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Livelihood vulnerability to climate variability and change in different agroecological zones of Gurage Administrative Zone, Ethiopia

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ABSTRACT

Introduction: Climate change and related extreme events are negatively affecting agricultural production where millions of smallholder farmers depend up on it. Ethiopian rain-fed agriculture system is becoming more vulnerable to the impacts of climate change. Identification of difference in the level of vulnerability of a system is important in selecting appropriate and effective adaption options to climate change. Thus, this study examined the vulnerability of farm household's livelihood to climate variability and change in different agroecological zones of Gurage Zone using the Livelihood Vulnerability Index (LVI) and Livelihood Vulnerability Index–Intergovernmental Panel on Climate Change (LVI–IPCC) methods. Data were collected from a representative of 357 sample households across three agroecological zones using a mixture of participatory methods.
Results: Results suggested that although there was difference in components relative value across agroecological zones, the overall LVI indicate that Sodo woreda (District) which is found in the lowland agroecological zone was more vulnerable to climate variability and change. This study found that vulnerability differences were attributable to variations in household characteristics, lack of access to infrastructure, low level of livelihood diversification, and lack of available technologies.
Conclusions: Therefore, this study calls for stakeholders to prepare context-specific intervention to reduce smallholder farmer's vulnerability to climate variability and change and strengthen the adaptive capacity of farm households.

1. Introduction

Climate change and related extreme events are negatively affecting agricultural production where millions of smallholder farmers depend up on it. The risk of food insecurity is greater nowadays in developing countries because livelihoods are more exposed and vulnerable to climate change [1]. Climate change is a global phenomenon which indiscriminately affects all sectors of the economy and all social groups. However, the level of vulnerability of a system, household, and location is differentiated dictated by environmental and socioeconomic factors [2,3]. Understanding the vulnerability of livelihood systems of poor people in the context of wider transformational shifts — social and political as well as biophysical — must now be seen as a normative priority [4].

Empirical findings (e.g. [5–7]) indicate that Africa's climate is already changing and the impacts are already being felt by communities across the continent. In sub-Saharan Africa, extreme events like drought already impede people's ability to grow crop and rear livestock [8,9]. This is mainly because of Africa's poor socio-economic development status and which in

turn affects the continent's aspiration towards sustainable development goals [5,10–12].

Projected climate change in Ethiopia is expected to result in increased variability in precipitation and in an increase in temperature (1.1 to 3.1 °C by 2060 and 1.5 to 5.1 °C by 2090) with associated increases in the frequency and intensity of extreme events like drought and flood [13]. These trends of increasing temperature, decreasing precipitation and the increasing frequency of extreme events are predicted to continue in the future in the tropics of Africa where Ethiopia is located [14,15].

Ethiopia is an agro-based economy where agriculture contributes 45% to the gross domestic product (GDP). Agriculture sector is a source of livelihood for more than 80% of the population. Despite its significant share of the overall economy, agriculture is predominantly rain-fed and as such vulnerable to climate change and extremes events [16]. For example, the major drought in 2002–3 resulted in a drop in food production by 26% [17]. Moreover, due to population growth and traditional agricultural practice there is pressure for natural resource which is likely to lead to deforestation and land degradation [18].

Different vulnerability assessments have been used to analyze climate vulnerability and its interplay with livelihood security which is required to identify and implement climate resilience interventions [19]. However, despite some research work on vulnerability to climate change, little

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empirical evidence exists on level of vulnerability to climate change at household and community level so far in Ethiopia in general and Gurage zone in particular. Previous studies on vulnerability to climate change in Ethiopia have mostly been macro-level studies. For example, a study by Deressa, Hassan, & Ringler [20] measured Ethiopian farmers' vulnerability to climate change across regional states using national aggregates data. Only a few studies have focused on measuring smallholder farmer's vulnerability to climate change at household and community level. Teshome [21] assessed agricultural land vulnerability to climate change at household level in Northwest Ethiopia. Similarly, Simane, Zaitchik, and Foltz [22] conduct a study on agroecosystem specific climate vulnerability in Choke Mountain.

Macro-level studies elsewhere in the country do not necessarily reflect the exposure of households or communities, nor do they capture in detail how households perceive or respond to shocks and stress. Vulnerability assessments relying on aggregate data could mask significant local-level variability and which might have directed to intervention failure [23,24]. Thus, local-based studies help to understand the role of context specific factors [25] which must be accounted for if associated interventions are to benefit vulnerable groups. Moreover, place based studies helps to address the challenges in the development of consistent factors or standard metrics that can be used to evaluate the resilience of communities to climate vulnerability and change. It is imperative to understand the vulnerability of natural resource-dependent households to climate variability and change at local level and fills the gap in the literature.

Thus, this study examined the vulnerability of farm households to climate variability and change in different agroecological zones of Gurage Zone.

2. Methodology of the study

2.1. Description of the study area

Gurage zone has a land size of about 5932 km^2 and consists 15 woredas [26] (Fig. 1).

Rain-fed agriculture is the main economic activity in the study zone. Gurage zone has two relatively discrete rainy seasons. Crops are primarily dependent on the summer (June to September) locally called *Kirmit* season, but spring season (February to April) locally called *Belg* season is also important for agricultural activity. The main food crops are enset (*Enset ventricosum*), barley, pulses, wheat and potatoes. Topographically the zone lies within an elevation ranging from 1000 to 3600 m above sea level. The annual average temperature of the zone ranges from 13 °C to 30 °C and the mean annual rainfall rages from 600 to 1600 mm. Considering the land utilization, 52% of the total area is agricultural land, 13 0.4% is a grazing land, 9.9% is a natural and man-made forest land, 7.3% unproductive land and other activities covered the remaining 17.6%.

Gurage zone has three agroecological zones:

The Gurage Lowland zone (*Locally called Kola*): is split into two separate geographical areas, located in the Eastern and Western lowlands of Gurage Administrative Zone, and includes parts of Abeshige and Sodo woredas. The elevation ranges from 1000 to 1500 m above sea level. Acacia trees and savannah grassland dominate the vegetation of the area. The Eastern part of the zone falls in the Rift Valley drainage system. Meki
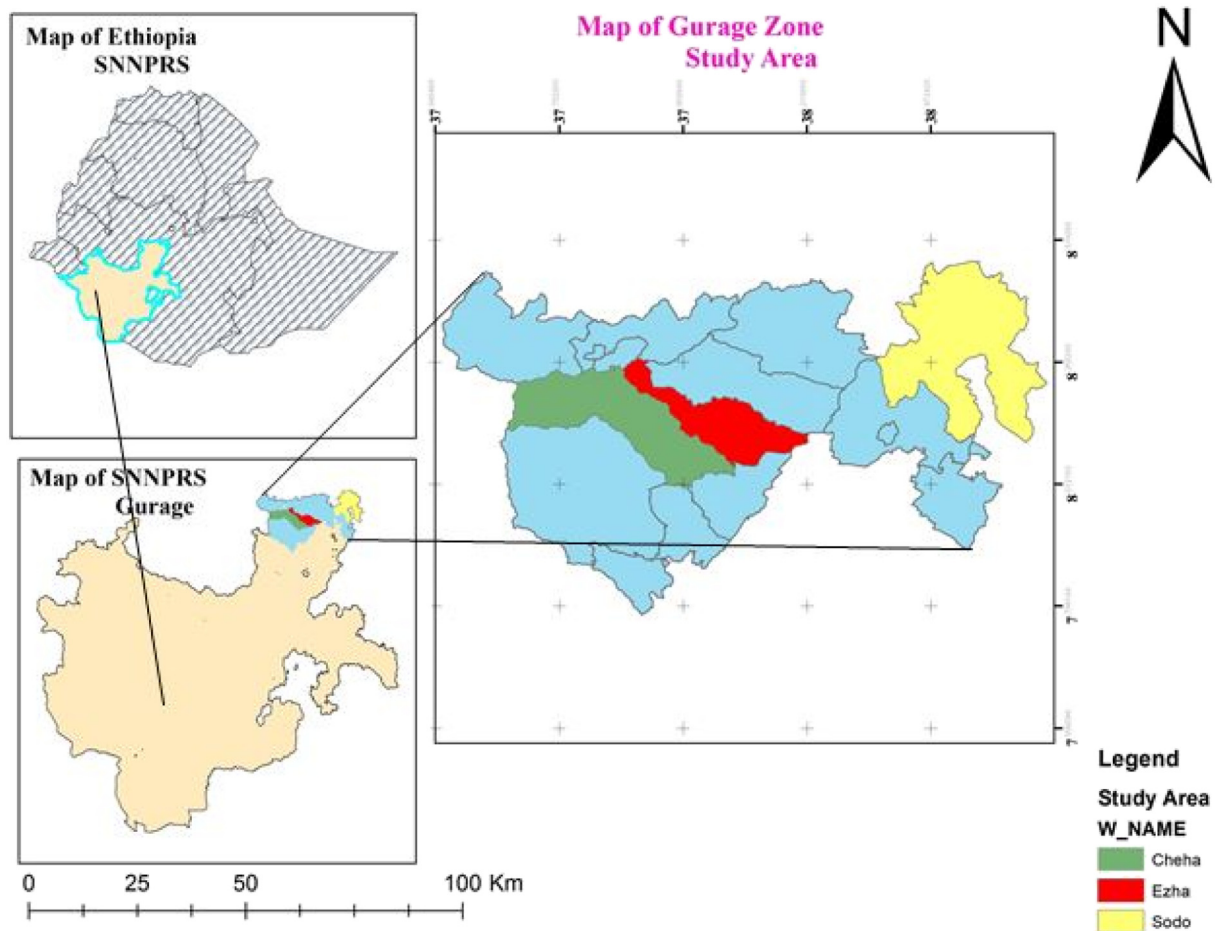

Fig. 1. Location map of the study zone.

and Ghibe River and its tributaries (Wabe, Walga, Kulit and Darge) are the major river. Mixed farming is the main livelihood source in the area [27].

The Gurage Midland (*Locally called Woina-dega*): includes parts of Ezha, Enemor and Ener, Cheha, Endegegn, Mehur Aklil, Kokir and Meskan woredas. It is located on the Eastern and Western escarpments of the Gurage Mountains. The main cultivation season is dependent on the Kirmit rains and rain-fed agriculture is the main economic activity. Belg rainfall is also important for agricultural activities. Enset and Qat are the major food and cash crops, respectively.

The Gurage Highland Zone (*Locally called Dega*): covers the highland parts of Ezha, Enemor and Ener, Sodo, Gumer, and Mehur Aklil woredas. Crops are primarily dependent on the Kirmit rains, but Belg rainfall is also important for agricultural activities. The main sources of income for households in the zone are the sale of crops, migratory urban employment, local employment (mainly casual agricultural work), and the sale of livestock [27].

2.2. Sources and methods of data collection

Vital information about the study was gathered from both primary and secondary data sources. Data presented in this paper were collected using a mixture of different data collection methods. A specific tool was used to respond to a series of guiding questions, and, on the opposite, a specific question was addressed by different methods: this helped particularly to triangulate information. The data were collected from March to October 2018. Data were collected from a representative of 357 sample households across three agroecological zones. The questionnaire survey was used to collect a range of information on households' capital assets, farmers' perception of climate change, and vulnerability situations. In addition, climatic context–including observations regarding patterns of temperature and rainfall; climate extremes; impacts of climate change and prevailing uncertainties were asked. Moreover, twelve Key Informant Interviews (KIIs) and two Focus Group Discussions (FGDs) for each agro-ecologies were carried out to triangulate, supplement, and enrich the data.

Records of extreme events at woreda level were collected from woreda Disaster and prevention office. Furthermore, meteorological data for the nearest station in each woreda were collected from the Ethiopian Meteorological Agency to analyze temperature and rainfall trends and seasonal variations. The reference period for the meteorological data was between 1983 and 2016.

2.3. Sampling techniques and procedures

A multi-stage sampling method was used in selecting respondents for the study. In the first stage, the administrative zone (i.e. Gurage Zone) was stratified purposively into three agro-ecologies namely Highland/Dega, Midland/Woina-dega and Lowland/Kola in order to measure the extent of vulnerability to climate change. Then, three woredas from each agro-ecologies, which can represent the administrative zone, were selected using simple random sampling technique. In the third stage, since there are a number of Peasant Associations (PAs) within different agro-ecologies of the selected woredas, PAs were stratified by agro-ecology and then random sampling were used to select representative PAs from each selected woreda based on their agro-ecology characteristics. In the last stage, representative households for the study were selected by employing simple random sampling technique. Then independent sample size was determined from each PAs using probability proportional to size (PPS) method to ensure equal representation of households in expectation of different household sizes in each PAs based on Israel [28]. The sampling frame for this study was the list of household heads which was obtained from the PAs. Using the formula indicated below, the sample household size was determined

for each woredas and proportionally distributed for each PAs of each woreda.

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

where:

n = the sample size the research uses,
N = total number of households in all PAs,
e = maximum variability or margin of error 5% (0.05), and
1 = the probability of the event occurring.

Based on the above formula a total sample size of 357 households were drawn and proportionally distributed to the six-PAs using the following formula.

$$ni = \frac{n \times Ni}{\sum Ni}$$

where:

n = determined sample size the research uses,
ni = households of the ith PA, and Ni = total households of the ith PA.

As a result, 75, 149 and 133 households from Sodo, Cheha and Ezha woredas were selected for the study, respectively.

2.4. Methods of data analysis

Both qualitative and quantitative data analysis method were employed to analyze the collected data. The quantitative data analysis was carried out using Statistical Package for Social Science (SPSS) 24.0. The baseline household survey data were used to conduct descriptive analysis of indicators describing households shock exposure, vulnerability, food security, and livelihood situation. The qualitative data analysis was used to interpret information from the FGDs and KIIs to capture contextual information about vulnerability and it was integrated with quantitative findings to provide a more comprehensive and contextually-specific picture of livelihood vulnerability at the local level.

2.4.1. Calculating the Livelihood Vulnerability Index

This study adapts the method used in Hahn et al. [19] and Mohan and Sinha [29] to calculate household livelihood vulnerability. The method is a balanced weighted average approach where each subcomponent contributes equally to the overall index even though each major component of different livelihood assets includes a different number of sub-components [30].

First, the indicators were standardized to an index by an equation:

$$IndexS_d = \frac{S_d - S_{\min}}{S_{\max} - S_{\min}} \tag{1}$$

After standardizing each indicator, the sub-components were averaged using Eq. (2) to calculate the value of each major component.

$$M_d = \frac{\sum_{i=1}^{n} IndexS_{di}}{n} \tag{2}$$

where Md = one of the seven major components for the woredas' sociodemographic (S), health (H), food (F), livelihood strategies (L) water (W), social network (SN), and natural disasters and climate variability (C); index represents the sub-components, indexed by i, and n is the number of sub-components in each major component.

Once values for each of the seven major components for a district calculated, they were averaged using Eq. (3) to obtain the woreda-level

$$LVI_d = \frac{\sum_{i=1}^{7} W_{mi} M_{di}}{\sum_{i=1}^{7} W_{mi}} \tag{3}$$

2.4.1.1. Expanded form.

$$LVI_d = \frac{W_S S_d + W_H H_d + W_F F_d + W_L L_d + W_W W_d + W_{SN} SN_d + W_C C_d}{W_s + W_h + W_f + W_l + W_w + W_{sn} + W_v} \quad (4)$$

where LVI, the LVI for the woredas, equals the weighted average of the seven major components. The weights of each major component, WMi, were determined by the number of sub-components. In this study, the LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable). This analysis was done by using SPSS-24 and MS-excel work sheet.

2.4.1.2. IPCC.

$$CF_d = \frac{\sum_{i=1}^{n} W_{mi} M_{di}}{\sum_{i=1}^{n} W_{mi}} \quad (5)$$

$$LVI - IPCC_d = e_d - a_d * s_d \quad (6)$$

On the bases of the analytical framework, vulnerability indicators and measurements were identified and operationalized. Measurable indicators are identified from observations and climate change adaptation and disaster risk reduction literatures as presented as follows (Table 1).

Table 1
Vulnerability indicators and unit of measurements.

Main component	Sub-components	Unit of measurements
Socio-demographic profile	Dependency ratio in the sample	Ratio
	%of female headed household	%
	% of HH heads who has not attended school	%
	Average years of farming experience	1/years
Health	Average time to nearest health center	min
	% of HHs reported at least one chronically ill member 12 m	%
	Percentage of households without sanitary latrine/toilet	%
Food	Average food insufficient months	1/month
	% of HHs faced with food shortage	%
	Average crop diversity index	1/# crops
	Percent of households that do not save crops in last 12 months	%
Livelihood strategies	Average farm land size of the household	ha
	Percentage of households solely reliant on agriculture as the main source of livelihood income and food	%
	Percentage of households with no solar plates for power supply	%
	Percentage of households with family members migrated outside communities	%
Water	% of HHs who haven't consistent water supply	%
	% of HHs utilizing natural water sys	%
	Average time to water source	min
Social network	% of household heads who have not been head of community in the last 12 months	%
	% of HHs who do not receive any kind of support/help from neighbors/relatives	%
	Average distance to nearest market	km
Natural disasters and climate variability	Average no. of drought, flood and frost in the last 5 years	Count
	Mean standard deviation of monthly average precipitation 2009–2016	mm
	Mean standard deviation of monthly average of average maximum daily temperature 2009–2016	°C
	Mean standard deviation of monthly average of average minimum daily temperature 2009–2016	°C

3. Results and discussion

3.1. Households' Livelihood Vulnerability Index

The results revealed that the livelihood vulnerability indices of the zone across different agro-ecologies ranged from 0.35 to 0.38. Smallholder farmers in Sodo woreda were found to be slightly more vulnerable to climate change than Ezha and Cheha woredas as measured by LVI, although the value of different components across the three agro-ecologies were different.

The different indices being relative values were compared across three agro-ecologies (Table 2).

Ezha showed greater vulnerable in terms of the socio-demographic profile, with a weighted average score of 0.35, followed by Cheha 0.3 and Sodo 0.3. The dependency ratio index was higher for Ezha than Sodo and Cheha woredas. Ezha woreda showed greater vulnerability (0.61) based on the percentage of household heads with no basic education than Cheha (0.52) and Sodo (0.37). Illiteracy hinder farmers' access to information, especially from written sources, thereby increasing their vulnerability to climatic stresses [31]. The study also showed Cheha woreda was less vulnerable (0.36) on years of farming experience than Sodo and Ezha woredas. Furthermore, approximately 14.7%, 12% and 10.1% of household heads in Sodo, Ezha and Cheha woredas were female-headed households, respectively.

Based on overall health vulnerability score, Ezha was more vulnerable with a weighted average score of 0.33, whereas Cheha woreda (0.23) showed less vulnerability. Ezha had greater vulnerability (0.46) for the average time a household took to reach a health facility than Cheha (0.4) and Sodo (0.45). Vulnerabilities to climate variability and change are in some cases also exacerbated by a lack of education and healthcare facilities, leading to economic impediments with long-term effects (J. [32]). Access to toilet was 79% in Cheha, 67% in Sodo and 57% in Ezha. Cheha showed less vulnerability (0.08) with respect to a household with family members with chronic illness than Sodo (0.09) and Ezha (0.1).

The study revealed that Sodo woreda was found to be the more vulnerable for the food component (0.47), whereas Cheha (0.35) and Ezha (0.33). Households in Sodo reported that, on average, 4 months per year they had struggled to provide adequate food for their families, which is higher than Ezha (3.57 month) and Cheha (3 month) per year. Farmers reported that the difficult periods for obtaining food occurred during the off-seasons and during inter-cultivation periods. About 40% of the households in Sodo woreda reported food insecurity while 36% for Cheha and 30% for Ezha. The extent to which climate change affect people's food security situation depends on their degree of exposure to climate shocks and vulnerability to these shocks [1]. The average crop diversity index showed that almost Cheha and Ezha woredas were similar and Sodo woreda scores average 0.43. 73% of households in Sodo reported they didn't save crops which is higher than Cheha (56%) and Ezha (48%).

Based on the weighted average score for the livelihood strategies component of LVI, both Cheha and Sodo showed greater vulnerability (0.43) than Cheha (0.41). Sodo woreda showed a greater vulnerability based on the percentage of households with family members migrated outside communities than Ezha and Cheha. Moreover, about 78% of the households in Cheha woreda dependent only on agriculture as a source of livelihood whiles 73% for Ezha and 65% for Sodo woredas. This implies that households in Sodo practiced slightly diversified livelihood activities compared with Ezha and Cheha woredas. Even though other research findings suggest that the fewer agricultural activities a household engages in, the more vulnerable it is to climatic stress [31], however, this research work pinpoint out that livelihood diversification is not a guarantee to reduce livelihood vulnerability. This was due to the fact that cross-cutting factors like access to credit, market and availability of technology influence the whole livelihoods system. Additionally, livelihoods are affected differently by various climate shocks and stressors, depending on the types of livelihoods and their ability to withstand impacts of extreme events [33].

Table 2

Indexed sub-components, major components, and overall LVI.

Main component	Sub-components	Units	Sodo/lowland		Cheha/midland		Ezha/highland	
			Actual value	Standardized	Actual value	Standardized	Actual value	Standardized
Socio-demographic profile	Dependency ratio in the sample	Ratio	53.67	0.268	43.7	0.218	55.23	0.276
	%of female headed household	%	14.7	0.15	10.1	0.1	12	0.12
	% of HH heads who has not attended school	%	37	0.37	52	0.52	61.3	0.61
	Average years of farming experience	1/years	24.6	0.4	28.5	0.36	28.2	0.38
	Weighted average score (st. dev.)			**0.3**		**0.3**		**0.35**
Health	Average time to nearest health center	min	30	0.45	30	0.4	35	0.46
	% of HHs reported at least one chronically ill member 12 m	%	9.3	0.09	8.7	0.08	10.5	0.1
	Percentage of households without sanitary latrine/toilet	%	33	0.33	21	0.21	43	0.43
	Weighted average score (st. dev.)			**0.29**		**0.23**		**0.33**
Food	Average food insufficient months	1/month	4	0.43	3	0.25	3.57	0.3
	% of HHs faced with food shortage	%	40	0.40	36	0.36	30.1	0.3
	Average crop diversity index	1/# crops	2.3	0.43	1.78	0.26	1.75	0.25
	Percent of households that do not save crops in last 12 months	%	63	0.63	56	0.56	48	0.48
	Weighted average score (st. dev.)			**0.47**		**0.35**		**0.33**
Livelihood strategies	Average farm land size of the household	ha	2.5	0.1	1	0.23	0.88	0.19
	Percentage of households solely reliant on agriculture as the main source of livelihood income and food	%	65.3	0.65	77.9	0.78	72.97	0.73
	Percentage of households with no solar plates for power supply		73.1	0.73	58.1	0.58	54.4	0.54
	Percentage of households with family members migrated outside communities		17.3	0.17	12.1	0.12	10.5	0.1
	Weighted average score (st. dev.)			**0.41**		**0.43**		**0.39**
Water	% of HHs who haven't consistent water supply	%	61.3	0.61	36.2	0.36	44.3	0.44
	% of HHs utilizing natural water sys	%	31.3	0.31	32.2	0.32	29.7	0.29
	Average time to water source	min	60	0.47	30	0.31	25	0.37
	Weighted average score (st. dev.)			**0.46**		**0.33**		**0.37**
Social network	% of household heads who have not been head of community in the last 12 months	%	81.3	0.81	83.2	0.83	88	0.88
	% of HHs who do not receive any kind of support/help from neighbors/relatives	%	32	0.32	25.1	0.25	33.2	0.33
	Average distance to nearest market	km	6	0.21	4.5	0.18	5	0.25
	Weighted average score (st. dev.)			**0.45**		**0.42**		**0.49**
Natural disasters and climate variability	Average no. of drought, flood and frost in the last 5 years	Count	5	0.45	3	0.27	7	0.63
	Mean standard deviation of monthly average precipitation 2009–2016	mm	48	0.367	50.05	0.38	47.13	0.37
	Mean standard deviation of monthly average of average maximum daily temperature 2009–2016	℃	1.32	0.41	0.85	0.49	0.83	0.34
	Mean standard deviation of monthly average of average minimum daily temperature 2009–2016	℃	1.6	0.24	1.12	0.5	0.96	0.29
	Weighted average score (st. dev.)			**0.36**		**0.41**		**0.41**
Livelihood Vulnerability Index				0.390		0.356		0.379

NB: The LVI is on a scale from 0 (least vulnerable) to 0.5 (most vulnerable).

Water vulnerability in rural area is mainly caused when agriculture sector is highly dependent on water sources and the existing infrastructure is poor [34]. However, due to lack of irrigation facility in the selected study areas, this study considered only water availability for domestic purpose in the water component of vulnerability. The water component of the LVI showed that Sodo woreda was more vulnerable (0.46) than Ezha (0.37) and Cheha (0.33) woredas. Almost there was a similar finding between households who depend more on natural water source for household purpose. The average time taken to get a water source was higher in Sodo woreda (around 1 h) than in Cheha (30 min) and Ezha (25 min). In addition, percentage of households who did not have a consistent water supply higher in Sodo (61.3%) woreda compared to Ezha (44.3%) and Cheha (36.2%) woredas. The majority of the households in all three study areas reported that there was a shortage in availability of pipe and bore holes. Many respondents from Sodo woreda mentioned that natural springs, and other natural water sources have dried up during the dry season. Moreover, they mentioned the availability of water in the source is also inconsistent.

In terms of social network component of LVI, Ezha woreda (0.49) was more vulnerable than Sodo (0.45) and Cheha (0.42). 81.3% of the households in Sodo and 83.2% in Cheha and 88% in Ezha reported that they have not taken any administrative position within their community. In terms of help from others, the finding showed that 75% in Cheha

households had received support/help from their neighbors/relatives, which is higher than Sodo and Ezha. Well developed and organized social networks are important for reducing household and community vulnerability to climate change [35]. Farmers in Sodo reported an average travelling distance of 6 km to the nearest market, whereas for Ezha (5 km) and Cheha (4.5 km).

Ezha and Cheha woredas had the highest vulnerability in terms of the natural hazard component of LVI. Ezha woreda recorded greater vulnerability to the average number of natural hazard events. The mean standard deviation of monthly average minimum and maximum daily temperatures in the 8-year period, with 0.24 and 0.41 for Sodo, with 0.5 and 0.49 for Cheha and with 0.29 and 0.34 for Ezha respectively. Indices recorded for the mean standard deviation of monthly average precipitation were 50.05 for Cheha, 48 for Sodo and 47.13 for Ezha (Fig. 2).

Overall LVI for Sodo was (0.39), Cheha (0.356) and Ezha (0.379), indicating relative vulnerability of these different areas to climate change.

3.1.1. LVI–IPCC

The LVI–IPCC analysis result showed (LVI–IPCC: Sodo −0.008, Cheha 0.043 and Ezha 0.029) (Table 3).

Fig. 3 shows a vulnerability triangle, which plots the contributing factor scores for exposure, adaptive capacity, and sensitivity. The triangle illustrates that Ezha woreda may be more exposed (0.32) to climate change
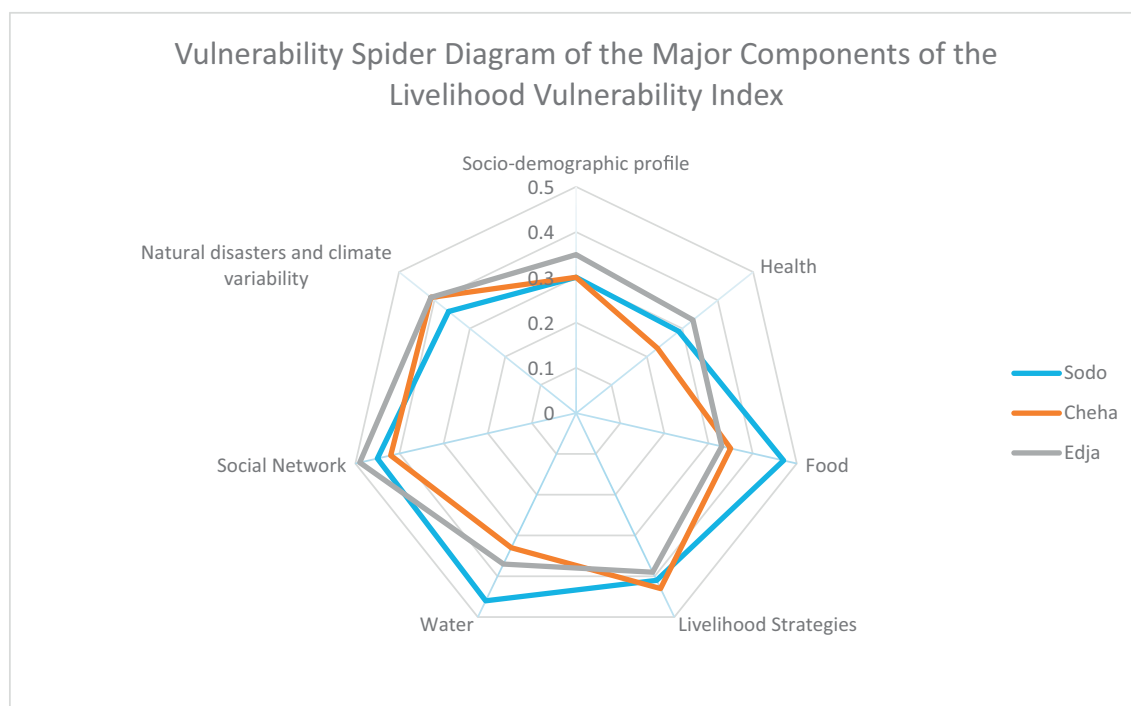
Fig. 2. Vulnerability spider diagram of the major components of the LVI for Gurage Zone.

impacts than Sodo and Ezha. However, Sodo woreda may be more sensitive to climate change impacts than Ezha and Cheha. Based on demographics, livelihoods, and social networks, Sodo showed a relative higher adaptive capacity.

Table 3
LVI–IPCC contributing factors calculation for Gurage Zone.

IPCC contributing factors to vulnerability	Sodo	Cheha	Ezha
Exposure	0.36	0.41	0.4
Adaptive capacity	0.38	0.3	0.34
Sensitivity	0.41	0.396	0.42
LVI-IPCC	−0.008	0.043	0.029

NB: The LVI–IPCC is on a scale from −1 (least vulnerable) to 1 (most vulnerable).

4. Conclusion and recommendation

The study examined the vulnerability of farm households in three agro-ecological zones of Gurage Zone using the LVI and LVI–IPCC methods for assessing relative vulnerability to climate change. Although there is difference in components relative value across the study areas, the overall LVI indicate that Sodo woreda which is found in the lowland agroecological zone were more vulnerable.

Livelihood diversification plays a key role in enhancing the resilience of household's livelihood to climate change. This finding also suggests that poorly managed livelihood activities also weakens adaptive capacities of households and increases their vulnerability. There is food insecurity in the study areas. The level of vulnerability, however, varies across households and agroecological zones. Households who are heavily dependent on natural resources to meet their food and livelihood are more affected by climate related events. There is evidence that climate change related disasters in the study areas weaken social capital, thereby reducing local community's adaptive capacities. Other factors like poor infrastructure, land shortage, population growth, lake of support by government and other concerned bodies were cited by

farmers as source of week social capital in the area. Moreover, this study found that climate-related disasters contribute to ecosystem degradation, including increased soil erosion, declining rangeland quality, deforestation and water shortage. Farmers reported that land management activities are necessary and crucial for improving natural resource use and management in the study areas. However, challenges prevail in terms of selecting suitable technologies and resource allocation which have likely decreased the efficiency and effectiveness of current natural resource management practices.

This study concludes that differences in vulnerability to climate variability and change were attributable to variations in household characteristics, lack of farm households' access to basic infrastructure, low level of diversification and lack of available technologies. Therefore, this study calls for stakeholders to prepare context-specific intervention to reduce smallholder farmer's vulnerability to climate change and strengthen the adaptive capacity of smallholder farmers.

List of abbreviations

|	
CSA	Central Statistics Authority of Ethiopia
EPCC	Ethiopian Panel of Climate Change
FAO	Food and Agricultural Organization
FGD	Focus Group Discussions
GDP	gross domestic product
HH	household
IFAD	International Fund for Agricultural Development
IPCC	Intergovernmental Panel on Climate Change
PAs	Peasant Associations
KII	Key Informants' Interviews
LVI	Livelihood Vulnerability Index
LVI–IPCC	Livelihood Vulnerability Index-Intergovernmental Panel on Climate Change
NMS	National Metrology Services of Ethiopia
PPS	probability proportional to size
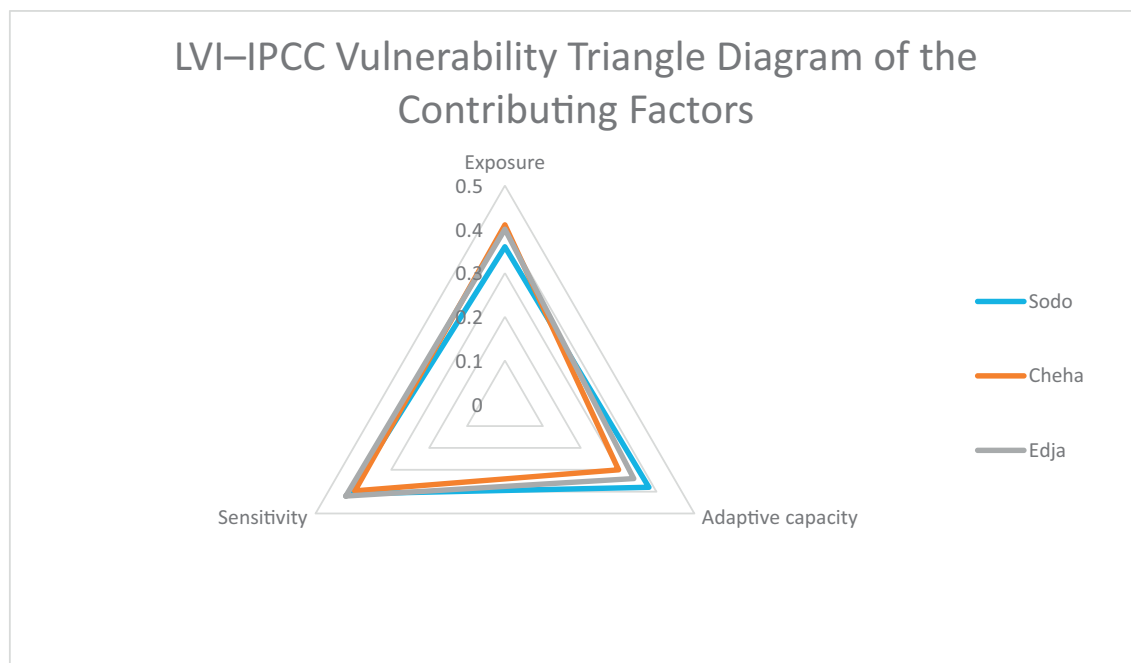
Fig. 3. Vulnerability triangle diagram of the contributing factors of the LVI–IPCC for Gurage zone.

SPSS   Statistical Package for Social Science
SNNP   Southern Nation, Nationalities and People Regional State
UNDP   United Nation Development Programme
UNFCCC United Nations Framework Convention on Climate Change
UNICEF United Nations Children's Fund
USAID   United States Agency for International Development
WFP   World Food Programme
WHO   World Health Organization

Ethical approval and consent to participate

Consent to participate in this study was received from everyone interviewed in Gurage Zone. College of Development Studies from Addis Ababa University was informed of the study.

Consent for publication

Not applicable.

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Authors' contributions

AB generated the idea, designed the study, designed the data collection tools, undertook fieldwork, analyzed the data, and developed the manuscript. BS participated in the design of the study, contributed in developing the data collection instruments, reviewed and made editorial comments on the draft manuscript. Both authors read and approved the final manuscript.

Declaration of Competing Interest

The authors declare that they have no competing interests.

Acknowledgements

References

[1] FAO (Food and Agricultural Organization), IFAD (International Fund for Agricultural Development), UNICEF (United Nations Children's Fund), WFP (World Food Programme) and WHO (World Health Organization) (2018) The state of food security and nutrition in the world 2018. Building climate resilience for food security and nutrition. Rome, FAO.

[2] Adger WN, Huq S, Brown K, Conway D, Hulme M. Adaptation to climate change in the developing world. Prog Dev Stud 2003;3:179–95.

[3] Adger WN. Adaptation to climate change in the developing world. Prog Dev Stud 2006;3(3):179.

[4] UNDP (United Nations Development Programme) (2014) Human development report 2014 sustaining human progress: reducing vulnerabilities and building resilience. Available from: http://hdr.undp.org. Accessed 18 March 2018.

[5] Boko, M., Niang, I., Nyong, A., Vogel, C., Githeko, A., Medany, M., et al (2007) Africa. Climate change 2007: impacts, adaptation and vulnerability. Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change. doi:https://doi.org/10.2134/jeq2008.0015br.

[6] IPCC (Intergovernmental Panel on Climate Change). Climate change 2014: impacts, adaptation, and vulnerability. Contribution of Working Group II to the fifth assessment report of the Intergovernmental Panel on Climate Change. Cambridge & New York: Cambridge University Press; 2014; 1757.

[7] Lobell DB, Bänziger M, Magorokosho C, Vivek B. Nonlinear heat effects on African maize as evidenced by historical yield trials. Nat Clim Change 2011;1(1):42–5. https://doi.org/10.1038/nclimate1043.

[8] Kebede A, Hasen A, Negatu W. A comparative analysis of vulnerability of pastoralists and agro-pastoralists to climate change: a case study in Yabello Woreda of Oromia Region, Ethiopia. Ethiop J Dev Res 2011;33(1):61–95. https://doi.org/10.4314/ejdr.v32i2.68611.

[9] Songok CK, Kipkorir EC, Mugalavai EM, Kwonyike AC, Ngweno C. Improving the participation of agro-pastoralists in climate change adaptation and disaster risk reduction policy formulation: a case study from Keiyo district, Kenya. In: Filho WL (ed) Experiences of climate change adaptation in Africa. Hamburg: Springer; 2011; 55–68.

[10] McBean G, Rodgers C. Climate hazards and disasters: the need for capacity building. Wires Clim Change 2010:871–84.

[11] UNFCCC (United Nations Framework Convention on Climate Change). The Nairobi work programme on impacts, vulnerability and adaptation to climate change. Bonn, Germany: Climate Change Secretariat UNFCCC; 2007.

[12] Yesuf M, Di Falco S, Ringler C, Kohlin G. The impact of climate change and adaptation on food production in low-income countries. International Food Policy Research Institute (IFPRI); 2008 [Discussion Paper 00828].

[13] NMA (National Meteorological Agency). Climate Change National Adaptation Program of Action (NAPA) of Ethiopia. Addis Ababa: NMA; 2007.

[14] EPCC (Ethiopian Panel of Climate Change) (2015) First assessment report of Ethiopian Panel on Climate Change, Working Group II: agriculture and food security. Published by the Ethiopian Academy of Sciences. Addis Ababa, Ethiopia. Available from: https://www.preventionweb.net/publications/view/46791. Accessed 13 June 2018.

[15] Mitchell T, Tanner TM. Adapting to climate change: challenges and opportunities for the development community. Middlesex, UK: Tearfund; 2006.

[16] Evans A. Resources, risk and resilience: scarcity and climate change in Ethiopia. Centre on International Cooperation. New York: New York University; 2012.

[17] Barnett C, Lemma T, Martin J, Mussa M, Vaillant C. Country programme evaluation: Ethiopia. Department for International Development (DFID). Evaluation report EV697; 2009.

[18] FAO. Climate-smart agriculture sourcebook. Rome: Food and Agriculture Organization; 2013 available at http://www.fao.org/3/i3325e.pdf.

[19] Hahn MB, Riederer AM, Foster SO. The livelihood vulnerability index: a pragmatic approach to assessing risks from climate variability and change—a case study in Mozambique. Glob Environ Chang 2009;19(1):74–88.

[20] Deressa TT, Hassan R, Ringler C. Measuring Ethiopian farmers' vulnerability to climate change across regional states. IFPRI discussion paper. Washington, D.C.: IFPRI; 2008; 806https://hdl.handle.net/10568/21518.

[21] Teshome M. Rural households' agricultural land vulnerability to climate change in Dembia woreda, Northwest Ethiopia. Environ Sys Res 2016. https://doi.org/10.1186/s40068-016-0064-3.

[22] Simane B, Zaitchik BF, Foltz JD. Agroecosystem specific climate vulnerability analysis: application of the livelihood vulnerability index to a tropical highland region. Mitig

[23] Adapt Strat Glob Chang 2014;21(1):39–65. https://doi.org/10.1007/s11027-014-9568-1.

[23] Eakin H, Bojorquez-Tapia L. Insights into the composition of household vulnerability from multi-criteria decision analysis. Glob Environ Chang 2008;18(1):112–27.

[24] Morse S, Fraser E. Making 'dirty' nations look clean? The nation state and the problem of selecting and weighting indices as tools for measuring progress towards sustainability. Geoforum 2005;36(5):625–40.

[25] Eriksen SH, Brown K, Kelly PM. The dynamics of vulnerability: locating coping strategies in Kenya and Tanzania. Geogr J 2005;171:287–305.

[26] CSA (Central Statistics Authority of Ethiopia). Population projection of Ethiopia for all regions at district level from 2014–2017. Addis: Ababa; 2013.

[27] USAID (United States Agency for International Development). Ethiopia Southern Nations, Nationalities and Peoples Region (SNNPR) overview of livelihood profiles; 2005.

[28] Israel GD. Determining sample size. University of Florida Cooperative Extension Service. EDIS: Institute of Food and Agriculture Sciences; 1992.

[29] Mohan D, Sinha S (2010) Vulnerability assessment of people, livelihoods and ecosystems. WWF-India. Retrieved from CAKE http://www.cakex.org/virtual-library/3458. [Accessed 16 June 2018].

[30] Sullivan C. Calculating a Water Poverty Index. World Dev 2002;30:1195–210. https://doi.org/10.1016/S0305-750X(02)00035-9.

[31] Adu DT, Kuwornu JKM, Anim-somuah H. Application of livelihood vulnerability index in assessing smallholder maize farming households' vulnerability to climate change in Brong-Ahafo region of Ghana. Kasetsart J Soc Sci 2018;39(1):22–32. https://doi.org/10.1016/j.kjss.2017.06.009.

[32] Hoddinott John. Shocks and their consequences across and within households in Rural Zimbabwe. J Dev Stud 2006;42(2):301–21. https://doi.org/10.1080/00220380500405501.

[33] FAO. Climate change and food security: risks and responses; 2016 (Rome).

[34] Pandey R, Kala S, Pandey VP. Assessing climate change vulnerability of water at household level. Mitig Adapt Strateg Glob Change 2014. https://doi.org/10.1007/s11027-014-9556-5.

[35] Thompson J, Scoones I. Addressing the dynamics of agri-food systems: An emerging agenda for social science research. Environ Sci Policy 2009. https://doi.org/10.1016/j.envsci.2009.03.001.