Agroecology-Based Local Communities Vulnerability To Climate Change In Tembaro District, Southern Ethiopia

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Abstract

Ethiopian agricultural system is almost all rain-fed agriculture systems, which is becoming more vulnerable to the impacts of climate change and variability. Identification of farmers' vulnerability level is important to select appropriate adaptation options to climate change. Thus, this study aimed to examine the vulnerability of communities' livelihood to climate variability and change based on different agro-ecological zones of the study area using the livelihood vulnerability index–intergovernmental panel on climate change (LVI–IPCC) method. The data was collected from a representative 154 sample households using stratified random sampling techniques. Also, the data was collected from December 2020 to February 2021 by interviewing the selected respondents, which was supplemented with focus group discussion and key informant interviews. There was a difference in vulnerability status between the selected agro-ecologies in the district depending on their livelihood strategies, access to infrastructure, characteristics of the household, and available technologies. The analysis yielded that, the overall vulnerability score for communities in highland agroecology was 0.029, midland agroecology was 0.038, and lowland agroecology was 0.114, which indicates that communities in law land agroecology are more vulnerable relative to midland and high land agro-ecologies. To enhance climate resilience or climate change adaptation strategies for vulnerable communities, there is a need to improve infrastructure facilities, diversification of livelihood strategies, provide improved seed varieties, and enhance soil and water conservation practices giving priority to more vulnerable communities. Decision-makers should plan adaptation in local contexts based on farmers' socioeconomic characteristics and livelihood strategies rather than adopting at international levels.

1. Introduction

Climate change is the dominant challenge across the world, which adversely affects the human and natural systems (1). Climate-induced hazards such as drought, flood, rainstorms, and cyclones are the major challenges adversely impacting human beings primarily due to their varying levels of vulnerability (2). Available global statistics revealed that the impact of climate change and variability-induced hazards in developing countries is much higher than in developed countries despite more exposure to the hazards (3). This shows that the difference in the level of vulnerability has resulted from different economic statuses, specifically in developing countries, it is attributed to over-dependence on the agricultural sector, low adaptive capacities, and the existence of many other hazards (4).

Agricultural activities are the backbone of the economies of most African countries that depend on the amount of rain during the rainy season (5). Thus, the increasing occurrence of climate variability-induced hazards such as occurrences of drought, variability of rainfall; flooding, and rainstorm represent serious threats to the people and their livelihoods (6). The climate change impact on agriculture is believed to be stronger in Sub-Saharan Africa (7). Specifically, the livelihoods of smallholder farmers in developing countries including Ethiopia are more vulnerable to recurrent climate variability-induced hazards like drought, late-onset and/or early cessation of rainfall, flooding, and rainstorms (8).

In Ethiopia, the average annual minimum and maximum temperatures have increased and the rainfall is characterized by seasonal and inter-annual variability in the last 50 years (5). The part of the country that experiences higher rainfall variability caused higher crop failures and livestock loss (9). Scholars suggest that droughts and the associated food insecurity and famine in the country are mainly caused by climate change

(10). Depending on the seasonal production system, the Belg (April to June) season suffers from greater rainfall variability than the Kiremt (July to September) season, and most Belg season growing areas (southern, eastern, and northeastern parts of the country) are suffering from the unreliable onset of the season and frequent crop failures (2).

In the country, the temperature has been increasing annually resulting in a decline in agricultural production, and cereal production is expected to decline still further by 12% under moderate global warming (11). Moreover, it has led to a decline in biodiversity, a shortage of food, increases in human and livestock health problems, rural-urban migration, and dependency on external support (8).

Factors aggravating the impact of climate change in Ethiopia are rapid population growth, land degradation, widespread poverty, dependency on rain-fed agriculture, lack of awareness by policy and decision-makers about climate change, and lack of appropriate policies and legislation (1). If the trend of warming and drying continues in Ethiopia, vulnerability among the agricultural farming and pastoral livelihoods is expected to increase (11). Communities in the lowland are more vulnerable due to shortage and variability of rainfall, a decline in crop production, chronic water shortages, floods, livestock, and human diseases, conflicts over pasture and water, and livestock and crop price fluctuations (12).

Accordingly, in recent times, a significant number of people in Ethiopia are being affected frequently by drought and flooding, which causes deaths and loss of assets and can lead to an appeal for international support (13). The problem is very serious in the arid and semi-arid areas, especially among the agriculture-dependent community (14). It is obvious that in Ethiopia, more than 85% of people's livelihood entirely depends on rain-fed agriculture which is vulnerable to climate-related hazards (15).

The Ethiopian economy is mainly dependent on agricultural production which is by large sensitive to climate variability, timely onset, amount, duration, and distribution of rainfall (16). Consequently, the rain-fed agricultural farmers of Ethiopia have been adversely impacted by climate variability-induced hazards such as variability of rainfall, flooding, and rainstorms (8). However, the level of impact varies with scales (national, regional, and local levels) due to the variations in their status of vulnerability to the inevitable climate variability and change. Few previous studies have been done at different scales: national level (17), regional (8) zonal level (19), and district (11).

The study area, Tembaro district in the Kembata Tembaro zone, southern Ethiopia is one of the areas characterized by high population pressure, serious land shortage, continuous cultivation, deforestation, and land degradation (20). Small-scale agriculture with traditional technology and subsistence production is a typical production system in the area. Due to very high population growth, there is a shrinkage of cultivable land per household and the landholding size for households is less than a quarter of a hectare. Furthermore, the land potential of the district is seriously threatened by soil erosion, resulting from the population pressure on land and climate variability (19). With this trend of population pressure and land fragmentation, ensuring a resilient livelihood system becomes a critical challenge.

According to (19), the Tembaro district farming community is suffering from climate disturbances like erratic rainfall in the June to September rainy seasons bringing drought and reduction in crop yields. The rainfall especially towards the end of the year has been reported as coming in more intense and destructive downpours, bringing floods, landslides, and soil erosion

To ensure a resilient livelihood system, identifying the vulnerability status and climate change adaptation strategy of the local communities is critical to delivering research-based evidence for decision-makers. Unless assessments on vulnerability and adaptation strategies of farming communities are conducted, enhancing climate-resilient community remains a dream. This calls for the need to assess the vulnerability of communities to climate change and their adaptation strategies. The overall aim is to identify the vulnerability status of the local community to climate change based on agroecological settings in the Tembaro district of southern Ethiopia.

2 Methodology

2.1 Description of the Study Area

The study was conducted in Tembaro district, Kambata tembaro zone, South Nation Nationalities and Peoples Regional State (SNNPRS), southern Ethiopia. Its elevation ranges from 1250 - 2600 m.a.s.l. It had 24 administrative Kebeles and was bordered by Omo River in the south, Hadero and Tunto zuria Woreda in the east, Soro woreda in the west, and Duna Woreda in the north. Geographically, it is located at 7° 11' to 7° 22 '30” latitude and 37° 21' 30” to 37° 36' 30” longitude. The total area of the district is about 33, 371.2ha (21).

The average minimum and maximum temperature of the study area are 16.3^{0}C and 26.5^{0}C respectively. The mean annual rainfall varies between 950 – 1300 mm *(22).* The area is characterized by a bimodal rainfall distribution including the “Belg season”, the short rainy season that occurs from March to May, and the “Kiremt” season, the longest rainy season which occurs from June to September *(20)*. Although the rainfall has a bimodal distribution, most of the crop production takes place during the “Kiremt” season (21).

The common types of land use in the district include cultivated land (39.9%), grazing land (4.7%), forest (11.8%), home garden agroforestry (31.6%), and settlement (4.8 %) and degraded area (7.2%) (21). The district is known for its dense natural forest mainly found in the periphery of Omo River and near the main town of Mudulla plantation forest in the degraded areas of the district.

The existing farming systems in the district are mixed, intensive and continuous cultivation and overgrazing are common farming practices in the area. The natural forest in the Tembaro district, particularly at the periphery of the Omo River, is under increased human pressure due to agricultural expansion, settlement, and overgrazing which are the major threats to the natural forest *(23).*

2.2 Sampling techniques and sample size Determination

A multi-stage sampling procedure was used to select the study district, Kebeles (smallest administrative unit in the district), and sample households. In the first stage, the district was selected purposely because the area is highly prone to climate change-induced shocks and stresses like recurrent droughts, floods, soil erosion, and landslides. Then the selected district was categorized into lowland, midland, and highland agro ecology based on the traditional climatic zone classification system of the agro-ecology (24). Agro-ecological zoning (AEZ) refers to the division of the living environment into smaller units, which have similar characteristics related to land suitability, potential production, soil properties, and climatic characteristic (25). In the second stage, three Kebeles: namely Gaecha from lowland, Bohe from midland, and Bada from highland agroecology were randomly selected out of the 7 Kebeles in lowland agro ecology, 9 Kebeles in midland agro ecology and 8 Kebeles from highland agroecology. Finally, a list of households was obtained from the respective Kebeles administrative office and stratified into rich, medium, and poor. The criteria for wealth category were landholding size, ability to purchase agricultural inputs and livestock numbers owned based on focus group discussions with selected local households and the development agents (DAs) of each kebele. The study by (8) also stated and used the major assets of a given community as criteria for determining wealth class. Owned Land size is an important source of livelihood and indicator of wealth in rural areas.

Table 1 Characteristics used to determine the wealth category of the household

Wealth Category	Respective criterion
Rich:	Own farm land > 2ha and/or 6 or more livestock. They could have a milk cow, one or more calves, and one or more pairs of oxen for plowing. They may have donkeys, sheep, and/or goats. They can purchase agricultural inputs (fertilizer, artificial chemicals, and improved seeds).
Medium:	Own farmland 1<X $\leq$ 2 ha having one pair of oxen and donkey. They are also able to buy fertilizer and improved seeds.
Poor:	Owing farmland 0.25 to 1 ha. They may/may not have one pair of oxen. But they are unable to buy agricultural inputs (fertilizer and improved seed). So they commonly borrow loans from the government to have fertilizer and improved seeds.

A total of 154 sample households (HHs) were selected randomly from the three Kebeles proportionally from each wealth category. The formula used to determine the sample size was following the Yamane's formula (26)

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

Where: n = the sample size the research uses,

N = Total number of household heads in study sites

e = maximum variability or margin of error 8% (0.08), and

1 = the events occurring probability

According to the Tembaro district finance and economic development office (TDFEDO), the total number of households in the study site was 4017, and hence, based on the formula indicated above 154 households were selected for this study. The total sample size distributed proportionally in each kebele is presented in Table 2.

Table 2: Sample household size distribution across selected kebele in each agro ecology.

	Agro-ecological zone	kebele	total households	sample households
1	Low land	Gaicha	956	37
2	Midland	Bohe	1596	61
3	Highland	Bada	1465	56
Total			4017	154

Approaches to measuring vulnerability

The livelihood vulnerability index (LVI) - IPCC (LVI- IPCC) was employed to estimate the vulnerability status of communities in the study area. The LVI included twelve major components and these components fully describe vulnerability in terms of exposure, sensitivity, and adaptive capacity. Sensitivity reflects the degree of biophysical response to a given change/variability in climate (27). According to (3), Exposure to climate change is defined as the "degree of climate pressure upon a particular unit of analysis, it may be represented as either long-term changes in climate situations, including the magnitude and frequency of extreme events". Adaptive capacity represents the ability of communities to cope with climate changes and variability (28). It is dependent on several socio-economic factors such as financial, physical, human, and social capital. Assets, technologies, infrastructure, and institutions are examples of indicators for adaptive capacity. Once exposure, sensitivity, and adaptive capacity were calculated, they were combined using the following equation:

LVI-IPCC= (E-Ac)*S

Where: LVI–IPCC=LVI for each kebele expressed using the IPCC Vulnerability framework,

E=calculated exposure score for the kebeles (equivalent to the Natural Disaster and Climate Variability major component) Ac=calculated adaptive capacity score for agroecology A (weighted average of the Socio-Demographic factors, Livelihood Strategies, and Social Networks, wealth, and infrastructure major components)

S= calculated sensitivity score for agroecology A (weighted average of the Health, Food, and natural resource and agriculture indicators major components).

It scaled the LVI–IPCC from -1 (least vulnerable) to 1 (most vulnerable). In general, the Steps to calculate the vulnerability index are summarized as:

Step 1: Indicators of vulnerability

Values for all the indicators were standardized for the agroecology

Indicator Index (Ix) = (Ik - I (min))/(I(max)–I(min))……………………………………….(1)

Where:

Ix = standard value for the indicator

Ik= Value for the Indicator I for a particular agroecology A.

I (min) = Minimum Value for the indicator across all the agro-ecologies

I (max) = Maximum Value for the indicator across all the agro-ecologies

Step 2: Profile of the sub-components

Indicator Indice values were combined to get the values for sub-component profiles

$$\text{Profile (P)} = \sum_{i=1}^{n} \frac{IX}{n} \quad \text{...} (2)$$

Where P= profile

Ix= indicator index

n =The profile for indicator numbers

i =The ith indicator index

Step 3: Major components of vulnerability

Values of the profiles under a sub-component were combined to get the value for major components.

$$\text{Component (C)} = \frac{\sum_{i=1}^{n} WPi * Pi}{\sum_{i=1}^{n} WPi} \quad \text{...} (3)$$

Where,

WPi is the weight of the Profile i

The weight of the profile depends on the weight of each sub-indicator.

Step 4: Vulnerability Index

The combination of the values of the three components gives the vulnerability Index.

Vulnerability Index = (Exposure – Adaptive Capacity) x Sensitivity……………………..... (4)

Scaling is done from 0 to 1 indicating low to high vulnerability

3. Result And Discussion

3.1. Socio-economic characteristics of households

Sex is a major demographic characteristic of the study population. Based on this, the sex distribution of the respondents shows that among the three agro-ecologies, in highland the percentage of male and female respondents was 88.24% and 11.76% respectively. In midland agroecology, the male and female respondents account for 86.27% and 13.73% respectively. Lowland agroecology accounts for 61.1% of male and 38.9% of female respondents. The male-headed households were less vulnerable to climate change-related shocks.

Generally, the male respondents in all sample Kebeles were 85.7% whereas the rest 14.3% were female respondents.

The age profile of Households

Regarding the age profile of the sample population, in highland 72.55% of respondents fall between 15-65 years, and 27.45% of the respondents are aged above 65 years old. Midland agroecology constitutes 78.43% of the population aged 15-65 and 21.57% of sample respondents aged above 65 years old. In lowland agroecology, the majority of sampled respondents 75 % are aged between 15 and 65 years, and 25% of respondents are aged above 65 years old. Households within the age group of 15-65 could generate income sources and they are considered less vulnerable to climate change impact. Relatively midland agroecology had more productive powers having 78.43% of the households within the age group of 15-65, followed by highland agroecology. This shows that midland agroecology was less vulnerable to climate impacts in terms of productive human resources.

Marital status of respondents

Among all respondents over the three agro-ecologies, 85.71% were married, 6.49% widowed and 7.79% were divorced. When this is interpreted at the agroecology level, in highland 88.24% of respondents were married, 5.88% divorced, and 5.88% were widowed. In midland, the majority of the households (86.27%) were married, 5.88% divorced and 7.84% were widowed. In lowland agroecology 82.69% were married, 11.53% were widowed and 5.76% were divorced, sample respondents.

Educational status

In the case of highland agroecology, the majority of respondents (45.10%) were illiterate, whereas, 39.22% and 15.68% of the households joined primary and secondary school, respectively. In midland agroecology, 76.47% were illiterate, 15.69% and 7.84% of respondents joined primary and secondary school, respectively. In lowland agroecology 80.77% were illiterate and 11.54% and 7.69% of them had joined primary and secondary school, respectively

Family size

Family size is an important variable determining the adaptive capacity of the households to climate change. It was observed that about 57.14% of the respondents had a total family size of 4-6, 33.11% of the respondents had a family size >6 and only a small percent (9.09%) of sample respondents had a total family size of 1-3 in the study area. When we proceed into each agroecology level, about 11.76%, 60.78%, and 27.45%, of respondents had the family size 1-3, 4-6, and greater than 6, respectively in highland agroecology. In midland agroecology 9.80% of respondents had a family size 1-3, 58.82% of respondents had a family size 4-6 and 31.37% of respondents had a family size greater than 6, in lowland agroecology, 5.76% of respondents had a family size 1-3, 51.92% of respondents had the family size 4-6 and 40.38% of respondents had the family size greater than 6

Livelihood strategies of households

According to each agroecology level, 62.75% of respondents in highland agroecology were engaged in agriculture and non-farm activities, 23.53% in full agriculture, and 13.73% in agriculture and safety net. In midland agroecology about 41.18% on agriculture and non-farm activities, 23.53% on fully agriculture, and 35.29% on agriculture and safety net. In lowland agroecology 46.15% on agriculture and safety net, 36.54% on full agriculture, and 17.31% on agriculture and non-farm activities. Households dependent on full agriculture and a safety net were more vulnerable to climate shocks than those dependent on non-farm activities. Relatively the highland agroecology was less vulnerable to climate change shocks.

3.2. Communities' livelihood vulnerability to climate change

In this study, the vulnerability of communities to climate change was disaggregated by agroecology. The Chi-square (χ2) test was used to see if there was a significant difference in climate change vulnerability status among communities based on their location or agro ecology.

vulnerability Category	Respective criterion
Communities with less vulnerability	Diversified income source with own farmland > 2ha and/or 6 or more livestock. They could have a milk cow, one or more calves, and one or more pairs of oxen for plowing. They may have donkeys, sheep, and/or goats. They can purchase agricultural inputs (fertilizer, artificial chemicals, and improved seeds).they have diversified income sources and are less dependent on agricultural income sources
Communities with intermediate vulnerability	Own farmland 1<X ≤ 2 ha, having one pair of oxen and donkey. They are also able to buy fertilizer and improved seeds.
More vulnerable communities	Owing farmland less than 1 ha and more dependent on agricultural income sources. They may/may not have one pair of oxen. They have infertile land for agriculture and they are unable to buy agricultural inputs (fertilizer and improved seed). So they commonly borrow loans from the government to have fertilizer and improved seeds.

The Chi-square (χ2)) result revealed that agroecology has a statistically significant effect on community vulnerability to climate change at a 5% level of significance.

Table 3: The effect of agroecology on the vulnerability status of communities

		Vulnerability status			Chi-square	effect size
Agroecology	Kebele	Communities with high vulnerability	Communities with moderate vulnerability	Communities with Low vulnerability	χ^2	
Highland	Bada	32%	28%	40 %		
Midland	Bohe	48%	21%	31%	12.991**	0.29**
Lowland	Gaecha	70%	16%	14%		

After the statistical test, the analysis for community vulnerability in agro-ecologies was provided in two steps. The findings of the individual indicator contributions to each of the indices for each agroecology are reported in the first phase, along with the overall Livelihood Vulnerability Index (LVI) (Table 4, Fig. 2). Second, we developed indices for the three dimensions of community vulnerability (exposure, sensitivity, and adaptive capacity) to climate change for each agro-ecology using the equation Livelihood Vulnerability Index - Intergovernmental Panel on Climate Change (LVI-IPCC) (Table 5, Fig. 3).

The livelihood vulnerability index results in Table 4 show factors contributing to communities' vulnerability in highland (Bada), midland (Bohe), and lowland (Gaecha) agroecology. The communities' livelihood vulnerability of the three agroecology indices of the twelve major indicators is summarized in the spider diagram (Fig. 2). As shown in figure 2 below the scale starts from 0.199 (less vulnerable) to 0.9 (more vulnerable) for the exposure and sensitivity components indicators and the inverse is true for the adaptive capacity component indicators.

3.2.1 Contributing factors for climate change vulnerability of communities

The major components of community vulnerability are grouped into the contributing factors namely exposure, sensitivity, and adaptation capacity to compute the LVI-IPCC (Table 5). Exposure includes the score of the climate variability and disaster index; sensitivity is composed of health issues, water access, input access for agricultural production, agriculture, and food are major indices. While adaptive capacity is made up of aggregated scores of six major components of the socio-demographic index, livelihood strategies, social network, technology/innovation, wealth, and infrastructure. Figure 2 depicts that communities in lowland agroecology scored higher indexed value for natural resources, food, and health issue index. In contrast, communities in the lowland agroecology scored lower values in wealth, technology, demographic, and social network indicators, whereas communities in the midland agroecology scored lower indexed values in climate variability and disaster, health, natural resources, food, infrastructure, and livelihood strategies indices and higher values in wealth, technology, agriculture, and social network indices. In contrast, the communities in midland agroecology have lower vulnerability factors for exposure components and intermediate scores for both adaptive capacity and sensitivity factors. Communities in the highland agroecology scored a higher adaptive capacity value, the intermediate score for exposure, and a low score for sensitivity as indicated in Table 4.

Table 4: major and sub-component Indexed score for vulnerability

Category	Major indicators	Indexed value of each component			Sub component indicator	Indexed value for each component		
		Bada	Bohe	Gaecha		Bada	Bohe	Gaecha
Adaptive capacity	Demographic Indicators	0.529	0.546	0.419	Percent of male-headed households	0.979	0.849	0.725
					percent HH heads had attended school	0.546	0.530	0.396
					Inverse of dependency ratio in the sample	0.478	0.460	0.327
					percent of productive age grouped family member	0.645	0.890	0.651
Adaptive capacity	Livelihood strategies indicators	0.611	0.520	0.532	Farm experience in year	0.348	0.350	0.321
					Access for energy source	0.576	0.482	0.475
					percent of HHs use change in the farming system	0.784	0.723	0.555
					percent of HHs planting high-yielding varieties	0.744	0.594	0.645
					percent of HHs practicing crop rotation	0.696	0.684	0.645
					percent of HHs diversified into non-farm income	0.694	0.524	0.595
					percent of HHs growing drought-tolerant crops	0.831	0.743	0.868
					percent of HHs practicing agro-forestry	0.826	0.544	0.685
Adaptive capacity	Social network indicators	0.598	0.446	0.367	percent of HHs Participant in group activities	0.634	0.543	0.515
					percent of HHs membership in farm organization	0.693	0.530	0.390
					percent of HHs having access to borrow money	0.713	0.410	0.370

					through social network			
					percent of HHs having access to local Gov.t assistance	0.575	0.570	0.330
					percent of HHs who have access to labor support from a community member	0.376	0.280	0.230
Adaptive capacity	Technology indicators	0.660	0.526	0.416	percent of HHs use soil water conservation	0.843	0.686	0.536
					percent of HHs use inorganic fertilizer	0.843	0.680	0.78
					Percent of HHs use improved seed supply	0.78	0.660	0.29
					Percent of HHs use of irrigation	0.196	0.080	0.060
Adaptive capacity	Wealth indicators	0.199	0.209	0.167	Farm size (hectare per HHs)	0.224	0.219	0.204
					Number of livestock in TLU/HHs	0.155	0.176	0.154
					Savings (amount of Birr per households)	0.153	0.151	0.151
					Non-agricultural income	0.117	0.113	0.108
Adaptive capacity	Infrastructure indicators	0.232	0.272	0.570	Access to schools(distance)	0.362	0.130	0.78
					Access to veterinary services(distance)	0.343	0.185	0.65
					Access to markets(distance)	0.215	0.205	0.33
					Access to savings(availability)	0.389	0.125	0.326
					Access to energy(source)	0.235	0.540	0.46
					Access to main road(distance)	0.285	0.535	0.68
					Access to health service(distance)	0.143	0.185	0.67
Sensitivity	Health	0.272	0.435	0.746	Percent of family	0.137	0.220	0.794

	indicators				members faced with chronic illness			
					Percentage of HHs faced with the incidence of malaria	0.060	0.200	0.824
					Percentage of HHs faced the incidence of water-borne disease	0.137	0.184	0.813
					Percentage of HHs faced with the incidence of deficiency disease	0.118	0.204	0.823
					Percent of HHs missed school or work days due to illness	0.260	0.345	0.745
					Percent of HHs without sanitary toilet	0.300	0.281	0.343
					Percent of HHs without health insurance	0.890	0.910	0.882
Sensitivity	Water access indicators	0.365	0.615	0.687	The inverse access to the water sources for domestic use	0.670	0.940	0.835
					average distance to water sources	0.060	0.090	0.539
Sensitivity	Input access indicators	0.373	0.493	0.583	Inverse of land suitability for farming	0.120	0.160	0.431
					The inverse of the use of soil and water conservation practices	0.220	0.340	0.476
					Inverse of irrigation potential	0.780	0.680	0.843
Sensitivity	Agriculture indicators	0.429	0.473	0.229	Average annual total rain fed agricultural production tons per HHs	0.078	0.086	0.168
					The diversity crop species(inverse)	0.290	0.660	0.780
Sensitivity	Food indicators	0.295	0.663	0.874	Food insufficient months/year	0.371	0.444	0.604
					Present of HH didn’t save crop last	0.295	0.563	0.874

					year			
Exposure	Climate variability and disasters	0.556	0.492	0.596	Mean standard deviation of maximum daily temperature 1989–2019	0.658	0.668	0.678
					Mean standard deviation of minimum daily temperature 1989–2019	0.383	0.393	0.403
					Mean standard deviation of monthly average precipitation 1989–2019	0.632	0.612	0.592
					Average no. of drought occurrences in the last 10 years	0.496	0.489	0.659
					Average no. of flood occurrences in the last 10 years	0.362	0.220	0.507
					Average no. of land slide occurrences in last 10 years	0.804	0.569	0.735

3.2.1.1 Components of Exposure

The indices for exposure of communities were developed based on six sub-components such as drought, landslide, flood, average precipitation, and average minimum and maximum temperature. The results revealed that the low land agroecology(Gaecha) was more exposed to climate-induced hazards, with a higher total exposure index (0.596), followed by midland agroecology(Bohe) having the indexed score of 0.492, and high land agroecology(Bada) having the indexed score 0.556, the least exposed site for climate-related shocks (Table 4). The result of the analysis reveals that in the lowland higher exposure index arises from the contributing factors such as the mean of the average minimum and maximum daily temperature, mean of average monthly precipitation, drought occurrences, flooding occurrences, and landslide occurrences. The factors were an average number of extreme event occurrences scored flood (0.507) and drought (0.659) in the last 20 years. This result is supported by (29) who reported that with the increase in the occurrences of extreme events, there was an increased vulnerability of the farmers' livelihood to climate changes

3.1.1.2 Components of Sensitivity

The term sensitivity to climate change of a system reflects the degree of response to a given change in the climate. Inputs for agricultural production, agriculture, food, water, and health indicators were selected as the sensitivity dimensions in this study. Variations in the natural assets like water access, health factors, food, and agricultural input profiles together govern the sensitivity levels (30) which supports the finding of this study

Access to agricultural input indicators

Soil and water conservation practice, land fertility for agriculture, and irrigation practices have been chosen as the indicators of the agricultural production inputs. Based on the calculated indices of the indicators for the communities of lowland, midland, and highland agro-ecologies scored 0.583, 0.493, and 0.373 average index values respectively. The average value revealed that the communities in the lowland agroecology had a higher sensitivity score, whereas communities in highland agroecology had a lower sensitivity score. This finding is in line with (8) reported as communities in the low land agro-ecologies were more sensitive to climate variability and change than communities in highland and midland agro-ecologies.

Agricultural indicators

The indicators in agriculture were annual total production and used crop species diversity. The index of agricultural indicators for communities in lowland, midland, and highland agro-ecologies were 0.229, 0.473, and 0.429 respectively. There was a difference among the three agro-ecological communities in terms of the indicator values. The total average annual production per household indicator score is highest for communities in the midland agroecology and the least for the lowland agroecology communities. Communities in the lowland agroecology having less amount of production resulted from the lowest per capita landholding size in the agroecology. This can be interpreted as the higher the productivity the higher the adaptive capacity, and the lesser the vulnerability. In terms of average positive changes in productivity per unit hectare, the study revealed that the highest yield is in the midland (0.473), whereas the least for lowland agroecology communities (0.229). The highest agriculture productivity in the midland agroecology is accounted for by the highest agricultural technology usage (use of fertilizer, pesticides, irrigation system) of the farmers. Regarding the crop diversity indicator score, the highest was found for communities in the highland and the least in lowland agroecology. It can be interpreted as the higher the crop diversity the lower the vulnerability. A diversified source of communities' livelihood minimizes the vulnerability of the community to climate variability and change (31) which supports this study found.

Health issue indicators

Based on the overall health sensitivity score, communities in the lowland were more sensitive with a weighted average score of 0.746, whereas communities in the midland (0.435) showed less sensitivity. Communities in the lowland had a high health index (0.824), showing that the community's well-being was more sensitive to climate-related shocks than other communities in midland and highland areas.

The sensitivity of the community members to chronic illness in the highland, midland, and lowland were 0.137, 0.220, and 0.794 respectively. Sensitivity to the incidence of water-borne disease in highland, midland, and lowland scores 0.137, 0.184, and 0.813 respectively. Sensitivity to the incidence of deficiency disease and health insurance were, in highland 0.118, 0.890, midland 0.204, 0.910, and lowland 0.823, 0.882 respectively. In general, this implies that communities in lowland agroecology are more sensitive than communities in midland and highland agroecologies. This result is similar to the findings by other studies such as (14), (15), and (8) who reported communities in the lowland agroecology were more sensitive to health-related issues relative to highland and midland agroecology.

Indicators of access to water

The indicators of access to water showed that communities in the lowland were more sensitive (0.687) than communities in the midland (0.615) and highland (0.365) agro-ecologies. The average time taken to get a water source was higher for communities in lowland (between 1 to 2 hours) than for communities in midland (between 30 to 60 min) and highland (less than or equal to 30 min). This indicates that communities in the low land agroecology were more sensitive than communities in the midland and high land agro-ecologies.

According to the FGD and KII, the majority of the households in the study areas reported that there was a shortage in the availability of pipe and boreholes. Communities from the lowland agroecology stated that natural springs and other natural water sources have dried up during the dry season and that leads to the inconsistency of water availability in the source. Sensitivity to water access in a rural area is mainly caused by the high dependence of livelihoods' on water sources and the existence of poor infrastructure to access the water resources (29) this finding supports our study output.

Food shortage indicators

The study revealed that communities in lowland agroecology were found to be with a high index for food shortage (0.874) than midland (0.663) and highland (0.295). Communities in the lowland agroecology reported that, on average, 8 months per year, they had struggled to provide adequate food for their families, which was higher than midland 6 months per year and highland 5 months per year. As the respondents reported that there were difficult periods for obtaining food during the off-season and inter-cultivation periods. The respondents in the lowland reported that they didn't save food grains but the highland and midland farmers saved food grains. This result is supported by (10) findings, that farmers who save food grains for off-season were less sensitive to food shortages than those who do not save food grains.

3.1.1.3 Components of Adaptive capacity

Adaptive capacity depends on several socioeconomic factors such as socio-demographic and wealth indicators. Each detail of the indicator values of the respected agroecology is presented in Table 4 above. The adaptive capacity and vulnerability are inversely related which means the higher adaptive capacity implies the lower the vulnerability of the community to climate change impact.

Wealth indicators

In this index, there are four indicators including average farm size, number of livestock, existing savings, and non-agricultural income per household (HH). The analysis of the index revealed that communities in the lowland agroecology had a low adaptive capacity having an average value of 0.167, whereas communities in the midland had a comparatively higher adaptive capacity with an average score of 0.209 and an intermediate adaptive capacity for highland communities with the score of 0.199. The lower adaptive capacity of communities in the lowland agroecology presumably accounted for the lower livestock ownership, lower average farm size per household, and minimal average non-agricultural income. In line with this, the average livestock number score was 0.176 for communities in the midland and 0.154 for the communities of the lowland agroecology. The result is interpreted as higher per capita livestock holding means a higher adaptive capacity (Table 4). The other indicator in this indices was the total average of agricultural landholding. Farmland size and adaptive capacity had a direct functional relationship; that means, as farmland size increases, adaptive capacity increases and vice versa (29). This is true because it provides an opportunity for crop diversification and the implementation of soil conservation measures. In terms of this indices score, the least adaptive capacity score for lowland communities has the value of 0.204, and the highest for highland communities havening an indexed score of 0.224. From this, it can be interpreted as communities in the lowland agroecology had law adaptive capacity than midland and highland agroecologies. Therefore, this entails that adaptive capacity was highly influenced by farmland holding size, and agricultural technology usage.

The income from non-agricultural (off-farm) activities was higher in the highland agroecology community than in the midland and lowland agroecologies. However, the analysis revealed that the overall non-agricultural income in the Tembaro district is minimal. This implies that the communities in the district were more dependent on agricultural income. In fact that the larger dependence on agriculture greatly increases vulnerability to climate change since cropping problems associated with climate variability can cause remarkable reductions in income. In terms of the average existing saving, the highest for communities in the highland agroecology (0.153) and the least for both midland and lowland agro-ecologies (0.151). This indicator has a direct relationship with adaptive capacity because farmers with higher savings become less vulnerable which is supported by (8) reported as farmers having good wealth status

Technology/innovation indicators

The technological usages of the community determine their level of adaptive capacity. The agricultural technology usage increases, productivity proportionally increased and the level of adaptive capacity increases, and vulnerability is reduced. The technology indices for communities in the highland, midland, and lowland AESs were 0.660, 0.526, and 0.416 respectively. Based on the indices value, it is clear that the highland AES has better adaptive capacity. The higher adaptive capacity of the highland AES was attributed to the relatively high number of agricultural inputs usages. The higher average productivity of communities in the highland agroecology in agricultural indices was attributed due to the higher usage of agricultural technologies like an improved seed, insecticides, use of irrigation, and fertilizer application. The least technology usage, which entails lower adaptive capacity (0.416), and the highest vulnerability of lowland AES were associated with low agricultural input usage (fertilizers, improved seeds, soil water conservation) and use of irrigation practice by communities.

This result supported by (12), (15), and (14) presented as an application of useful agricultural inputs and technology has a great role in enhancing the adaptive capacity to reduce the farmers' vulnerability to climate variability. Generally, according to sources from the district agricultural officials verified during the focus group discussion, farmers in the tembaro district have a long tradition of using agricultural inputs (fertilizers, improved seeds, soil water conservation); however, an insufficient supply of these inputs was the major problem in the area. In the study area, there was a low performance of the local breeds, inadequate veterinary service, and a high prevalence of animal diseases are some of the constraining factors that adversely affect livestock productivity in the district.

Indicators of infrastructure

Infrastructure is another issue that determines the level of adaptive capacity of the community residing in the study area. Indicators of infrastructure like access to schools, veterinary services, markets, savings, electricity, main road, and health service were assessed in the study area. Out of the total seven indicators included in the infrastructure indices, the analysis for time spent to access all main roads, schools, and veterinary services have an inverse functional relationship with adaptive capacity. This shows that, as time spent to access basic infrastructures or services decreases, adaptive capacity increases, vulnerability decreases, and vice versa.

The result implies that the average time spent to access health services in the highland, midland, and lowland were scored the inversed index value for the indicators 0.143, 0.185, and 0.67 respectively. Therefore, this shows that as the time spent to access health increases, the adaptive capacity of the community decreases and vice versa for indicators in the specific agro-ecologies. The same procedure was followed to determine the indices of access to schools, veterinary services, and markets. In the access to electricity indicator, out of the total surveyed respondents, 86.3% of communities in midland, 97.8% in highland, and 91.5% in lowland agro-ecologies had no access to electricity which implies that the community has less adaptive capacity in terms of access to electricity.

The highest infrastructure average index value was observed from the communities of midland agroecology 0.084 and the least value was observed from the communities of lowland agroecology 0.053. The higher index value means higher adaptive capacity and lower vulnerability. According to (15), insufficient access to infrastructural services results in law adaptive capacity and more vulnerability of smallholder farmers to climate-related risks and its effect, which supports this study's found.

Indicators of livelihood strategies

Indices for livelihood strategies of communities were developed based on eight sub-components, and their indexed average score for communities in the highland, midland, and lowland agro-ecologies were 0.611, 0.520, and 0.532 respectively. The years of farm experience, source of energy, and change in the farming system, planting high-yielding varieties, practicing crop rotation, diversification into non-farm income, growing drought-tolerant crops, and practicing home garden agroforestry are the indicators that determine the adaptive capacity. In this case, the livelihood strategies index for communities in the highland agroecology was relatively higher implying its large contribution to enhancing the adaptive capacity of the community. Communities in lowland and midland agroecology have a low chance of making possible adjustments to anticipate the impacts of climate variability as compared to the highland agroecology. Experience on-farm work was one of the indicators used to determine the livelihood strategy indices for the agro-ecological systems. It is expected that farming experience provides the opportunity to moderate adaptive capacity to climate change impacts through adjustments in terms of choosing appropriate crop types and varieties, selection of optimal planting date, and practicing relevant crop production practices (30), the idea supports the finding of this study.

Social network indicators

It is the most important indicator to determine the adaptive capacity of the community. Under the adaptive capacity the social network index score is highest for communities in highland agroecology 0.59, and least for lowland agroecology 0.367. The least adaptive capacity of the lowland is attributed to a low level of participation in group activities, membership in farm organizations, low local government assistance, and low labor support from community members. Social indices evaluate the social capital like norms, values, and attitudes that predispose people to cooperate; develop trust, reciprocity, and obligation, and establish common rules and sanctions mutually agreed upon it (13). Also, this finding is in line with (27) who cited as a strong social network with community increases the adaptive capacity in which the level of vulnerability is reduced.

Demographic indicators

The demographic indicators are the inverse of dependency ratio, household head attended school, male-headed household, and productive age group of the family members. Communities in lowland agroecology showed the least adaptive capacity in terms of the demographic index, with a weighted average score adaptive capacity of 0.419, followed by communities in midland agroecology at 0.546 and communities in highland agroecology at 0.529. Inverses of the dependency ratio index were lower for communities in lowland agroecology than high land and midland agroecologies. Communities in High land agroecology showed a high adaptive capacity score (0.344) based on the increased percentage of household heads with basic education than midland agroecology (0.320) and lowland agroecology (0.291). This is supported by illiteracy hindering farmers' access to information, especially from written and media sources, thereby increasing their vulnerability to climatic stresses (6). In general, the vulnerability indexes of the twelve major components were summarized in the spider diagram (Fig. 2) below

The above diagram generated a similar result as discussed above in the form of a diagram, communities in the lowland agroecology scored higher values in almost all exposure and sensitivity components indexes and lower values in adaptive capacity component indexes. But communities in the high land agroecology scored higher values for adaptive capacity and lower values for almost all exposure and sensitivity components. In general, the climate, health, infrastructure, natural resources, and water indicators were strong determinants of vulnerability. The demographic, technology, agriculture, and social network profiles were other determinants that played an intermediate role with fewer differences among the communities in different agro-ecologies. Wealth and livelihood strategies indicators were not major factors as there were few significant differences among the agro-ecologies. This result is in line with the finding of (12), (15), and (8) presented as communities in different agro-ecologies have different scores of exposure, sensitivity, and adaptive capacity which results in a difference in communities' vulnerability levels among the agro-ecologies.

3.1.2 Overall vulnerability factors

The overall vulnerability index and a composite of LVI for each agroecology were calculated using the methodology in Eqn. (1) – (4) and that results in the overall communities vulnerability factors (exposure, sensitivity, and adaptive capacity) as presented in Table 5 below.

LVI-IPCC = (Exposure-Adaptive capacity)*Sensitivity

Table 5: vulnerability factor index and overall vulnerability score for agro-ecologies

Contributing factors	Bada	Bohe	Gaecha
Adaptive capacity	0.472	0.420	0.412
Sensitivity	0.346	0.536	0.623
Exposure	0.556	0.492	0.596
Overall VI-IPCC	0.029	0.038	0.114

The study used the scale of vulnerability from 0 (vulnerable) to + 1 (most vulnerable) and based on the calculation of LVI-IPCC (Eq. 4). The high values of exposure relative to adaptive capacity yield positive vulnerability scores of communities to climate change. The third factor, sensitivity can be used as a multiplier, such that higher sensitivity of community in agroecology for which exposure exceeds adaptive capacity results in a large positive (i.e., high vulnerability to climate change) LVI score. The analysis yielded the overall vulnerability of communities to climate change at 0.029, 0.038, and 0.114 for communities in highland, midland, and lowland agro-ecologies respectively (Table 5). According to this result, the relative exposure is high (0.596) and adaptive capacity is low (0.412) for communities in lowland agroecology relative to other agro-ecologies. This indicates the positive LVI score, which was classified as communities are more vulnerable since it indicates an adaptive capacity deficit and high exposure having a higher score of sensitivity as a multiplier relative to other agro-ecologies. On the other hand, exposure is medium (0.556) and adaptive capacity is high (0.472) for communities in highland agroecology, which shows the overall vulnerability of the community is estimated to be low relative to other agro-ecologies. Communities in the midland agroecology exhibit an intermediate vulnerability value. This result is similar to the findings of (29), and (12) reported as communities in lowland agroecology were more vulnerable compared to high land and midland agroecologies. In general vulnerability triangle (Fig. 3) depicted the contributing factor scores in the form of the diagram as follows:

In terms of the geographic feature, Tembaro district lowland agroecology accounts for the largest (44.7%), whereas the midland and highland agroecologies account for 26.9% and 28.4% of the total land area respectively. These further explained that 28.4% of the study area communities were under a relatively low vulnerability to climate variability and change. The estimated LVI further suggests that 44.7% of communities in the lowland agroecology with warm semiarid climatic conditions of the district are categorized as under the highest relative vulnerability. Communities in the midland agroecology covering a land area of 26.9% have a moderate vulnerability relative vulnerability status to climate change.

4. Conclusion And Recommendations

The finding examined the vulnerability of the local community to the changing climate in three agro-ecological zones of the Tembaro district using the LVI–IPCC approach. There was a difference in communities' vulnerability relative value across the three agro-ecological zones in the study area. The overall LVI indicates that communities in low land agroecology were more vulnerable compared to these communities in high land and midland agroecologies. The indicators like poor infrastructure, land shortage, and less livelihood diversification are the factors for communities' vulnerability to climate change, which were cited by communities as a source of weak adaptive capacity in the study site. Moreover, this study identified that climate-related disaster that affects the communities' livelihood including landslide, drought, flooding, and increased soil erosion, The study summarized the differences in communities' vulnerability in different agro-ecologies to climate variability and change which was resulted from a lack of community households' access to basic infrastructure, variations in livelihood strategies, low level of income source diversification, and lack of available technologies. Lack of access to infrastructures such as access to electricity and water resources, and health centers were major constraints that lead communities to become more vulnerable to climate change in the study area. Thus, there is a need for institutional support for the implementation of infrastructures like pipe water resources availability, health center accessibility, and access to electricity to cope with changing climate. In the study area, communities in the lowland area are more vulnerable to climate shocks than communities in midland and highland agro-ecologies, so there is a need for the implementation of additional adaptation strategies to the changing climate. Based on the findings decision-makers have to look away to provide critical inputs that can improve the communities' adaptation strategies and implement new adaptation strategies to climate change.

Abbreviations

BoARD bureau of agriculture and rural development

CIA central intelligence agency

FGD focus group discussion

IPCC intergovernmental panel on climate change

IX indicator index

KII key informant interview

LVI livelihood vulnerability index

M.a.s.l meter above sea level

NMA national meteorology agency

SNNPRs south nation nationalities people regional state

TDAO Tembaro district administrative office

TDEFO Tembaro district economy and finance office

WP weight of the profile

Declarations

Endnotes

Tropical livestock unit (TLU) conversion factor: cattle = 0.7, horse = 0.8, mule = 0.7, donkey = 0.5, sheep/goat = 0.1, chicken = 0.01 (source: 32)

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Authors' contributions

Degineh Herano and Muluken Mekuyie generated the idea and designed the study. Degineh carried out the data collection, data analysis, and write-up. Muluken provided statistical assistance, read, and revised the manuscript. Finally, both authors read and approved the final version of the manuscript.

Competing interests

The authors declare that they have no competing interests

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Figures

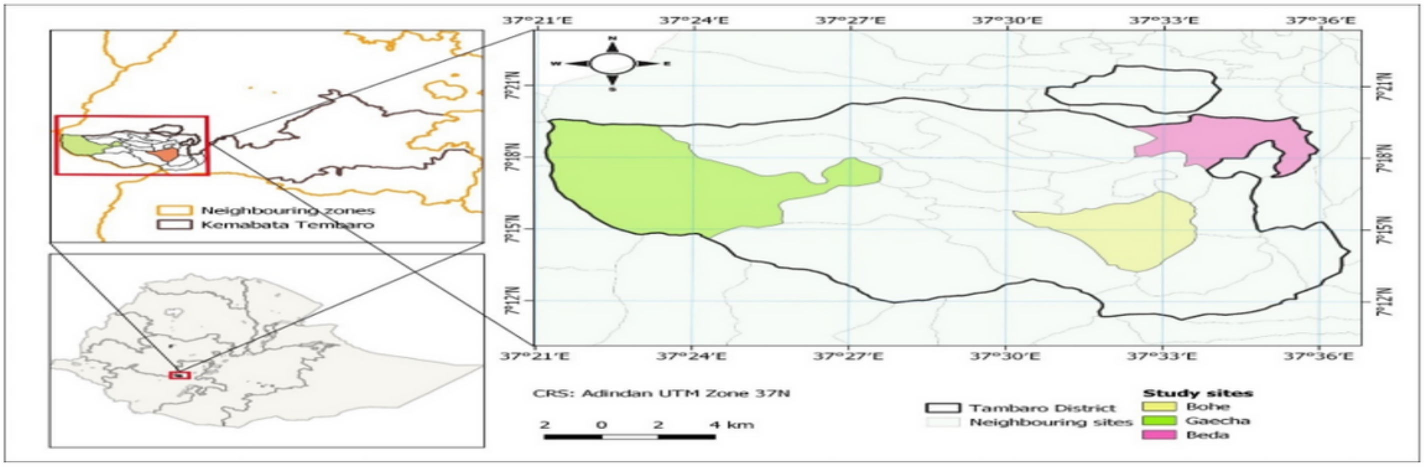

Figure 1

Map of Tembaro District

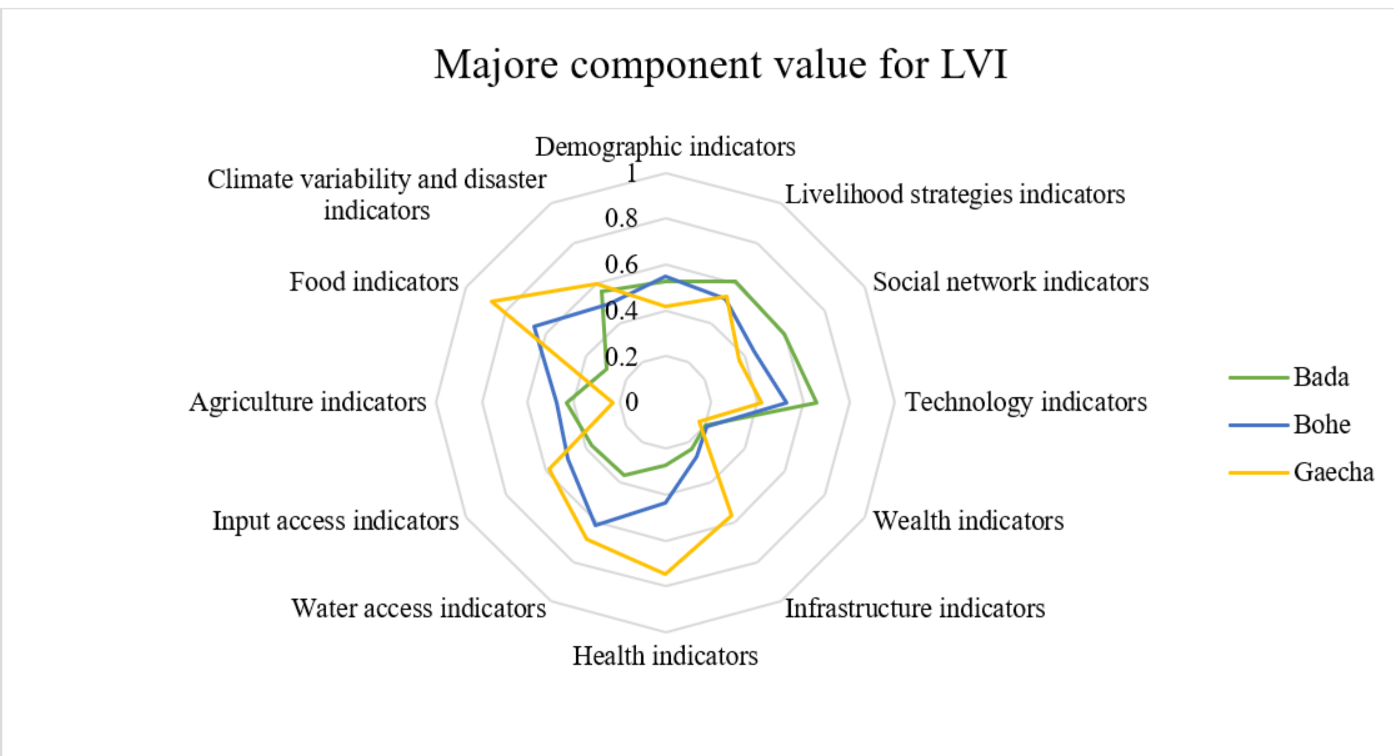

Figure 2

LVI of major components representation in the form of spider diagram

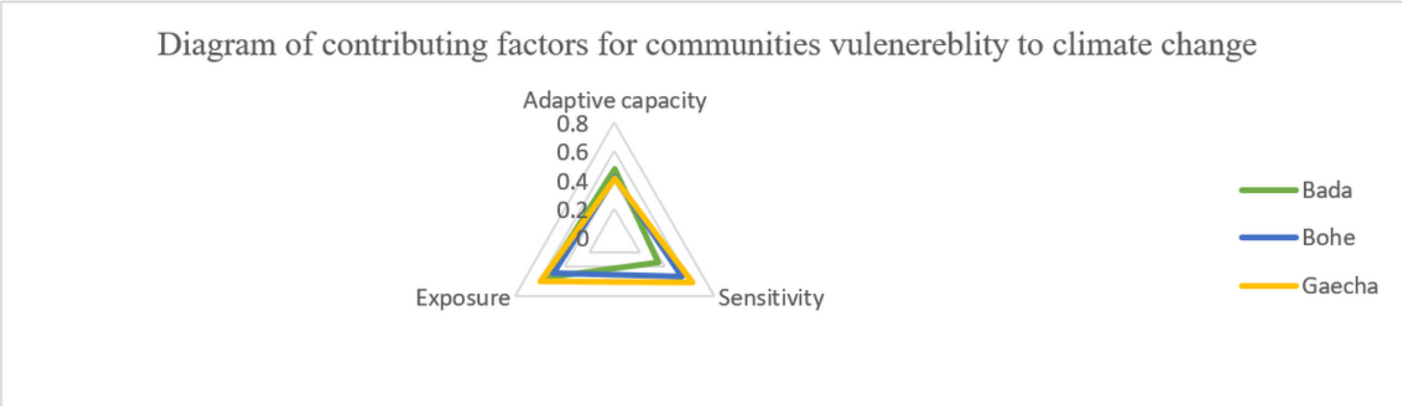

Figure 3

LVI-IPCC contributing factors diagram