes (%)	Yes (%)	Total
Drought	67.2	82.2	73.8
Flood	11	2.2	7.1
Economic shocks	8.9	5	7.2
Disease/epidemic	5.3	8.4	6.7
Food crisis	6.6	1.9	4.6
Conflict	0.9	0.2	0.6

Source: Survey, February to March, 2022

Respondents were asked if they believed the frequencies of drought and flood hazards had increased. The majority of respondents (73%) agreed that drought frequency has increased, while about 16% disagreed. Regarding the frequency of flooding, 39% of respondents agreed, while 45% disagreed (Table 7). Pastoralists' and agro-pastoralists' perceptions reflected the climate trends observed in arid and semi-arid pastoral areas over the past couple of decades. The results indicate that climate-induced drought and flood hazards are becoming more frequent and severe, posing threats to the livelihood activities of pastoral communities. Therefore, both pastoralists and agro-pastoral households have experienced livelihood shocks over the past five years being attributed to climate shocks.

Table 7 PAP households' perception on occurrence of drought and flood hazards (N=1332)

Statement	Responses (%)				
	Agree	Strongly agree	Neutral	Disagree	Strongly disagree
Frequency of drought occurrence has increased	44.2	28.7	10.7	11.0	5.4
Frequency of flooding occurrence has increased	24.2	15.1	16.3	34.8	9.6

Source: Survey, February to March, 2022

In addition to the household survey results, qualitative data also revealed the prevalence of challenges affecting the livelihoods of pastoral communities. Table 8 presents a summary of the challenges reported by the discussants of FGDs conducted in six Woredas of the study regions. The analysis of qualitative data showed that most of these challenges are closely related to the hazards and shocks described in Table 6.

Table 8. Climate Change-induced Challenges affecting PAP in the Woredas

Region	**Woreda**	**Perceived challenges reported in the FGDs**
Afar	Amibara	Drought, invasive plant (prosopis juliflora), flooding, conflict.
Benishangul-Gumuz	Kurmuk	Climate change, persistent drought, invasion of tsetse fly
Gambella	Itang	Drought, famine, animal disease, flood, increased temperature, shortage of rain, shortages of food for human and feed for animal, low productivity, crop failure, poor basic service delivery, expensive livestock vaccine, animal disease transmission.
Oromia	Fentalle	Rainfall shortage and unexpected rain cessation; rainfall variability for the summer season; heavy rain sometimes and flooding; expansion of Lake Basaqa causing displacement of households; invasive tree (prosopis juliflora).

Region	Woreda	Perceived challenges reported in the FGDs
SNNPR (the former)	Benatsemay	Shortage of financial services (rural financing); marketing-related challenges (access to marketing information for their livestock products); farming inputs price variation and escalation; traditional way of animal husbandry (low productivity); lack of all-weather road to access the market for live animals and products; climate change with frequent drought.
Somali	Shabelay	Drought, flooding, pest infestation (grasshopper), cconflict, rainfall shortage and unexpected cessation of rain; variability of rainfall, fragmentation of farm land due to population increase.

Source: Summary of findings from FGDs conducted in Six Woredas, February-March, 2022.

4.4 Perceived Impacts of Climate-Induced Hazards

As shown in Table 9, most respondents (71.2%) reported that these hazards led to the death of livestock. Around 70% have experienced crop losses or damage in the last five years, and 44% of surveyed households reported facing climate-induced shocks, such as illness or death of household members, as well as market shocks.

Table 9 Impacts of climate-induced hazards (N=1332)

Items	Responses	Agro-pastoralists	Pastoralists	Total
Did you encounter death of livestock due to climate-induced hazards in the last five years?	Yes	525 (62.4)*	66 (13.5)	949 (71.2)
	No	317 (37.6)	424 (86.5)	383 (28.8)
Did you encounter crop loss/damage due to climate-	Yes	277 (32.9)	129 (26.3)	926 (69.5)
	No	565 (67.1)	361 (73.7)	406 (30.5)

Items	Responses	Agro-pastoralists	Pastoralists	Total
induced hazards in the last five years?				
Did you encounter any market shocks, illness and a death of the household member due to reasons associated with climate-induced shocks during the surveyed period?	Yes	322 (38.2)	262 (53.5)	584 (43.8)
	No	520 (61.8)	228 (46.5)	520 (61.8)

Source**:** Survey, February to March 2022.
***** Figures in the parenthesis are percentages.

Considering the growing impact of climate change and other stressors, qualitative research participants offered additional insights that complemented the survey findings. The FGDs held in Benishangul Gumuz highlighted the severe problems caused by drought. The participants expressed their views on the effects of drought leading to other stressors, as follows:

> Drought is a common hazard in the area, often leading to food crises. Another significant shock in the area is animal disease caused by the tsetse fly, which can result in the complete collapse of animal husbandry. Overall, the main negative impacts of drought and animal disease include crop loss, particularly of maize, and livestock death (FGD, Benishangul Gumuz, Kumruk Woreda, Agobela Kebele, February-March 2022).

During the FGD in the former SNNPR, participants reflected on past droughts, focusing on the devastating 2015/16 drought. The discussants shared: "We lost a large number of livestock. Due to the shock, we had to sell the remaining cattle, move some to other areas, and use crop

residues as fodder for the remaining animals (FGD in the former SNNPR, in Bena Tsemay Woreda, Shalla Guyayo kebele, February-March 2022).

In surveys conducted in Afar region kebeles, both pastoralists and agropastoralists identified drought as the most prevalent phenomenon. An in-depth interview held with a pastoralist in the Afar region revealed the following:

> Drought is a common occurrence in our kebele, and we constantly face its consequences. We are on the brink of another drought if we don't receive rain soon. The most devastating drought occurred a few years ago, lasting for four consecutive years. During that time, we lost everything. Some members of our community lost all their animals, while others were forced to leave the area permanently. Through the grace of Allah, we recovered from that drought, though we lost family members, including children and elders. To survive, we had to sell our livestock at very low prices. Some of us even had to slaughter and eat animals that were near death. Additionally, we sent stronger livestock with shepherds to search for grazing land and water in other areas (Key informant interview, in Halaydege Kebele, Afar Region, February –March 2022).

Another key informant from the Afar region emphasized that flooding is a major cause of shocks that have affected the lives of many pastoralists and agro-pastoralists. Providing context by describing situations from the past three years, the informant revealed the following:

> Flooding severely affected our Kebele in August and September of 2021, resulting in a disaster. The overflowing Awash River surrounded and submerged our Kebele underwater. Some individuals even had to be rescued by a helicopter. We not only suffered from crop losses, but also lost family members, animals, property, and homes during this time. Consequently, we were unable to prepare the land for the next season. The water persisted in our area for an extended period, affecting our community with waterborne diseases

such as cholera (Key informant interview, in Bedulale Kebele, Afar Region, February-March 2022).

The analysis of quantitative and qualitative data revealed that climate-induced hazards and shocks are increasingly frequent and severe, posing major threats to the livelihoods of pastoral communities. Therefore, it can be said that the perceptions of pastoralists' and agro-pastoralists' are consistent with climate change trends observed by researchers in arid and semi-arid pastoral areas (Mulinge, 2013; Girma and Zelalem, 2022; Matiwos et al., 2022). Both pastoralists' perceptions and research evidence suggest that pastoral areas, the growing population, and rain-fed crop and livestock production are heavily impacted by extreme weather and climate change.

4.5 Livelihood Vulnerability of PAPs to Climate Change

4.5.1 Exposure to the Impacts of Climate Change

Exposure is attributed to temperature and rainfall variability as well as extreme climate events such as drought and flooding. Table 10 shows that the Somali region was highly exposed to the impacts of climate change, including temperature rise, rainfall variability, and the occurrence of extreme climate events, with index values of 0.69, 0.78, and 0.75, respectively. The Benishangul-Gumuz region was the second most exposed region in terms of temperature (0.68) and rainfall (0.68) indicators. Oromia was highly exposed, next to the Somali region, with respect to rainfall (0.75) and temperature (0.62) indicators. The overall exposure index showed that the Somali (0.74) and Oromia (0.67) regions were highly exposed, whereas Gambella (0.37) and Afar (0.50) were the least exposed regions (Table 10).

Table 10 Exposure of livelihood vulnerability index along with indexed major and sub-components.

Individual components	AFA	BSG	GMB	ORO	SNP	SOM	Sub-components	AFA	BSG	GMB	ORO	SNP	SOM
HD	0.93	1	0.4	0.79	0.79	0.94	Temp.						
WN	0.29	0.95	0.36	0.82	0.63	0.65		0.54	0.68	0.35	0.62	0.52	0.69
CS	0.4	0.09	0.29	0.24	0.15	0.47							
OR	0.53	0.61	0.29	0.8	0.61	0.88							
CR	0.37	0.62	0.31	0.77	0.57	0.89	Rainfall	0.50	0.68	0.35	0.75	0.57	0.78
RD	0.2	0.6	0.36	0.64	0.39	0.45							
OU	0.89	0.9	0.45	0.8	0.69	0.9							
FF	0.33	0.71	0.42	0.8	0.72	0.93	Climate Extreme	0.47	0.43	0.42	0.58	0.47	0.75
FD	0.6	0.15	0.42	0.36	0.22	0.56							
Exposure Index								**0.50**	**0.63**	**0.37**	**0.67**	**0.53**	**0.74**

HD = number of hot days increased, WN = number of warm nights increased, CS = The degree of coldness of cold seasons increased, OR = The onset of rainfall becomes more unpredictable, CR = The cessation of rainfall becomes more unpredictable, RD = number of rainy days decreased, OU = The occurrence of untimely rainfall increased, SC = Sub-component, FD = The frequency of drought occurrence has increased, FF = The frequency of flooding occurrence has increased.

4.5.2 Sensitivity of study regions to impacts of climate change

Sensitivity, as depicted above, refers to the degree to which a system is impacted, either positively or negatively, by climate variability or climate change (IPCC, 2007). The level of sensitivity is determined by the nature of households' livelihoods and the resources available to fund adaptation measures (Denbel et al., 2024). Pastoralists rely on livestock production, while agro-pastoralists depend on a mixed crop-livestock production system, both of which are sensitive to climate change. Therefore, pastoral households are the most vulnerable due to their climate-sensitive livelihoods and limited resources for financing adaptation measures (Mulinge, 2013; Girma and Zelalem, 2022).

As shown in Table 11, the Somali region was highly sensitive to the impacts of climate-related extreme events. It had index values of 0.83 for livestock deaths and crop losses, and 0.76 for market shocks and food shortages. The former SNNPR was the second-most sensitive region to extreme events, with index values of 0.79 for livestock deaths and crop losses, and 0.66 for market shocks and food shortages. The Oromia region was also highly sensitive, with index values of 0.79, 0.71, and 0.67 for livestock deaths, crop losses, and livestock diseases, respectively.

In terms of overall sensitivity, Somali and the former SNNPR were the two most sensitive regions to climate-related impacts, with index values of 0.80 and 0.74, respectively. Afar, Oromia, and Gambella were moderately sensitive, with index values of 0.57, 0.56, and 0.55, respectively. Benishangul-Gumuz exhibited the lowest sensitivity, with an index value of 0.38 (Table 11).

Table 11 Sensitivity of livelihood vulnerability index along with indexed major and sub-components

Individual components	AFA	BSG	GMB	ORO	SNP	SOM	Sub-components	AFA	BSG	GMB	ORO	SNP	SOM
DL	0.74	0.46	0.62	0.79	0.76	0.84							
CL	0.53	0.63	0.67	0.71	0.8	0.85	SC 1	0.66	0.51	0.63	0.72	0.79	0.83
LD	0.72	0.45	0.6	0.67	0.8	0.81							
AF	0.45	0.22	0.54	0.29	0.63	0.86	SC 2	0.43	0.19	0.44	0.31	0.66	0.76
SH	0.4	0.15	0.33	0.33	0.69	0.65							
Sensitivity Index								0.57	0.38	0.55	0.56	0.74	0.80

DL = The death of livestock encountered due to climate-induced hazards in the last five years, CL = The crop loss/damage encountered due to climate-induced hazards in the last five years, LD = The diseases that have affected livestock during climatic extremes (low rainfall, high rainfall and high temperature from the normal range), AF = The absence of food to eat in the household due to lack of money or other resources the past four weeks, SH = The market shocks, illness and death encountered by a household member/s associated with climate-induced shocks during the surveyed period.

4.5.3 Adaptive Capacity of PAP

Resilience involves both capital and capacity. Capital includes assets, skills, and services that households own, while capacity refers to households' ability to increase or decrease their capital during times of stress by using skills and connections to adapt positively. Capitals are considered more static elements, while capacity indicators are seen more dynamic (Serfilippi and Ramnath, 2018; Béné et al., 2012). Adaptive capacity is essential for achieving resilience and can be assessed alongside various livelihood outcomes (UNDP, 2013).

Instead of relying on coping strategies, implementing new, stable adaptation practices could enhance the resilience of rural livelihoods in drought-prone areas (Selvaraju et al., 2006). Therefore, having assets available and adjusting livelihood systems and management are vital for communities to adapt to the impacts of climate-related extreme events. Changes in a system and access to capacity assets (capital) to better reduce risks of exposure and sensitivity demonstrate adaptive

capacity (Béné et al., 2012). In the analysis of households' adaptive capacity in the surveyed regions, six sub-components were used. The components include adjusting crop production, adjusting livestock management, investment in asset building, pastoral mobility, coping practices, and access to livelihood capitals such as human, physical, natural, and financial capitals (Table 12).

As shown in Table 12, the former SNNPR region exhibited relatively higher adaptive capacity in terms of adjusting crop production, livestock management, investing in asset building, pastoral mobility, and access to capital, with indexed values of 0.53, 0.40, 0.43, 0.48, and 0.47, respectively. The Afar region also showed relatively high adaptive capacity across the abovementioned indicators, with indexed values of 0.30, 0.25, 0.25, 0.28, and 0.31, respectively. However, the Benishangul-Gumuz and Gambella regions exhibited lower capacity, with overall indexed values of 0.16 and 0.18, respectively. The Oromia region had the lowest adaptive capacity across four indicators, with indexed values of 0.06, 0.04, 0.06, 0.01, and 0.19, respectively.

4.5.4 Overall Vulnerability Scores

Table 13 shows that the vulnerability index indicated different levels of exposure for the surveyed regions. The Somali, Oromia, and Benishangul-Gumuz (BSG) regions scored 0.74, 0.67, and 0.63, respectively, indicating higher exposure to natural disasters, such as droughts and floods, over the last five years. These regions also face increasing risks of temperature rise and rainfall variability. SNNPR and Afar regions had moderate exposure levels (0.53 and 0.50), while the Gambella region had a lower exposure level (0.37).

In terms of sensitivity, the Somali and the former SNNPR regions were experiencing very high levels, with index values of 0.80 and 0.74, respectively. This was attributed to issues such as crop losses, livestock disease, food shortages, market shocks, and illness. The Afar, Oromia and Gambella regions had moderate sensitivity, with index values of 0.57, 0.56 and 0.55 respectively. The Benishangul-Gumuz region had lower sensitivity, with an index value of 0.38 (refer to Tables 11 and 13).

Table 12 Adaptive capacity livelihood vulnerability index along with indexed major and sub-components

Individual components	AFA	BSG	GMB	ORO	SNP	SOM	Sub-components	AFA	BSG	GMB	ORO	SNP	SOM
CD	0.31	0.25	0.26	0.05	0.53	0.04							
PR	0.33	0.09	0.25	0.05	0.58	0.03	Adjusting crop production	0.30	0.16	0.22	0.06	0.53	0.03
CV	0.28	0.19	0.22	0.06	0.51	0.03							
CC	0.29	0.11	0.13	0.06	0.48	0.02							
PF	0.26	0.04	0.18	0.05	0.49	0.16							
PS	0.38	0.04	0.16	0.05	0.48	0.03							
LN	0.26	0.24	0.09	0.05	0.37	0.04	Adjusting livestock management	0.25	0.08	0.13	0.04	0.40	0.07
DF	0.26	0.08	0.12	0.03	0.43	0.06							
DS	0.25	0.04	0.15	0.03	0.41	0.09							
HC	0.1	0.06	0.06	0.03	0.24	0.05							
PT	0.37	0.63	0.31	0.11	0.53	0.03							
FD	0.36	0.04	0.2	0.06	0.49	0.04	Investment in asset building						
LA	0.34	0.03	0.21	0.08	0.33	0.04							
HED	0.19	0.04	0.13	0.02	0.47	0.12		0.25	0.11	0.18	0.06	0.43	0.05
WHT	0.07	0	0.16	0.05	0.49	0.03							
CLC	0.28	0.06	0.09	0.05	0.29	0.03							
ENC	0.11	0	0.15	0.04	0.42	0.04							
IHM	0.18	0	0.12	0.01	0.48	0.14	Pastoral mobility	0.18	0	0.12	0.01	0.48	0.14
DOA	0.2	0	0.04	0.06	0.2	0.02	Coping practice	0.2	0	0.04	0.06	0.2	0.02
HCP	0.62	0.61	0.42	0.25	0.52	0.27	Livelihood capitals						
PCP	0.12	0.18	0.11	0.08	0.16	0.08		0.31	0.42	0.26	0.19	0.47	0.16
NCP	0.45	0.53	0.37	0.33	0.69	0.20							
FCP	0.05	0.35	0.14	0.11	0.52	0.08							
Adaptive capacity Index								**0.26**	**0.16**	**0.18**	**0.07**	**0.44**	**0.07**

CD = Crop diversification (growing different varieties of food and cash crops, PR = Planting drought resistant crop varieties along with high yield crops, CV = Using improved crop and livestock varieties, CC = Changing cropping calendar/changing planting and harvesting dates, PF = Purchase and provide supplementary feed (fodder, crop-residues concentrate), PS = Preserving/managing pasture and storing animal feed, LN = Shift from livestock to non-farm activities, DF = Diversifying, changing or supplementing livestock feed, DS = Diversify livestock species/types, HC = Change herd composition/shifting to camel/small ruminants/poultry/beekeeping, PT = Planting trees, FD = Fodder crops diversification and development /planting drought tolerant fodder trees, LA = Diversify livelihood activities (labour, charcoal/firewood selling, petty), HED = Herd destocking, WHT = Employing water harvesting technologies, CLC = Shift from livestock to crop production, ENC = Enclosure/controlled grazing/rotational grazing, IHM = Increased herd mobility/migration, DOA = Depending on aid (government/NGOs) remittance, HCP = Human capital, PCP = Physical capital, NCP = Natural capital, FCP = Financial capital.

In terms of adaptive capacity, the former SNNPR exhibited a relatively high capacity compared to other regions, with an indexed value of 0.44. This was followed by the Afar region with an indexed value of 0.26. These higher capacities were attributed to adaptive strategies such as crop diversification, planting drought-resilient and improved crops, as well as feed and fodder diversification, engaging in non-farm activities, species diversification, and planting trees. Additionally, these regions had better access to livelihood capitals, including natural and human capitals. For more details, refer to tables 12 and 13, Tables A5-A7, and Table A9 in the Appendix I.

The Gambella and Benishangul-Gumuz regions have low adaptive capacity, with indexed values of 0.18 and 0.16, respectively. This is primarily due to a low level of livestock and crop management, limited livelihood diversification and low access to physical and financial capitals (See Tables 12 and 13; Tables A5-A7, and A9 in the Appendix I).

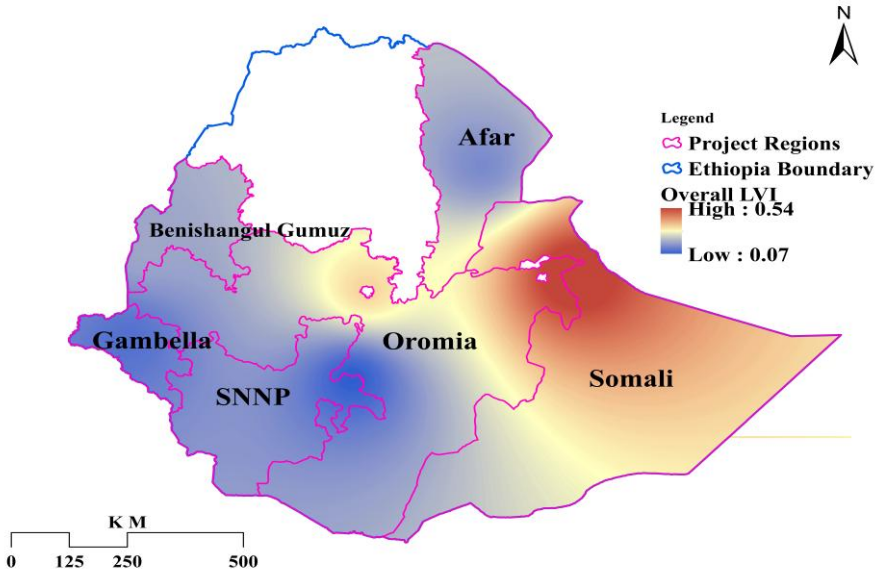
The Somali and Oromia regions had the lowest adaptive capacity, with an indexed value of 0.07. This is attributed to the lack of crop diversification, absence of drought-tolerant crops, limited non-farm activities and low access to livelihood capitals such as physical, financial, and human capitals (See Tables 12 and 13; Tables A5-A7, A9 in the Appendix I). As a result, surveyed households from these regions are the most vulnerable to climate-induced shocks and their impacts.

Generally, the surveyed communities have shown low adaptive capacity in terms of six sub-component indicators, with the highest indexed value being 0.44 for the former SNPPR and the lowest value being 0.07 for the Somali region (See Table 12 and Figure 3). This indicates that households in both regions have a low level of adaptive capacity to the consequences and impacts of climate variability and extreme events.

Table 13 Indexed major components and the overall LVI.

Sub-component	AFA	BSG	GMB	ORO	SNP	SOM	Major components	AFA	BSG	GMB	ORO	SNP	SOM
Temp.	0.54	0.68	0.35	0.62	0.52	0.69	Exposure	0.50	0.63	0.37	0.67	0.53	0.74
Rainfall	0.48	0.60	0.39	0.67	0.52	0.75							
CLE	0.47	0.43	0.42	0.58	0.47	0.75							
SC 1	0.66	0.51	0.63	0.72	0.79	0.83	Sensitivity	0.57	0.38	0.55	0.56	0.74	0.80
SC 2	0.43	0.19	0.44	0.31	0.66	0.76							
ACP	0.30	0.16	0.22	0.06	0.53	0.03	Adaptive capacity	0.26	0.16	0.18	0.07	0.44	0.07
ALM	0.25	0.08	0.13	0.04	0.40	0.07							
IAB	0.25	0.11	0.18	0.06	0.43	0.05							
PSM	0.18	0	0.12	0.01	0.48	0.14							
CRP	0.2	0	0.04	0.06	0.2	0.02							
LVC	0.31	0.4175	0.26	0.19	0.47	0.16							
Overall LVI [LVI = Sensitivity × (Exposure – Adaptive capacity)]								**0.14**	**0.18**	**0.10**	**0.33**	**0.07**	**0.54**

CLE = climate extremes, ACP = Adjusting crop production, ALM = Adjusting livestock management, IAB = Investment in asset building, PSM = Pastoral mobility, CRP = Coping practice to get more food, LVC = Livelihood capitals, LVI = Livelihood vulnerability index.



Source: The map is prepared based on the index values calculated from household survey data.
Figure 3: Overall LVI Map

4.6 Discussions

This article presents empirical findings on climate vulnerability in pastoral and agro-pastoral systems by moving beyond simple assessments of exposure and sensitivity to a more structurally grounded understanding of adaptive capacity as the key factor for livelihood resilience. The regions studied showed high exposure to rising temperatures, rainfall variability, recurring droughts, and episodic flooding. The findings indicate that vulnerability outcomes are primarily influenced by institutional, economic, and capital constraints. This expands the practical application of the IPCC vulnerability framework (IPCC, 2007; 2022) by empirically showing that adaptive capacity is not just a moderating factor but the main leverage point for resilience transformation.

The results contribute theoretically to socio-ecological systems theory (Turner et al., 2003) by empirically validating the interconnectedness of pastoral livelihoods and ecological variability. In these systems,

climate shocks immediately lead to rangeland degradation, livestock deaths, and food insecurity because productive capital is linked to natural capital. However, the study advances this framework by showing that ecological coupling alone does not determine vulnerability levels. Instead, institutional coupling, access to markets, veterinary services, infrastructure, finance, and governance quality determine whether exposure results in a crisis or remains a manageable risk.

The findings enhance resilience scholarship (Béné et al., 2012) by empirically distinguishing between absorptive, adaptive, and transformative capacities. Pastoral and agro-pastoral households are actively using absorptive and adaptive strategies such as adjusting crop production, herd mobility, and diversifying livelihoods. These actions demonstrate agency and local innovation. However, transformative capacity which involves fundamental changes in governance structures, market integration, land tenure security, and capital accumulation, remains significantly limited in highly vulnerable regions like Somalia and Oromia. This structural limitation creates a resilience ceiling, where local adaptation takes place but systemic vulnerability remains.

This article improves understanding of vulnerability and adaptation strategies. Empirical evidence shows that repeatedly using erosive coping strategies, such as distress livestock sales, reliance on aid, and asset liquidation decreases future adaptive capacity, thus reinforcing a dynamic vulnerability trap. This is in line with entitlement theory (Adger & Kelly, 1999), which demonstrates that vulnerability arises not just from hazard severity but also from restricted access to economic and institutional entitlements during stressful periods. Additionally, it emphasizes that spatial differentiation is a governance issue, not just a climatic one.

Administrative regions with similar levels of exposure exhibit significantly different vulnerability outcomes due to disparities in access to human, financial, physical, and natural capital. This highlights the importance of integrated vulnerability approaches (Füssel & Klein, 2006) that focus on the interaction between biophysical risk and socio-economic structure. Additionally, the article promotes the idea of structural adaptation deficits in pastoral systems, where local

households innovate within constraints, but macro-level systems (markets, infrastructure, and policy design) fail to keep pace with increasing climate risks.

This article contributes to vulnerability scholarship by demonstrating that adaptive capacity is just one aspect of vulnerability, but a crucial factor for fostering resilience in climate-sensitive pastoral and agro-pastoral systems. To achieve sustainable resilience, it is essential to implement coordinated actions such as governance reform, infrastructure investment, financial inclusion, and institutional strengthening. These efforts will ensure that local adaptive innovations are complemented by systemic changes.

5. Conclusions and Recommendations

5.1 Conclusions

Pastoral and agro-pastoral households have observed warming trends in temperature, unpredictable rainfall patterns, and an increase in the frequency and severity of climate-induced hazards and shocks. The onset and cessation of rainfall, as well as the timing and intensity of rainfall, have become unpredictable. Climate-induced hazards and shocks are occurring more frequently and are becoming more severe, posing significant threats to crop and livestock production. The perceptions of pastoralists and agro-pastoralists align with the climate trends observed in arid and semi-arid pastoral areas. These regions have a growing population and rely heavily on rain-fed crop and livestock production, both of which are greatly impacted by climate variability and extreme weather events.

It has been observed that changing rainfall patterns affect annual cropping decisions and the mobility of pastoral herds to access pasture and browse trees that are patchy in response to rainfall availability. Therefore, it can be concluded that climate-induced hazards and shocks will continue to be major constraints on the livelihoods of pastoral communities. This indicates that, besides coping strategies, there is a need to develop and implement new and stable adaptation practices to enhance the resilience of rural livelihoods in pastoral areas.

Implementing appropriate adaptation measures would help lessen the adverse impacts of climate change-induced hazards and shocks.

Pastoral and agro-pastoral households have already started practicing adaptation strategies, such as investing in asset building and climate insurance, adjusting their livestock management, and crop production practices. These efforts are essential for chancing livelihood resilience. Therefore, it can be affirmed that the adaptation strategies employed by PAPs incorporates aspects of absorptive and adaptive capacity measures, reflecting proactive actions and adjustments within existing livelihood systems to reduce the potential impacts of climate-induced hazards and shocks.

The adaptation strategies, used by pastoral and agro-pastoral households demonstrate significant changes in response to climate change, which poses risks to their livelihoods. During a crisis, these households usually rely on short-term measures to increase income and food supply to handle seasonal shortages. The observed shifts in livelihood pathways with long-term effects indicate a change in approach that can be viewed as innovative strategies. These strategies could be leveraged by external interventions and programs intended for pastoral areas.

5.2 Recommendations

Resilience needs shift from reactive hazard response to strengthening structural capacity. As current programs primarily focus on increasing absorptive capacity but overlook gaps in adaptive and transformative capacities. Key actions should include investing in climate-smart infrastructure, expanding financial inclusion, improving mobile pastoral veterinary and extension services, enhancing market integration, and reforming land governance to safeguard mobility corridors. Interventions should prioritize systemic capacity-building over simple asset replacement by evaluating absorptive, adaptive, and transformative capacities separately and promoting diversified, value-added livelihoods. To break the cycle of repeated asset erosion, it is crucial to coordinate efforts that strengthen adaptive and transformative capacities in response to the rapid and structural impacts of climate change. Specifically, it is important to advocate for the following targeted actions:

i. Climate-induced hazards and resulting shocks will pose significant challenges to the livelihood activities of PAPs. Therefore, future development policies, interventions, and programs should integrate these shocks into their planning.
ii. The adaptive strategies employed by PAPs to enhance their current livelihood activities are proactive measures aimed at reducing the effects of climate-related hazards and resulting shocks. Future development policies, interventions, and programs focused on building resilience should support PAPs' efforts.
iii. External interventions and programs aimed at building resilience should emphasize the local absorptive, adaptive, and transformative capacities practiced by pastoral communities. The external resilience-building efforts and the adaptive/absorptive actions of pastoral communities should collaborate to ensure synergy between government and community initiatives.

REFERENCES

Abraham Sewonet (2002). Breaking the cycle of conflict in Gambella region: Assessment report, Ethiopia. United Nations Emergencies Unit for Ethiopia (UN-EUE).

Adger W.N and Kelly P.M. 1999. Social Vulnerability to Climate Change and the Architecture of Entitlement. *Mitigation and Adaptation Strategies for Global Chang*, 4: 253–266.

Adger W.N., Huq S., Brown K., Conwaya D., and Hulmea, M. (2003). Adaptation to climate change in the developing world, in Progress in Development Studies 3,3, pp. 179–195.

Amusa, T. A1, Esheya, S. E2, Efedua, J. C. (2022). Adaptive Capacity of Farmers to Climate-Induced Shocks under Fadama III Additional Financing In Kaduna State, Nigeria. Journal of Community & Communication Research, Vol. 7 No. 2, December 2022

Araos M., et al., (2021). Tracking global adaptation to climate change. *Nature Climate Change*, 11, 989–997. https://doi.org/10.1038/s41558-021-01178-7.

Asmare Shetahun Alemneh. (2024). Conflict Transformation in South Omo Zone Pastoralist and Agro-Pastoralist Community of

Ethiopia. *Pastures & Pastoralism, 02, 20-33.* Doi: https://doi.org/10.33002/pp0202

Ayele, T., Dedecha, D., & Duba, D. (2020). The impact of climate change on pastoralist livelihoods in Ethiopia: A review. *Journal of Resources Development and Management*, *63*(2020), 63-02.

Badar Alam Iqbal and Farha Naaz Ghauri (2011). Climate Change: The Biggest Challenge in 21st Century. Mediterranean Journal of Social Sciences Special Issue Vol. 2, No. 6.

Behnke, R., Devereux, S., White, R., Wekesa, M., & Teshome, A. (2007). The Productive Safety Net Programme in Pastoral Areas: Pilot Design. *Addis Ababa*.

Béné, C., Wood, R. G., Newsham, A., & Davies, M. (2012). Resilience: new utopia or new tyranny? Reflection about the potentials and limits of the concept of resilience in relation to vulnerability reduction programmes. *IDS Working Papers*, *2012*(405), 1-61.

Bruno Soares, M., S. Gagnon, A., & M. Doherty, R. (2012). Conceptual elements of climate change vulnerability assessments: a review. *International Journal of Climate Change Strategies and Management*, *4*(1), 6-35.

Chayot Gatdet (2023). The pastoralism system in South-Western Ethiopia: The practices, constraints, and determinants in Itang Special district, Gambella Region. *Cogent Food & Agriculture*.

Cochran, W. G. (1977). *Sampling techniques* (3rd eds.). John Wiley & Sons.

College of Development Studies (CDS). 2023. Socio-economic and Food Security Situation of Pastoral and Agro-Pastoral Regions of Ethiopia. Final Report Submitted to the Lowlands Livelihood Resilience Project (LLRP), Ministry of Peace.

Constas, M. A., d'Errico, M., & Pietrelli, R. (2022). Toward Core Indicators for Resilience Analysis: A framework to promote harmonized metrics and empirical coherence. *Global Food Security*, *35*, 100655.

David Ondijo (2009). Pastoralists Dropout Study in Jijiga, Shinile and Fik Zones of Somali Region, Ethiopia. Report submitted to Region Revitalizing Agricultural/Pastoral Incomes and New Market Program, Save the Children, UK.

Degfie Teku and Sintayehu Eshetu (2024). Impact of climatic variability and extreme incidences on the physical environment,

public health, and people's livelihoods in Ethiopia. *Frontiers in Climate, p.1435138.*

Denbel Bedo *et al.,* 2014. Vulnerability of Household Livelihoods to Climate Variability and Change in the Central Rift Valley Sub-Basin of Ethiopia. *Heliyon, Vol. 10.*

Deressa, T., Hassan, R. M., & Ringler, C. (2008). *Measuring Ethiopian farmers' vulnerability to climate change across regional states*. International Food Policy Research Institute (IFPRI), *IFPRI discussion papers 806,*

Devereux S. 2006 Vulnerable Livelihoods in Somali Region, Ethiopia. *IDS Research Report*, Issue 57.

Esmale Tessemal (2019). A Comparative Study of Resilience of Pastoral and Agro-pastoral Households to Climate Change-Induced Shocks and Stresses in Asayita Woreda of Afar Regional State, Ethiopia. MA Thesis, Addis Ababa University.

FAO (2020). Core Indicators for Resilience Analysis: Toward an Integrated Framework to Support Harmonized Metrics.

Fareh Abdulkadir Mohammed (2011). Opportunities and Challenges in Implementing Poverty Reduction Policies in Pastoral Communities: A Case Study from the Somali Regional State, Ethiopia. MA Thesis Submitted to Ritsumeikan Asia Pacific University.

Faulkner, J. P., Murphy, E., & Scott, M. (2020). Developing a holistic 'vulnerability-resilience'model for local and regional development. *European Planning Studies*, *28*(12), 2330-2347.

Füssel, H. M., & Klein, R. J. (2006). Climate change vulnerability assessments: an evolution of conceptual thinking. *Climatic change*, *75*(3), 301-329.

Gallopin G.C. (2006). Linkages between vulnerability, resilience, and adaptive capacity. Global Environmental Change, 16, 293-303.

Getu, M., & Mulinge, M. M. (Eds.). (2013). *Impacts of climate change and variability on pastoralist women in Sub-saharan Africa*. African Books Collective.

Girma Asefa and Zelalem Bekeko (2022). Drought vulnerability and impacts of climate change on livestock production and productivity in different agro-ecological zones of Ethiopia. *Journal of Applied Animal Research.* VOL. 50, NO. 1, 471–489.

Hahn, M. B., Riederer, A. M., & Foster, S. O. (2009). The Livelihood Vulnerability Index: A pragmatic approach to assessing risks from climate variability and change: A case study in Mozambique. *Global environmental change*, *19*(1), 74-88.

IPCC (2007). Climate Change 2007: Synthesis Report. Contribution of Working Groups I, II and III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change IPCC, Geneva, Switzerland, 104 pp.

IPCC (2022). *Climate Change: Impacts, Adaptation and Vulnerability. Contribution of Working Group II to the Sixth Assessment Report of the Intergovernmental Panel on Climate Change.* Cambridge University Press. https://doi.org/10.1017/9781009325844

Kevin E Trenberth (2005). The Impact of Climate Change and Variability on Heavy Precipitation, Floods, and Droughts. Encyclopedia of Hydrological Sciences. Edited by M G Anderson. National Center for Atmospheric Research, Boulder, CO, USA.

Lautze, S., Aklilu, Y., Raven-Roberts, A., Young, H., Kebede, G., & Leaning, J. (2003). Risk and vulnerability in Ethiopia: Learning from the past, responding to the present, preparing for the future. *Report for the US Agency for International Development. Addis Ababa, Ethiopia*.

Lemma, Y., Beyene, F., & Hundie, B. (2013). Climate change and variability: implications for household food security in agro-pastoral areas of Jigjiga District, Eastern Ethiopia. *Ethiopian Journal of Economics*, *22*(1), 71-106.

Lokuthula Msimanga and Geoffrey Mukwada (2022). Themes in climate change and variability within the context of rural livelihoods. A systematic literature review. Research in Globalization 5 (2022).

Magnan, A. K., et al. (2022). Loss and damage associated with impacts of climate change: A conceptual framework. *Annual Review of Environment and Resources*, 47, 241–267. https://doi.org/10.1146/annurev-environ-112320-095457

Manyena, B.S. (2006). The Concept of Resilience Revisited, in *Disaster, 30 (4) 433-450.* Overseas Development Institute ODI.

Mekete Girma (2023). Production system of indigenous goat population reared in pastoral and agro-pastoral districts of SNNPR, Ethiopia. *Int. J. Agril. Res. Innov. Tech. 13(1): 51-59.* https://doi.org/10.3329/ijarit.v13i1.68007

Melka, Y., Fenta, M., & Jordaan, A. (2019). Vulnerability of Southern Afar pastoralists to climate variability and change, Ethiopia. *Jàmbá: Journal of Disaster Risk Studies*, *11*(1), 1-8.

Mengistu Asmamaw, Seid Tiku and Argaw Ambelu (2019). Exploring households' resilience to climate change-induced shocks using Climate Resilience Index in Dinki watershed, central highlands of Ethiopia. *PloS one*, *14*(7), e0219393.

Meskerem, A. et al., (2023). Best Practices on Adoption of New Technologies and Systems for Resilience Building in Ethiopia. EU RESET Plus, *Cordaid,* Fair & Sustainable Ethiopia and Addis Ababa University.

Miller, F., Osbahr, H., Boyd, E., Thomalla, F., Bharwani, S., Ziervogel, G., ... & Nelson, D. (2010). Resilience and vulnerability: complementary or conflicting concepts? *Ecology and Society*, *15*(3).

Ministry of Peace (2019). *Environmental and Social Management Framework (ESMF),* Lowland Livelihood Resilience Project (LLRP), Federal Democratic Republic of Ethiopia (FDRE), Final Report, Addis Ababa, Ethiopia.

MoFPDA (2018). A Summary of Context Analysis of Pastoral and Agro-Pastoral Areas to Enrich and Update Draft Policy and Strategy Framework. Report prepared by SEGEL Research and Training Consulting PLC for Ministry of Federal and Pastoral Development Affairs, Addis Ababa, Ethiopia.

Mohamed, A. A. (2019). Pastoralism and development policy in Ethiopia: a review study. *Budapest International Research and Critics Institute (BIRCI-Journal): Humanities and Social Sciences*, *2*(4), 01-11.

Newell, B., Crumley, C. L., Hassan, N., Lambin, E. F., Pahl-Wostl, C., Underdal, A., & Wasson, R. (2005). A conceptual template for integrative human–environment research. *Global Environmental Change*, *15*(4), 299-307.

Pavanello, S. (2009). Pastoralists' vulnerability in the Horn of Africa: Exploring political marginalisation, donors' policies and cross-border issues–Literature review. *Humanitarian Policy Group (HPG) Overseas Development Institute London, UK*.

Ranasinghe, R., et al. (2021). Climate change information for regional impact and for risk assessment. In *IPCC AR6 Working Group I*. Cambridge University Press. https://doi.org/10.1017/9781009157896.015

Samuel Befekadu Getu (2020). The Disaster Profile of Ethiopia. University of Oviedo-Department of Medicine Unit for Research in Emergency and Disaster

Selvaraju, R., Subbiah, A. R., Baas, S., & Juergens, I. (2006). Livelihood adaptation to climate variability and change in drought-prone areas of Bangladesh: Developing institutions and options.

Serfilippi, E., & Ramnath, G. (2018). Resilience measurement and conceptual frameworks: a review of the literature. *Annals of Public and Cooperative Economics*, *89*(4), 645-664.

Shetie Gatew and Nura Guyo (2024). Livelihood vulnerability of Borana pastoralists to climate change and variability in Southern Ethiopia, *International Journal of Climate Change Strategies and Management Vol. 16 No. 1, 2024 pp. 157-176*, Emerald Publishing Limited. https://www.emerald.com/insight/1756-8692.htm.

Singh, C., et al. (2021). Interrogating 'coping' and 'adaptation' in climate change research. *Climate and Development*, 13(7), 585–595. https://doi.org/10.1080/17565529.2020.1763447.

Tatek Belay and Tadele Melese (2024). Livelihood vulnerability of rural households to climate variability and change: An agroecological system-based approach in northwestern Ethiopia. Heliyon (10) 2024.

Thomalla, F., Downing, T., Spanger-Siegfried, E., Han, G., & Rockström, J. (2006). Reducing hazard vulnerability: towards a common approach between disaster risk reduction and climate adaptation. *Disasters*, *30*(1), 39-48.

Tigist Abrham and Muluken Mekuyie (2022). 'Effects of climate change on pastoral households in the Harshin District of the Somali Region, Ethiopia', Jàmbá: *Journal of Disaster Risk Studies 14(1),* a1202. https://doi.org/10.4102/jamba.v14i1.1202.

Tofu, D. A., Fana, C., Dilbato, T., Dirbaba, N. B., & Tesso, G. (2023). Pastoralists' and agro-pastoralists' livelihood resilience to climate change-induced risks in the Borana zone, south Ethiopia: Using resilience index measurement approach. *Pastoralism*, *13*(1), 1-14.

Tschakert, P., et al. (2023). Climate risk and vulnerability assessment frameworks: Reconciling social and biophysical perspectives. *WIREs Climate Change*, 14(2), e814. https://doi.org/10.1002/wcc.814

Turner, B. L., Kasperson, R. E., Matson, P. A., McCarthy, J. J., Corell, R. W., Christensen, L., ... & Schiller, A. (2003). A framework for vulnerability analysis in sustainability science. *Proceedings of the national academy of sciences*, *100*(14), 8074-8079.

United Nations Development Program (UNDP) (2010). Pastoralism in Ethiopia: its total economic values and development challenge. A knowledge management study implemented by SOS- Sahel Ethiopia.

United Nations Development Program (UNDP) (2013). Community Based Resilience Assessment Capacity Framework and Methodology. Disaster Risk Reduction Action Plan. UNDP Drylands Development Center.

United Nations International Strategy for Disaster Risk Reduction (UNISDR) (2005). Hyogo Framework for 2005-2015: Building Resilience of Nations and Communities to Disasters.

Vollenweider X. (2015). Measuring Climate Resilience and Vulnerability: A case study from Ethiopia. Famine Early Warning Systems Network Technical Support Contract (FEWS NET), USAID.

Wondwosen Michago (2017). The Nuer Pastoralists – Between Large Scale Agriculture and Villagization: A case study of the Lare District in the Gambella Region of Ethiopia. Current African Issues (CAI) No. 64. The Nordic Africa Institute UPPSALA.

Workneh Negatu. *et al.,* 2011. A Comparative Analysis of Vulnerability of Pastoralists and Agro-pastoralists to Climate Change: A Case Study in Yabello Woreda of Oromia Region, Ethiopia. *Ethiopian Journal of Development Research* Vol. 33. No.1.

World Bank (2005). Risk and Vulnerability Assessment. Document of the World Bank, Report No. 26275-ET.

World Bank and DFID (2019). Vulnerability and Resilience in the Ethiopian Lowlands of Ethiopia: Building a More Developmental Approach to Responding to Shocks: Challenges and Future Prospects.

World Bank and IFAD (2018). Pastoral Development in Ethiopia: Trends and the Way Forward. Assessment of Four Decades of Pastoral Development.

Yalemtsehay Debebe and Mekuria Argaw (2022). Climate Change Vulnerability Analysis Methods for Human and Natural Systems: A Review. Research on Humanities and Social Sciences, www.iiste.org ISSN 2224-5766 (Paper) ISSN 2225-0484 (Online) Vol.12, No.21.

Zarafshani, K., Sharafi, L., Azadi, H., & Van Passel, S. (2016). Vulnerability assessment models to drought: toward a conceptual framework. *Sustainability*, *8*(6), 588.

Appendix I: Descriptive statistics of the components and sub-components

Table A1 Indicators of temperature (%)

Region	Hot days increased	Warm nights increased	Coldness increased
Afar	93	29	40
Benishangul	100	95	9
Gambella	40	36	29
Oromia	79	82	24
SNNPR (the former)	79	63	15
Somali	94	65	47

Table A2 Indicators of rainfall (%)

Region	Onset of RF	Cessation of RF	Rainy days decreased	Untimely RF
Afar	53	37	20	89
Benishangul	61	62	60	90
Gambella	29	31	36	45
Oromia	80	77	64	80
SNNPR (the former)	61	57	39	69
Somali	88	89	45	90

Table A3 Indicators of extreme climate events (%)

Region	Drought	Flooding
Afar	33	60
Benishangul	71	15
Gambella	42	42
Oromia	80	36
SNNPR (the former)	72	22
Somali	93	56

Table A4 Indicators of sensitivity (%)

Region	Livestock death	Crop loss	Livestock disease	Food shortage	Shocks & deaths
Afar	74	53	72	45	40
Benishangul	46	63	45	22	15
Gambella	62	67	60	54	33
Oromia	79	71	67	29	33
SNNPR (the former)	76	80	80	63	69
Somali	84	85	81	86	65

Table A5 Indicators of adjusting crop production (%)

Region	Crop diversification	Drought resistant crop	Improved crop	Cropping calendar
Afar	31	33	28	29
Benishangul	25	9	19	11
Gambella	26	25	22	13
Oromia	5	5	6	6
SNNPR (the former)	53	58	51	48
Somali	4	3	3	2

Table A6 Indicators of adjusting livestock management (%)

Region	Supplementary Feed	Manage pasture	Livestock to non-farm	Feed diversification	Livestock species diversification	Herd composition
Afar	26	38	26	26	25	10
Benishangul	4	4	24	8	4	6
Gambella	18	16	9	12	15	6
Oromia	5	5	5	3	3	3
SNNPR (the former)	49	48	37	43	41	24
Somali	16	3	4	6	9	5

Table A7 Indicators of investment in asset building (%)

Region	Planting trees	Fodder diversification	Livelihood activities	Destocking herd	WHTs	Livestock to crop	Enclosure
Afar	37	36	34	19	7	28	11
Benishangul	63	4	3	4	0	6	0
Gambella	31	20	21	13	16	9	15
Oromia	11	6	8	2	5	5	4
SNNPR (the former)	53	49	33	47	49	29	42
Somali	3	4	4	12	3	3	4

Table A8 Indicators of pastoral mobility and copping practice (%)

Region	Herd mobility	Depending on aid
Afar	18	20
Benishangul	0	0
Gambella	12	4
Oromia	1	6
SNNPR (the former)	48	20
Somali	14	2

Table A9 Indicators of livelihood capital (%)

Region	Human capital	Physical capital	Natural capital	Financial capital
Afar	62	12	45	5
Benishangul	61	18	53	35
Gambella	42	11	37	14
Oromia	25	8	33	11
SNNPR (the former)	52	16	69	52
Somali	27	8	20	8

Acknowledgments

The authors of this article conducted a survey and prepared a report on the "Socio-economic and Food Security Situation of Pastoral and Agro-Pastoral Regions of Ethiopia" which was submitted to the Lowlands Livelihood Resilience Project, under the Ministry of Peace in 2023. Therefore, the authors would like to acknowledge the Ministry of Peace (Ethiopian Federal Democratic Republic), the World Bank (Ethiopian Office) and the College of Development Studies (Addis Ababa University) for funding the survey. The data used in this article were collected during the survey.