Livelihood vulnerability of Borana pastoralists to climate change and variability in Southern Ethiopia

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Abstract

Purpose – The purpose of this study results and recommendations will have a paramount significance for policymakers, policy advocates, development planners and practitioners who may be in need of such information for reconsideration, evaluation and inclusion into their respective development and humanitarian programming and operational strategies. Above all, the study result has further provided the local community with viable adaptation strategies to climate-induced changes in the study area.

Design/methodology/approach – This study was conducted to measure the livelihood vulnerability of Borana pastoralists to climate change and variability in southern Ethiopia. Pastoralists' households were sampled using multistage sampling techniques. A total of 27 socio-economic and biophysical indicators were used to reflect vulnerability components: adaptive capacity, exposure and sensitivity. Principal component analysis was used to develop weights for indicators and to produce livelihood vulnerability index to classify households according to their level of vulnerability. Ordinal logistic regression was used to identify the determinants of vulnerability to climate-induced stresses.

Findings – The results showed that 24.4% of households were highly vulnerable, 60.3% were moderately vulnerable and 15.3% of households were less vulnerable to climate-induced stresses. Factor estimates of the logistic model further revealed that early warning information, bush encroachment, coping strategy, temperature, drought frequency, provision of humanitarian services and food shortage during the normal season of the year have a significant influence on vulnerability in the study area.

Social implications – The study's results and recommendations will be of great significance to policymakers, development planners, and practitioners who require such information for reconsideration, evaluation, and inclusion in their respective development and humanitarian program and operational strategies. Most importantly, the study's findings have provided the local community with practical adaptation strategies to climate-induced changes in the study area.

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Originality/value – The study explored pastoralist perception of climate change and variability and measured the livelihood vulnerability of pastoralists' households to climate change and variability and finally investigated viable adaptation and coping strategies in the study area.

Keywords Borana pastoralist, Climate variability, Drought, Livelihood vulnerability, Vulnerability index

Paper type Research paper

1. Introduction

Climate change is a major challenge for natural ecosystems and human societies (IPCC, 2014). The climate of Africa is warmer than it was 100 years ago, and model-based predictions of future climate change for the continent suggest that this warming will continue and, in most scenarios, accelerate (Hulme *et al.*, 2001). The report by Intergovernmental Authority on Development (IGAD), Climate Prediction and Applications Centre (ICPAC) in 2007 showed that extreme climate events such as floods and droughts are devastating most economic, social and environmental systems in Africa.

The Greater Horn of Africa (GHA) is home to a significant number of pastoralists whose livelihood system is based on livestock production in the arid and semi-arid lands (ASALs). The Borana lowlands of southern Ethiopia are among the most climate-vulnerable regions in the country (Bekele and Kebede, 2014). The main livelihood of the Borana pastoralists, livestock rearing, is severely affected by climate change and variability (Hurst *et al.*, 2012 Amsalu *et al.*,2013; Iticha and Husen, 2018). These climatic factors, along with other stressors such as land degradation, resource conflicts, poor infrastructure and marginalization, have reduced the resilience and coping capacity of the pastoralist communities (Iticha and Husen, 2018). The Borana lowlands are typical of the arid and semi-arid areas in the Horn of Africa, where rainfall is low and erratic, temperatures and evaporation rates are high (USAID, 2016). These areas have experienced increasing frequency and intensity of droughts and floods, leading to food insecurity, human and animal diseases and other crises (Oxfam, 2010).

Vulnerability is a complex and multidimensional concept that depends on the context and discipline (Opiyo *et al.*, 2014; UNEP, 2002). It has different aspects, such as exposure to hazards (Deressa, 2010), socio-economic status and access to resources (Amwata, 2013) or coping and recovery ability (Cutter, 1996). It also varies with the ecological situation and the emergency preparedness of the community. Cutter (1995) defined vulnerability as "the potential for loss" from the interaction of hazards and social profiles. Bohle (2001) described it as a measure of human welfare that includes environmental, social, economic and political factors. This study used an integrated method to assess the vulnerability of Borana pastoralists to climate change, following the IPCC (2012) definition of vulnerability as a function of exposure, sensitivity and adaptive capacity to climate change. This approach differs from some previous studies that focused on either exposure (Deressa, 2010) or socio-economic status and access to resources (Amwata, 2013).

Poor communities are more vulnerable to climate change, as they have limited resources, housing, infrastructure, insurance, technology and information to cope (IPCC, 2013). Vulnerability is defined differently by various studies, depending on the focus and context. Some studies see vulnerability as the lack of adaptive capacity in social and natural systems. Others measure vulnerability as a mix of adaptive capacity, sensitivity and exposure to hazard (Adger, 1999; Brooks *et al.*, 2005; Opiyo *et al.*, 2014). Adaptive capacity is the ability to adjust to or withstand the changing context; it is the ability to implement adaptation measures that reduce the impacts of climate change (Ongoro and Ogara, 2012).

Sensitivity is the degree to which a system is affected by climate change and its extremes; it describes the conditions that trigger or mitigate an impact (IPCC, 2013). Exposure is the nature and change in climate variables and extreme events; it is the physical impact of climate change such as a change in rainfall or temperature (Ongoro and Ogara, 2012; IPCC, 2013).

Indicators are proxies to characterize and assess vulnerability, which cannot be directly observed or measured (Carter and Makinen, 2011). The indicator method selects and combines some indicators from the whole set to indicate the levels of vulnerability. Vulnerability is usually a function of three indicators (Carter and Makinen, 2011): exposure to climate change (E), sensitivity to its effects (S) and adaptive capacity for coping with the effects (AC). These indicators are interrelated and influence each other. For example, high exposure may increase sensitivity, while low adaptive capacity may worsen vulnerability (Fortini and Schubert, 2017). It is important to assess vulnerability holistically and consider the interactions among the indicators. The indicator selection process often involves a combination of methods including literature review, survey, and expert and stakeholder consultations (Sharma *et al.*, 2016).

The ability of communities to cope with climate change depends on various demographic, socio-economic and institutional factors (Carter and Makinen, 2011). Several studies have identified different characteristics that influence the adaptation measures by communities, such as age, gender, household size, income, assets, education, extension services, credit and savings, facilities, climate change perceptions, social capital, membership of farmer-based organizations, land ownership, agro-ecological environments and natural resource conditions (Ndamani and Watanabe, 2016; Ayal and Leal Filho, 2017; Gebru *et al.*, 2020).

Pastoralist households' vulnerability and adaptation to climate change depend on demographic (Awiti, 2022), socio-economic and institutional factors. Demographic factors (household size, gender, age) affect labor, food security, resource access, decision-making and knowledge. Older pastoralists have more traditional knowledge but less exposure to new information (Mwadzingeni *et al.*, 2022). Socio-economic factors (income, assets, credit, livelihood diversification) affect farm technology adoption (Zamasiya *et al.*, 2017), adaptation investment (Atube *et al.*, 2021), livestock reliance and adaptation methods (Deressa *et al.*, 2009). Institutional factors (extension services, information, awareness, participation) affect climate information availability and timeliness (Deressa *et al.*, 2009; Belay *et al.*, 2017), adaptation decision-making (Maddison, 2007), social capital and collective action (Ayal and Leal Filho, 2017).

Africa needs an integrated assessment approach for vulnerability studies at a micro-scale to account for local contexts (IPCC, 2013). Pastoral households need to understand their vulnerability to climate change at a specific geographic level to tackle climate change challenges effectively (Klein, 2008). However, most of the literature and discourses on vulnerability focused on theoretical insights or analysis at a regional or national scale, with implications for system-wide planning (Fussel and Klein, 2006; Hinkel, 2011). Moreover, there is a lack of scientific information and in-depth analysis on household vulnerability and adaptation strategies to climate variability in the ASALs of East African countries (Bryan *et al.*, 2013). Therefore, this study analyzes the vulnerability of Borana pastoralist communities at the household level. The household-level analysis captures the local context and specific characteristics of the pastoralist communities that influence their vulnerability to climate change and variability. Unlike the earlier studies that used either predefined indicators, (Brooks *et al.*, 2005) or expert judgment (Adger, 1999) to assess vulnerability, this study used a combination of indicators to measure vulnerability by computing indices and the weighted average for the selected indicators. The indicators were selected based on

researchers' observations, literature review and the opinions of the Borana pastoralist community in the Yabello district. This is important for design of effective adaptation strategies to reduce the risks associated with climate variability and change in the study area.

This paper analyzes and evaluates the vulnerability of Borana pastoralists in southern Ethiopia to climate change and variability using an integrated method. This is important for designing interventions that can enhance the resilience of pastoralist households to climate risks. The paper adds to the literature on climate change vulnerability assessment by providing empirical evidence and insights on the pastoralist communities in ASALs, which are often overlooked or marginalized in climate change research and policy. It also examines the determinants of vulnerability and the coping strategies of pastoralists using quantitative and qualitative data.

2. Methodology

2.1 Study area

The study was conducted in Yabello district of Borana zone, which is located in the extreme southern lowlands of Ethiopia (Figure 1). Yabello has a large population of the Borana tribe, and pastoralism is the main source of livelihood for the majority of households (Dalle *et al.*, 2005). The main livestock kept in the area includes cattle, sheep, goats, camels and equines. The main crops (through small-scale farming) are maize, teff and haricot beans (Tilahun *et al.*, 2017). Borana zone is agro-ecologically comprised of arid and semi-arid ecological zones with bi-modal rainfall patterns of an average range of 400–700 mm (Berhanu and Beyene, 2015). The long dry season occurs from December to February, and the short dry season occurs from June to August (Mintesnot, 2009). The mean annual temperature ranges between 19 and 26°C (Aklilu and Alebachew, 2009).

2.2 Study design

This study used multistage sampling techniques that involved probability and nonprobability sampling methods. Yabello district was purposively selected because it has a high population of pastoralists who are affected by climate variability and change and its extremes. The district was stratified into two groups based on its livelihood system: pastoral and agro-pastoral. Two kebeles were randomly selected from each group using the lottery method. Accordingly, Cholkasa and Dida Yabello kebeles were sampled from the agro-pastoral group, whereas Dikale and Dambi kebeles were sampled from the pastoral group. The formula developed by Cochran (1977) was used to determine sample size. A random sampling technique was applied to select respondent household heads. For the selected households whose heads were absent, the next household was chosen and interviewed.

To determine the sample size, Cochran's (1977) formula was used as follows:

$$\mathrm{n} = \frac{NZ^2PQ}{d^2(N-1)+Z^2PQ} = \frac{(2,540)(3.8416)(0.9)(0.1)}{(0.0025)(2,539)+(3.8416)(0.9)(0.1)} = \frac{1,189.36}{8.9432} = 131$$

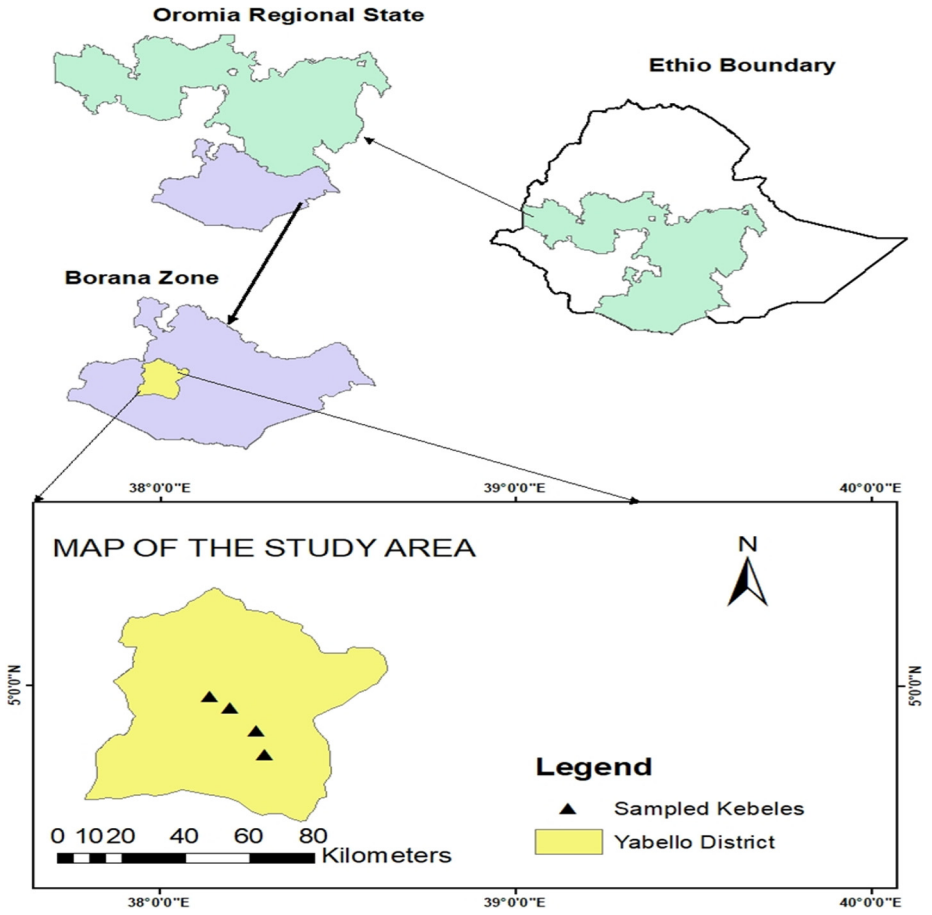
Where:

n = required sample size;

P = the proportion in the targeted population estimated to have characteristic being measured ($P = 0.9$);

Q = 1-P which, 1 – 0.9;

N = total number of households in the study area (in four kebeles);



Source: Author's own creation

Figure 1.
Map of the study area

Z = Standardized normal variable and its value that corresponds to 95% Confidence interval equals 1.96; and
d = Allowable error (0.05).

The distribution of respondent household heads in each kebele was Dikale (total HH: 737; sampled HH: 38), Dambi (420; 22), Dida Yabello (871; 45), Cholkasa (512; 26), total (2,540; 131).

2.3 Data collection and analysis

Data were collected using semi-structured questionnaires administered to household heads in the four kebeles (the smallest administrative unit) in the Yabello district. A total of 131 household questionnaires were administered, four focus group discussions (FGDs) with gender parity (each FGD consisting of six individuals) were conducted separately in sampled kebeles and 20 key informant interviews were conducted between January 2020 and May 2020. The questionnaire used for the study was divided into household demographics, socio-economic

characteristics, source of family income, livestock and crop production, basic amenities owned, access to extension service, access to credit facilities, perception to climate change, adaptation strategies, access to weather information and other relevant information. Quantitative and qualitative data analyses were carried out using Statistical Package for Social Sciences (SPSS version 20) software.

2.4 Vulnerability analysis

Vulnerability is the susceptibility or inability of a system to cope with the adverse effects of climate change, including climate variability and extremes (Raghavan *et al.*, 2018). Vulnerability depends on three components: adaptive capacity, exposure and sensitivity. Adaptive capacity is the ability of a system to adjust to climate change and reduce its potential damages. Exposure is the extent to which a system is subject to climatic hazards, such as droughts, floods and temperature changes. Sensitivity is the degree to which a system is affected by climatic stimuli, both positively and negatively. These components interact to determine the net effect of vulnerability, which can be expressed by the equation (IPCC, 2012):

$$\text{Vulnerability} = \text{Adaptive capacity} - (\text{Exposure} + \text{Sensitivity}) \quad (1)$$

The integrated vulnerability assessment method was used to analyze the vulnerability of Borana pastoralists to climate change. This method combines both the socio-economic and bio-physical factors to measure vulnerability to climate change and its extremes (Cutter, 1996; Füssel, 2009; Deressa, 2010; Opiyo *et al.*, 2014). The integrated approach also combines both internal factors of a vulnerable system and its exposure to external hazards to determine vulnerability (IPCC, 2012). It defines vulnerability as a function of the character, magnitude and rate of climate variation to which a system is exposed, its sensitivity and its adaptive capacity. The higher the adaptive capacity, the less vulnerable the household to climate change impact and vice versa (Füssel, 2009; IPCC, 2012; Fenta *et al.*, 2018; Olufemi *et al.*, 2019). This method uses a combination of indicators to measure vulnerability by computing indices and the weighted average for the selected indicators. The indicators used in this study were selected based on researchers' observation, literature review and the opinion of the Borana pastoralist communities in Yabello district. Community involvement is important in selecting indicators for vulnerability analysis because vulnerability to climate variability and change is location-specific (Adger, 2006; Gallopín, 2006; Olufemi *et al.*, 2019). This study identified 27 socio-economic and biophysical indicators to reflect climate vulnerability components: adaptive capacity, sensitivity and exposure.

2.4.1 Selected indicators and their effects on vulnerability. This study used the IPCC (2012) definition to categorize the vulnerability indicators. Adaptive capacity is represented by wealth, infrastructure, access to information and literacy level. Wealth enhances the ability of communities to cope and recover from climate extremes. The size of herds is one of the indicators used by Borana pastoralists to measure the level of wealth of pastoralist households. The household's wealth was calculated using the Tropical Livestock Unit (TLU) conversion factor adopted by Pica-ciamarra *et al.* (2011). Educated household heads can understand, interpret and act on information and available opportunities. The availability of basic infrastructures plays an important role in adaptation to climate change. It increases the ability of pastoralists to diversify their sources of income, thereby enhancing their adaptive capacity. Likewise, the availability of animal health posts can enhance the provision of preventive treatments for diseases associated with climate change. O'Brien *et al.* (2007) reported that areas with better infrastructure are more likely to have a higher

capacity to adapt to climate variability and change. Sensitivity, on the other hand, is represented by demographic characteristics like household size, gender and age of household head. Exposure in this study is represented by extreme climatic events such as drought frequency, change in environmental temperature, amount of precipitation and bush encroachment which in this study regarded as vegetation change.

2.4.2 Households vulnerability index (HVI). The principal component analysis (PCA) was used to generate factor scores for calculating the vulnerability index (VI) for the households. In this study, the first principal component is the linear index of all the variables that captures the highest amount of information common to all variables. The VI was determined based on three vulnerability components (adaptive capacity, exposure and sensitivity). The VI of the household was calculated using the equation below:

$$V_i = \left(A_1X_{1J} + A_2X_{2J} + \ldots\ldots\ldots + A_nX_{nj}\right) - \left(A_1Y_{1j} + A_2Y_{2j} + \ldots.. A_nY_{nj}\right) \quad (2)$$

where:

V_i = vulnerability index;
X_s = indicators for adaptive capacity;
Y_s = indicators for exposure and sensitivity; and
A_s = First component score of each variable computed using PCA.

The values of X and Y were obtained by normalizing the values of vulnerability indicators using their mean and standard deviations. In this study, the VI was calculated using 27 vulnerability indicators selected for adaptive capacity, exposure and sensitivity. VI was generated for 131 pastoralist households interviewed in sampled kebeles. The vulnerability of households was categorized into highly vulnerable, moderately vulnerable and less vulnerable. The percentage of households that fall into each of the vulnerable categories in four kebeles was also calculated. The average VI for each of the sampled kebeles was also determined by calculating the mean VI of sampled households in kebeles.

2.4.3 Significance of the indicators. The level of influence of the indicators on the vulnerability of the households was analyzed using the ordinal logistic regression model. The model is used when results are presented in ordinal scales, as in this study where the vulnerability was categorized into highly vulnerable, moderately vulnerable and less vulnerable households. This model provides a more parsimonious representation of the data when the dependent variable is ordered. This is different from some of the earlier studies that used either linear regression models (Opiyo *et al.*, 2014) or binary logistic models (Deressa, 2010) to analyze the factors affecting vulnerability. The reduced form of ordinal logistics regression that was used in this study is the one described by Greene (2002) is given as:

$$Y_j^* = X_j^i\beta + \mathrm{Uij} \quad (3)$$

where Y = Level of vulnerability and involves ordered vulnerability categories, $Y = 1$ is given to highly vulnerable households, $Y = 2$ is to moderately vulnerable households and $Y = 3$ is given to less vulnerable households. Y^* is the given state of vulnerability. The *Xij* are the explanatory variables determining vulnerability level. βs is parameters estimated, and *Uij* is the disturbance term.

3. Results and discussion

The results showed that 17% of the households had herd size less than 2.5 TLU, 85% had more than five family members and 82% of respondents had more than three dependents,

aged less than 15 years and 65+ years (Table 1). Pastoralism requires more labor availability. Thus, households with more dependents were more vulnerable to climate-related hazards. Smaller households were more likely to withstand climate change and its extremes (Opiyo *et al.*, 2014). The findings also showed that 77% of the households were illiterate, which increased their vulnerability to climate-induced shocks and stresses. Educated household heads could understand, interpret and act on information and available opportunities.

As shown in Table 1, 15% of the household heads were women who were more vulnerable to climate-induced shocks and stresses as they had low access to assets, credits, social participation and climate information. On the other hand, 67%, 77% and 89% of the households had no access to extension services, credit and early warning information, respectively, indicating their vulnerability to climate-induced shocks such as droughts. The findings also indicated that about 60% of the households had no multiple coping strategies, and only 41% of households had diversified livestock (more than two domestic animal

Hypothesized variables	No. household (%)	Influence on vulnerability
Adaptive capacity indicators		
Herd size: own less than 2.5 TLU	17	+
Mobility: able to move livestock freely	32	–
Crop-farming income: with income from crop farming	22	–
Non-farm income: with income from non-farm activities	35	–
Visit by extension officers: no access to extension services	67	+
Access to early warning information: no access to the information	89	+
Credit access: have no access to credit	77	+
Livestock diversity: own 2+ domestic animal types	41	–
HH coping strategies: more than 2 coping strategies	40	–
Humanitarian service: have no access to food aid	63	+
Own radio; have own radio	31	–
Own mobile phone: have own mobile phone	35	–
Access to electricity: have electricity access	4	–
Education level: no primary education	77	+
Experience in the area: 45+ years	29	–
Distance to the veterinary clinic: more than 10 km	73	+
Distance to market. more than 10 km	72	+
Sensitivity indicators		
Sex of HH head: female-headed households	15	+
Age of HH head: 50+ years	48	+
HH size: 5+ persons	85	+
Marital status: single (including divorced and widowed)	23	+
Households having food shortages during the normal season of the year	35	+
Dependents: greater than 3	82	+
Exposure indicators		
Rainfall: noticed decrease	86	+
Temperature: noticed increase	92	+
Drought frequency: frequent (between 1 and 5 years)	85	+
Vegetation change: high encroachments with low pasture	89	+

Notes: TLU = tropical livestock unit (1 TLU is equivalent to 250 kg); + = positive sign shows that the variable increases vulnerability; – = negative sign shows that the variable decreases vulnerability
Source: Author's own creation

Table 1. Adaptive capacity, sensitivity and exposure indicators and their effects on vulnerability (total HH: 131)

types). Also, 32% of households had access to free mobility, 22% and 35% had income from crop farming and non-farm activities. The results also revealed that 72% and 73% of the households complained that they had to travel more than 10 km to access markets and veterinary services, respectively (Table 1). The availability of basic infrastructures played an important role in adaptation to climate change. It increased the ability of pastoralists to diversify their sources of income, thereby enhancing their adaptive capacity. Likewise, the availability of animal health posts could enhance the provision of preventive treatments for diseases associated with climate change. O'Brien *et al.* (2007) reported that areas with better infrastructure were more likely to have a higher capacity to adapt to climate variability and change. The results also revealed exposure to climate shocks and stresses (Table 1). Further, 86% of the respondents indicated that they experienced decreasing rainfall, while 92% of the households noticed increasing temperatures for the past three decades. Furthermore, 85% of households experienced an increasing frequency of droughts, while 89% of the household heads had observed vegetation change expressed by high encroachments (mostly invasive species) with low pasture in the past 30 years. Dalle *et al.* (2006) reported that encroachment of woody plants had been a major threat to the livelihood of Borana pastoralists.

3.1 Pastoralist perception about climate change and variability

The study found that 86% of the Borana pastoralist perceived that rainfall amount is decreasing, while 14% perceived that rainfall is either unpredictable or they do not know if rainfall amount has changed over the past 30 years. Most respondents perceived that seasonal and annual rainfall amounts and the number of rainy days have decreased, while drought frequency and severity increased. FGDs also agreed that rainfall is reducing, and there is an increase in drought and dry spell occurrences. They observed significant environmental change over the past three decades, such as a reduction in the amount and quality of grass, shorter rain seasons and insufficient rainfall for ponds and pastures. The study result agreed with Alemayehu *et al.* (2020), which indicated that there were changes in temperature and rainfall, expressed mainly in terms of patterns in weather experienced; higher temperatures, below normal rainfalls and short rainy seasons, higher frequency and intensity of extreme weather events.

The study found that most Borana pastoralists perceived that the average temperature is increasing, rainfall is decreasing and drought frequency and severity are increasing. These perceptions are consistent with the global climate model for East Africa, which indicates that climate change may increase temperature by 4°C by the end of the century (IPCC, 2007). The study also found that drought was a high risk for pastoralists. Previous studies confirmed that drought had increased severely and shortened its cycle in ASALs of East Africa (Hillier and Tim, 2011; Viste *et al.*, 2013; Tofu *et al.*, 2023). The survey data showed that about 66% of respondents reported that drought occurred every 3–5 years, 14% reported the occurrence every 2–3 years, 7% reported 5–7 years and 1% reported that the drought occurred every year.

3.2 Measuring vulnerability of households

PCA was conducted (using SPSS vr.20) to develop the vulnerability indices and measure the vulnerability of households quantitatively. The appropriateness of the data was first checked depending on the Kaiser–Meyer–Olkin (KMO) and Bartlett's tests values. According to Li and Weng (2007), if the KMO value is greater than 0.5 and Bartlett's test value is less than 0.1, the factor analysis can be run. It is observed that the KMO measure of sampling adequacy was 0.617, indicating that the model was fairly acceptable (Table 2).

PCA was finally run on the indicators listed in Table 1 to generate the factor scores. Table 3 shows the result of the factor score for the first PCA and its association with the vulnerability variables. The result of PCA revealed that two components were extracted with eigenvalues greater than 1, explaining 95.44% of the total variation. It is observed that 87.18% and 8.25% of the variation were explained by the first and second principal

Table 2.
KMO and Bartlett's test result for the factor score analysis

KMO measure of sampling adequacy	0.617
Bartlett's test of Sphericity	
Approximate chi-square	862.284
Df	351
Sig.	0.000

Source: Author's own creation

Table 3.
The first PCA of the social, economic and environmental variables' factor scores

Factors	Factor scores
Social vulnerability variables	
Sex of HH head: female-headed households	–0.137
Age of HH head: 50+ years	0.570
Education level: no primary education	–0.299
Experience in the area: 45+ years	0.998
HH size: 5+ persons	0.333
Marital status: single (including divorced and widowed)	0.143
Visit by extension officers: no access to extension services	–0.022
Access to early warning information: no access to the information	0.140
Households having food shortages during the normal season of the year	–0.090
Dependent: greater than three	0.365
Economic vulnerability variables	
Herd size: own less than 2.5 TLU	–0.17
Mobility: able to move livestock freely	–0.098
Crop-farming income: with income from crop farming	0.067
Non-farm income: with income from non-farm activities	–0.165
Credit access: have no access to credit	–0.105
Livestock diversity: own 2+ domestic animal types	0.011
HHs coping strategies: more than 2 coping strategies	–0.094
Humanitarian service: have no access to humanitarian services	0.053
Own radio	0.005
Own mobile phone	–0.024
Access to electricity: have electricity access	0.224
Distance to veterinary clinic: more than 10 km	–0.079
Distance to market: more than 10 km	–0.004
Environmental vulnerability variables	
Rainfall: noticed decrease	0.025
Temperature: noticed increase	–0.015
Drought frequency: frequent (between 1 and 5 years)	–0.058
Vegetation change: high encroachments with low pasture	–0.003

Notes: HHs = Households; TLU = Tropical livestock unit (1 TLU = is equivalent to 250 kg; FAO, 2011)
Source: Author's own creation

components, respectively. The first principal component is the linear index of all the variables that captures the highest amount of information common to all variables. The first principal component was used in this study to generate the factor scores (weight) because it explains 87.18% of the variations.

The VI of pastoralist households was computed as the net effect of adaptive capacity (AC) minus exposure (E) and sensitivity (S) [equation (2)]. The indicators of AC, E and S were derived from the first PCA, following the method of Olufemi *et al.* (2019). The variables with higher factor scores had higher influence on VI in the study area. VI was calculated for each of the 131 households studied and categorized into less vulnerable, moderately vulnerable and highly vulnerable based on their VI scores. The criteria for categorizing VI levels were based on expert's opinion, literature review (Fenta *et al.*, 2018; Olufemi *et al.*, 2019) and the analysis of the results of this study.

The VI of households in four kebeles of the Yabello district ranged from +3.79 to –4.34, indicating a high disparity in their vulnerability level. Table 4 shows the VI levels and situations of pastoral households in the study area. Less vulnerable households (15.3% of the total) had a VI score from +1.5 to +3.79 and could still cope with the effects of climate change and variability but with a high risk of becoming more vulnerable in the future. Moderately vulnerable households (60.3% of the total) had a VI score from –0.99 to +1.49 and needed immediate, but short-term support during climate-induced shock. Highly vulnerable households (24.4% of the total) had a VI score from –0.98 to –4.34 and could not cope with climatic stress and needed urgent intervention. They were critically affected by climate change and variability (Table 4).

VI: Vulnerability index; highly vulnerable: The most susceptible households for slight shock and need intensive care; moderately vulnerable: households who need temporary support to recover when they are hit by hard climate-induced shock; less vulnerable: coping households – households in a susceptible situation but still capable to cope (Fenta *et al.*, 2018).

Table 4 shows that most of the households were moderately vulnerable in all of the Kebeles. Dambi had the highest number of highly vulnerable households, followed by Cholkasa, D/Yaballo and Dikale. D/Yaballo had the highest number of moderately vulnerable households, followed by Dikale, Cholkasa and Dambi. Dikale had the highest number of less vulnerable households, followed by D/Yaballo, Dambi and Cholkasa. The vulnerability level of pastoralist households was related to their socio-economic and demographic characteristics (Adhikari and Taylor, 2012; Zhang *et al.*, 2018).

Pastoralism is a labor-intensive livelihood system (Fenta *et al.*, 2018), and older household heads are more vulnerable to climate-induced hazards. Households without access to extension agents and adaptation options are significantly vulnerable to climate

	Vulnerability level of households						
	Highly vulnerable (VI from –0.98 to –4.34)		Moderately vulnerable (VI from –0.99 to +1.49)		Less vulnerable (VI from +1.5 to + 3.79)		
Kebele	Frequency	%	Frequency	%	Frequency	%	Total (%)
Dikale	6	15.8	24	63	8	21	100
Dambi	9	41	10	45.4	3	13.6	100
D/Yabello	8	17.8	30	66.7	7	15.5	100
Cholkasa	9	34.6	15	57.7	2	9	100

Source: Author's own creation

Table 4. VI of households in four kebeles

change, as they lack information or economic capacity to cope with extreme events. Households with restricted livestock mobility and no access to humanitarian aid are highly susceptible to climate shocks. Female-headed households are more vulnerable than male-headed households, due to gender discrimination for resources and opportunities. Adhikari and Taylor (2012) reported that women and children are particularly affected by disasters, accounting for more than 75% of displaced persons. A study of 141 countries over the period 1981–2002 found that natural disasters kill more women than men. Gender mainstreaming into CBA can address the situation of men and women as equal actors in the development process (UNDP, 2010). Several studies in Eastern Africa suggested that pastoralist women need specific targeting in climate change adaptation planning (UNDP, 2010; Opiyo *et al.*, 2014; Mengistu, 2017; Fenta *et al.*, 2018; Olufemi *et al.*, 2019).

Findings by Hinkel (2011) and Opiyo *et al.* (2014) have shown that household size and age of the household head have a significant influence on the vulnerability of the households to climate change and climate extremes. The same study justified that smaller households are usually less susceptible to climate extreme events such as drought because food scarcity is one of the main challenges during drought, and the less the household size, the easier it is to cope with the scarcity of food. Dambi kebele contains the highest mean age (54) of the household heads, which might contribute to the highest index.

The result of VI statistics of sampled kebeles is also presented in Table 5. The VI of the kebeles was determined by calculating the average VI for households in each kebele. The result showed that there is no significant difference between kebeles as well as between pastoral and agro-pastoral communities ($P > 0.05$). This difference can be attributed to livelihood diversification (Zhang *et al.*, 2018). Agro-pastoral households were practicing crop farming alongside livestock keeping, while pastoralists were solely dependent on their livestock as a source of income. The overall result showed that agro-pastoral households had better adaptive capacity and were less vulnerable than pastoral households (Table 5).

3.2.1 Factors influencing household vulnerability in the study area. The vulnerability of pastoral households to climate change is determined by various factors that affect their resilience and sensitivity. Resilience is the ability of a household to absorb stresses and maintain its structure, function and feedback, while sensitivity is the degree to which a household is modified or affected by perturbations (Adger, 2006; Gallopín, 2006). These factors can be classified into macro (economic, institutional and environmental setting) and micro (access to resources, adaptation and coping strategies) levels at the household level (Gallopín, 2006; Zhang *et al.*, 2018). Based on an ordered logistic regression model, eight predictor variables were found to have a significant influence (at 5% level of significance) on the vulnerability of pastoral households in the study area. These variables are early warning

		VI statistics				
Kebele	HH count	Mean	SD	Range	Variance	Kurtosis
Dikale	38	0.29	1.53	6.64	2.3	–0.165
Dambi	22	–0.51	1.74	6.04	3.0	–0.898
D/Yaballo	45	0.18	1.53	7.49	2.4	0.568
Cholkasa	26	–0.31	1.79	7.39	3.2	–0.100
Community						
Pastoralist	60	–0.0007	1.63	6.64	2.69	–0.651
Agro-pastoralist	71	0.0006	1.63	8.13	2.67	0.144

Table 5.
Average VI for kebeles/communities

Note: SD = standard deviation; $P = 0.934$
Source: Author's own creation

information, bush encroachment (land cover change), coping strategy, temperature change, provision of humanitarian services, drought frequency and food shortages during the normal season of the year (Table 6). These variables affect the resilience and sensitivity of pastoral households in different ways and have potential consequences on their livelihoods:

- *Age of household head*: The age of household head has a positive effect on vulnerability. Older household heads are more vulnerable to climate change than younger ones, as they have lower education, income and health levels (Tenaw, 2021). They also lack access to information, technology and innovation that can help them adapt (HPG, 2009). Policies that support older households, such as social security, health care, education and training, could reduce their vulnerability.
- *Access to information*: Access to information has a negative effect on vulnerability. Information helps households to make informed decisions, plan and take actions to cope and adapt (IPCC, 2007). It also increases awareness, knowledge and skills that can improve livelihood outcomes. Therefore, policies that improve access to information, such as providing radio, television, mobile phones and internet services, disseminating climate forecasts and early warning systems, organizing community meetings and workshops and involving local media and NGOs, could reduce vulnerability.

Variables	Estimate	SE	Wald	*p*-value
Sex of HH head: female-headed households	–3.146	3.927	0.642	0.423
Age of HH head: 50+ years	–0.314	0.123	6.482	0.011*
Education level: no primary education	–0.386	1.083	0.127	0.721
Experience in the area: 45+ years	–0.026	0.081	0.107	0.743
HH size: 5+ persons	0.067	0.678	0.010	0.921
Marital status: single (including divorced and widowed)	0.801	1.931	0.172	0.678
Visit by extension officers: no access to extension services	–0.184	1.458	0.016	0.899
Access to early warning information: no access to the information	8.033	3.058	6.900	0.009*
Households having food shortages during the normal season of the year	–8.264	2.286	13.067	0.000*
Dependent: greater than three	0.129	0.902	0.020	0.886
Herd size: own less than 2.5 TLU+	3.417	3.422	0.997	0.318
Mobility: able to move livestock freely	0.976	1.653	0.349	0.555
Crop-farming income: with income from crop farming	–0.060	1.940	0.001	0.975
Non-farm income: with income from non-farm activities	–0.606	2.434	0.062	0.803
Credit access: have no access to credit	–2.056	2.373	0.751	0.386
Livestock diversity: own 2+ domestic animal types	0.043	1.630	0.001	0.979
HH coping strategies: more than 2 coping strategies	–4.170	1.826	5.217	0.022*
Humanitarian service: have no access to humanitarian services	7.408	2.067	12.846	0.000*
Own radio	–0.974	1.547	0.397	0.529
Own mobile phone	1.341	1.484	0.816	0.366
Access to electricity: have electricity access	1.902	10.885	0.031	0.861
Distance to veterinary clinic: more than 10 km	1.506	1.623	0.861	0.354
Distance to market: more than 10 km	0.306	1.461	0.044	0.834
Rainfall: noticed decrease	0.654	1.046	0.390	0.532
Temperature: noticed increase	–4.222	1.697	6.189	0.013*
Drought frequency: frequent (between 1 and 5 years)	–9.047	2.175	17.306	0.000*
Vegetation change: bush encroachments with low pasture	–10.489	3.268	10.305	0.001*

Notes: SE = standard error; The Wald statistics is the square of the ratio of the coefficient to its standard error; p-value is statistical significance expressed at $P < 0.05$
Source: Author's own creation

Table 6. Factors influencing household's vulnerability to climate change and variability

- *Household coping strategies*: Household coping strategies have a negative effect on vulnerability. Coping strategies help households to reduce losses, maintain assets and sustain livelihoods in the face of shocks and stresses (Alemayehu *et al.*, 2020). Coping strategies also enhance adaptive capacity by increasing flexibility, diversity and options (Opiyo *et al.*, 2014). Therefore, policies that promote household coping strategies, such as providing incentives, subsidies and insurance schemes, facilitating collective action and cooperation, supporting local institutions and networks and strengthening social capital and norms, could help increase household coping strategies and reduce vulnerability.
- *Humanitarian services*: Humanitarian services reduce vulnerability to climate change. Humanitarian services help households cope with and recover from disasters and crises and protect their rights, dignity and security (Guye *et al.*, 2023). Therefore, policies that enhance humanitarian services, such as increasing funding, coordination and accountability, improving targeting, delivery and monitoring mechanisms, ensuring participation, consultation and feedback of beneficiaries and integrating humanitarian and development interventions, could reduce vulnerability.
- *Temperature*: Temperature has a positive effect on vulnerability. It affects water availability and quality, crop growth and yield, livestock health and productivity, human health and comfort biodiversity and ecosystem services. Temperature also worsens heat stress, evaporation rates, pest infestations and disease outbreaks (Donatti *et al.*, 2020). Therefore, policies that mitigate temperature rise, such as reducing greenhouse gas emissions, promoting renewable energy sources, improving energy efficiency and enhancing carbon sequestration, could reduce vulnerability.
- *Drought frequency*: Drought frequency increases vulnerability to climate change. It reduces water availability and quality, crop growth and yield, livestock health and productivity, human health and well-being and biodiversity and ecosystem services. Droughts also worsen food insecurity, poverty, conflict and migration (Opiyo *et al.*, 2015). Therefore, policies that prevent or reduce drought occurrence and impact, such as improving water management and conservation, promoting drought-tolerant crops and breeds, providing irrigation and fodder facilities, enhancing drought preparedness and response plans and supporting drought recovery and rehabilitation programs, could reduce vulnerability.
- *Vegetation change*: Vegetation change has a positive effect on vulnerability. Vegetation provides food, fuel, fiber, medicine and income for pastoralists. Vegetation also regulates water cycle, soil fertility, climate and biodiversity. Vegetation loss or degradation is caused by overgrazing, deforestation, land conversion, fire and climate change (Ayal and Leal Filho, 2017). Therefore, policies that restore or enhance vegetation cover and quality such as promoting sustainable land use and management practices, encouraging afforestation and reforestation activities, supporting community-based natural resource management and conservation initiatives, enforcing environmental laws and regulations and compensating environmental services, could reduce vulnerability.

The Borana pastoralists have a rich and diverse knowledge of their environment, which helps them to manage natural resources and adapt to climate change. However, this knowledge is threatened by external factors such as land degradation, population growth, policy interventions and socio-economic changes. This could harm the biodiversity, ecosystem services and resilience of the rangelands. The Borana pastoralists rely on

livestock production for their livelihoods. They use strategies such as herd splitting, cattle mobility, herd diversification and bush burning to cope with their environment. However, these strategies are challenged by factors such as market fluctuations, droughts, conflicts, diseases and sedentarization. This affects their food security, income and well-being. The pastoralists have a strong culture and identity that is based on their pastoral way of life. They have a complex social organization that is regulated by customary institutions, norms and values. However, these institutions are pressured by factors such as state policies, modernization, education and migration. This affects their social capital, empowerment and self-determination.

The present study result concurs with previous studies that Borana Lowlands are encroached by woody plants beyond the critical level. This affects rangeland management and pastoral livelihoods. The causes are less use of indigenous knowledge, poor understanding of the pastoral system and conversion of pastoral land to other activities. The fire ban in the 1970s also increased bush expansion. The rangelands in south and eastern Ethiopia are poor due to drought, overgrazing and bush encroachment. The pastoralists in Yabello district lack enough and good pasture because of bushes, land fragmentation and livestock overstocking. They used to control pasture with fire, but the government prohibited it and now spends money to clear the bush.

According to the study by the International Federation of Red Cross and Red Crescent Societies (IFRC), drought is an inevitable consequence of the weather patterns in the Horn of Africa, and therefore, development efforts in pastoralist areas can be prioritized, strengthened and refocused based on credible and specific early warning information. Severe droughts that occurred in Borana during 2000, 2006, 2008 and 2011 seasons (Stark and Terasawa, 2011) caused huge livestock deaths. Climate information is becoming a valuable resource for confronting and living with an increasingly uncertain future (Care, 2014). Based on reliable early warning information, early humanitarian services such as Productive Safety Net Programs (PSNP) can be broadened and deepened; community capacities can be recognized and enhanced. Above all, most of the negative impacts of climate change can be mitigated through national and local government programs like IFRC. Readiness to respond to early warning is critical to intervene timely. This involves some preparatory planning of the response ahead of the emergency call when these systems send warning alarms (Yilma *et al.*, 2009).

4. Conclusions

This study analyzed the vulnerability of Borana pastoralists in Yabello district to climate change and variability using indicators developed by the researcher and the stakeholders. The results showed that most households are highly or moderately vulnerable to climate-induced stresses, and that several factors such as early warning information, bush encroachment, coping strategy, temperature, drought frequency, provision of humanitarian service and food shortage have significant influence on vulnerability. The study also found that there is a direct link between the level of infrastructural development and the level of vulnerability, and that there is high disparity in the vulnerability levels of households within and among kebeles in the district. The study recommends four ways to enhance the resilience of Borana pastoralists:

- supporting the integration of indigenous and scientific knowledge for natural resource management and adaptation;
- improving the access and quality of basic infrastructures such as markets, veterinary services, extension services, credit facilities and early warning information;

- promoting livelihood diversification and innovation through crop farming, non-farm activities and livestock diversification; and
- recognizing and respecting the culture and rights of Borana pastoralists and empowering them to participate in decision-making processes.

The study also suggests more studies on spatial and temporal variations of vulnerability and adaptation strategies among different pastoral communities in Ethiopia and other countries in the Horn of Africa.

To bridge the gap between local and global knowledge and to foster collaboration and co-learning among different stakeholders, it is important to explore the potential synergies and tradeoffs between indigenous and scientific knowledge systems for enhancing the resilience and sustainability of pastoral livelihoods. It is also highly important to examine the role of social, economic and institutional factors in influencing the adoption and implementation of adaptation and coping strategies among pastoralists. This would help to understand the drivers and barriers for adaptation and coping, as well as to address the underlying causes of vulnerability among pastoralists.

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