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Analysis of Smallholders' Vulnerability to Climate Variability in the Rift Valley Areas of Arba Minch *Zuria* District, Southern Ethiopia

Asnake Boyana Ayele, [1] **Teshome Yirgu Bayu,** [1] **Abera Uncha Utallo**[1]**, Thomas Toma Tora**

1. Department of Geography and Environmental Studies Arba Minch University, Arba Minch, Ethiopia

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Abstract

The study assessed smallholders' vulnerability to climate change and variability, which challenges development in rural-lowland kebeles of Arba Minch Zuriya District, Southern Ethiopia. 360-questionnaire survey households were the main sources from which primary data was gathered. Both purposive (non-probability) and systematic random probability sampling techniques were used to select the respondents. Secondary data were obtained from relevant published and unpublished materials. The livelihood vulnerability index (LVI), the LVI-IPCC on Climate Variability, and descriptive statistics were used to analyse the extent of smallholders' vulnerability to climate variability. The results revealed a significant increment in the average annual temperature, no clear pattern in annual rainfall, and higher rainfall variability. Adaptive capacity (0.5139), sensitivity (0.683), and exposure (0.5043) were the three contributing factors weighted while quantifying the smallholders' vulnerability extent. Technically, 3 dimensions of livelihood vulnerability categorized into 5 major components with their index values for demographic profile (0.5375), livelihood strategies (0.448), infrastructure and social networks (0.5564), health (0.3252), and food and water (0.4242) were used to calculate smallholders' vulnerability to climate change and variability. The result of the LVI-IPCC was found to be (0.056). Resilience-building and adaptation methods are critical for minimizing the vulnerability of smallholder farmers. It is suggested that agriculture specialists and other concerned stakeholders should work together to develop lowland-appropriate rural livelihood vulnerability reduction measures.

***Keywords**: Adaptive capacity; Arba Minch Zuriya; Climate change; LVI; Smallholders*

1. INTRODUCTION

In the history of mankind, humanity has been facing varied changes both in social and environmental scenarios that require adaptation strategies for sustainable survival (Wang et al., 2022). Smallholder farmers stand for 75% of the world's farms, comprise 60% of the agricultural workforce worldwide, and provide over 80% of the food consumed in the developing world (Lowder et al., 2016; UNEP, 2013). Despite the importance of smallholder farmers to the agricultural sector, they often have limited resources to maintain or increase agricultural productivity, live in environmentally fragile and remote locations, and are often marginalized from social and development assistance programs. In such areas, ongoing stresses such as the fragmentation of landholdings also affect many smallholder farmers (Harvey et al., 2014; Vorley et al., 2012).

On almost all continents and across the seas, the effects of climate change have recently been felt by natural and human systems (Ebrahim et al., 2022). Seasonal activities, migration patterns, abundances, and species interactions are some of the global impacts of climate change, as are negative effects on crop yields. In many regions, changing precipitation or melting snow and ice are altering hydrological systems, affecting water resources in terms of quantity and quality. Terrestrial, freshwater, and marine species have shifted their geographic ranges (Ebrahim et al., 2022; IPCC, 2014).

2. STATEMENT OF THE PROBLEM

Currently, Sub-Saharan African countries are facing several socio-economic and environmental challenges. Some of them are poverty, diminishing resource degradation, controlling alarming population growth, improving low agricultural productivity (Temesgen, 2010). LVI was utilized to examine smallholders' livelihood vulnerability under climate change and variability by taking the primary and subcomponents of livelihood capital (Abate & Olsson, 2009).

In Ethiopia, like many other developing countries, agriculture is used as the single largest source of livelihood for the majority of the population. It also provides the largest share of economic activity, accounting for half of the GDP (CIA-World Fact Book, 2013). As agriculture is the backbone of the country, itis believed to continue to be the determinant sector to bring sustainable economic development to the country in the future as well (CSA, 2012). Nevertheless, agricultural economies in Ethiopia are heavily dependent on the timely onset, amount, duration, and distribution of rainfall. Different works of literature emphasize that countries that have economies largely based on weather-sensitive agriculture are vulnerable to climate change and its adverse results (Dejene, 2011; Feyisa, 2010).

Ethiopia, with a population of 113.7 million, is the second-most populous country in Africa (CSA, 2019). The country's economy is principally dependent on rain-fed agriculture, which is largely a 'low input and low output' subsistence production system. The overwhelming proportion (95%) of the cropped area and national annual crop production is under smallholder rain-fed farming. Apart from this, Ethiopia is frequently cited as a country that is highly vulnerable to climate variability and change (Conway & Schipper, 2011; Kindie et al., 2015; World Bank, 2010).

Historically, Ethiopia has been prone to climate-related hazards where the rainfall is highly erratic. In addition, most rain falls heavily and with considerable spatiotemporal variability. Ethiopia's high vulnerability to climate change and related consequences arises from a plethora of drivers. First, due to the heavy dependency of the economy on rain-fed agriculture and the risks associated with rainfall variability in this regard, long-term records indicated that repeated rainfall failures resulted in chronic food insecurity. This includes famines due to substantial losses of crops and livestock. Second, as a result of the low level of transfer and adoption of improved agricultural technologies and practices, they are required to meet the production needs of the changing environment. Thirdly, the topographical conditions that cause severe land degradation problems are coupled with the low adaptive capacity to adverse impacts of climate variability and change (Kindie et al., 2015; Simane et al., 2014; World Bank, 2010).

In the country, for the last 50 years, the average annual minimum temperature has shown an increasing trend of 0.2 °C per decade (Tesfaye et al., 2015). The annual rainfall variability in most parts of the country remains above 30% (Kindie et al., 2016). Pieces of evidence also suggest that recurrent droughts and the associated food insecurity and famine in Ethiopia are mainly caused by climate, particularly rainfall variability. In terms of seasonal production, the Belg (April to June) season suffers from greater rainfall variability than the Kiremit (July to September) season, and most Belg season growing areas (eastern, northeastern, and southern parts of the country) are suffering from the unreliable onset and cessation of the rainfall season and recurrent crop failures (Abera et al., 2011; Conway & Schipper, 2011; Kindie et al., 2016).

Under climate variability and change, shreds of evidence indicate that changes in rainfall patterns cause the relocation of suitable areas of agricultural production for different crops in Ethiopia. It was anticipated that by 2020, the major cereal crops of Ethiopia, such as maize, teff, sorghum, and barley, were to lose over 14%, 11%, 7%, and 31% of their suitable areas of production, respectively. Besides, climate variability and change also affect the duration of crop growth by slowing or hastening growth and development processes (Evangelista et al. 2013). Additionally, Kassie et al. (2014), using two crop simulation models under various climate change scenarios, predicted a reduction of maize growth duration by 14 to 33 days in the Central Rift Valley of Ethiopia in 2050 compared to the present due to higher temperatures and variable rainfall conditions.

According to Tessema and Simane (2019) and the IPCC (2014), vulnerability is defined as "the propensity or predisposition to be adversely affected" and includes a wide range of ideas and aspects, such as sensitivity to risk and a lack of coping and adaptability skills. Smallholder farmers in Ethiopia are especially vulnerable to climate change owing to their reliance on rain-fed agriculture, limited adaptation ability, and reliance on natural resources for subsistence (Asfaw et al., 2021).

Even though there are few research works that have been done by different contributors on the vulnerability of agriculture to climate change, they focused on the farmer’s vulnerability by considering the socio-economic aspects and overlooking the agro-ecological factors, which play a great role in its vulnerability to any change (Kindie et al., 2015; Simane et al., 2014; Temesgen, 2010; World Bank, 2010). In addition, the existing studies paid more attention to large-scale vulnerability to climate change and variability than small-scale vulnerability, like at the household level. Also, the population of Arba Minch *Zuriya* District is an agrarian community that mainly depends on rain-fed farming. This condition exposes the area to climate variability and changes, along with adverse outcomes. Though this is the case, there has not been much investigation into the vulnerability of smallholders to variability and change in climate in the study district.

Due to the above-mentioned conditions, it is imperative and very important to quantify how much smallholder farmers are vulnerable to climate change at the grassroots level (households and communities). Consequently, as a way of filling the gaps stated above, this study aims to investigate the vulnerability extent of smallholders to climate variability in the Arba Minch *Zuriya* district at the household level. This study is significant for helping build climate-resilient households in lowland communities and scaling up to other geographies with a similar setup. In order to attain the aforementioned goal, the following specific research objectives were set: a) to examine the level of smallholder farmers' vulnerability to climate change and variability. b) To identify adaptive mechanisms used by smallholder farmers to respond to climate change and variability.

3. MATERIALS AND METHODS

3.1 Description of the Study Area

Arba Minch *Zuriya* District is found in the Southern Nations, Nationalities, and People Regions (SNNPR), which geographically is situated between 4° 42'30" to 6°10'00" N latitude and 37°07'30" to 37°23'30" E (Fig. 2). The district is one of the rural administrative districts in the Gamo Zone, with a total land area of 736.7 km^2 and divided into 18 *kebeles*. It is located 505 kilometres south of Addis Ababa in the Great Rift Valley. Arba Minch *Zuriya* District is bordered on the south by the Derashe Special District, on the west by Gacho Baba and Bonke newly established districts, on the north by Dita and Chencha Districts, on the northeast by Mirab Abaya District, on the east by the Oromia National Regional State, and on the southeast by the Amaro Special District. This also includes a portion of the two lakes and their islands, Abaya, Chamo, and Nechsar National Park.

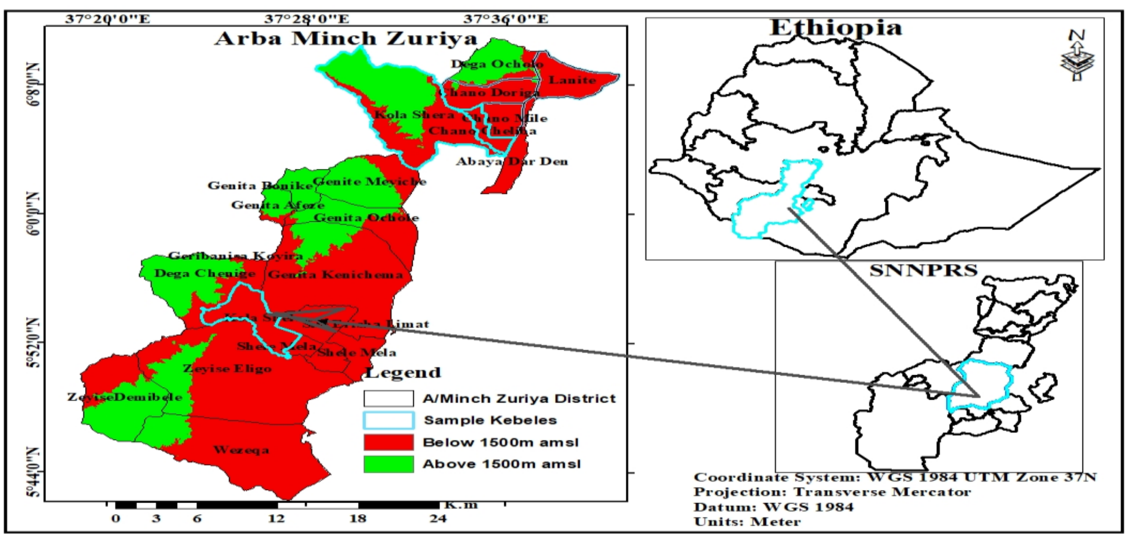


Figure 1: Map of the Study Area

3.1.1 Physiographical Description

Topographically, escarpments and narrow valleys characterize the study district. The slope ranges from 20% to 70%, which results in massive soil erosion, and its altitude lies between 1190 and 2559 meters above sea level (Habtamu et al., 2017). The drainage patterns follow the general topographic orientation, so that small rivers rising from the Gamo highlands drain to lakes Abaya and Chamo. Amongst, Hare and Baso drain to Lake Abaya whereas Kulfo, Sile, and Segen rivers drain to Lake Chamo (Arba Minch Zuria District Rural Development Office, 2020). The geology of the lower part of the study area falls into a quaternary volcano, which serves as a substrate for the dry Afromontane vegetation (Habtamu et al., 2017).

3.1.2 Demography, Land Use and Economic Activity

According to CSA (2019), Arba Minch *Zuriya* District has a total population projected based on CSA 2007 of 114,134 persons, of which 52,786 (46.25%) were males and 61, 348 (53.75%) were female counterparts; 8.76 to 10.06% of the population are village dwellers. According to the CSA's (2007) Census, the majority of the population in this district was Protestant, with 53.91% identifying that belief; 29.31% estimated Ethiopian Orthodox Christianity; and 12.6% held other beliefs.

Agriculture is found to be the backbone of the district's economy. It serves as a means of occupation for almost all the population. Banana production is particularly prevalent in lowland and semi-arid sections of the district, where farming is regarded as a source of both direct and indirect revenue for people's subsistence (BOFED, 2018). There are two cropping seasons within a year, locally known as *Gabba* and *Sila*. *Gaba's* season of cultivation partially coincides with the equivalent of summer (Kiremit), and Sila's season is similar to that of spring (*Tseday*) in Ethiopia. During the *Sila* season, crops are planted in July and August and harvested in November, while the *Gabba* crops are planted in March and April and collected in July and August (Molla & Fitsume, 2017).

3.2 Research Design, Approach and Sampling Procedure

Research design is a blueprint that guides the entire process of research activity. A cross-sectional survey design using households as a unit of analysis was used in this work, wherein both probable and non-probable sampling techniques were employed. The research approach implemented in this study was a mixed approach that was used to triangulate data using both qualitative and quantitative techniques to understand the problem clearly (Creswell, 2014).

The sample *kebeles* were carefully chosen from the Arba Minch *Zuriya* District. This is due to the fact that the adverse impacts of climate variability and change are worsening, per the authors' familiarity with the study areas. Discussions held with the different agriculture office experts initiated the researchers to quantify the extent of climate variability and change using indices and strengthen it through qualitative data. The three *Kolla kebeles* were chosen because of their shared lowland agro-ecology, easy access, and people's livelihood strategies and vulnerability to climate variability impacts, among other important considerations.

Sequentially, to perform the sampling process, a multi-staged sampling technique through a combination of sampling procedures was used to select the *Kebeles* (the lowest-level administrative units under the Federal Democratic Government of Ethiopia) and the final respondent households. In the second stage, three lowland study *kebeles*, namely*, Kolla Shara, Chano Chalba, and Kolla Shelle*, were selected. These selected *Kebeles* were known for their high level of vulnerability based on discussions with the agriculture office experts, considering the altitudes below 1500 meters for the lowland and highland of local agro-ecological zone demarcations. (Bezabih et al., 2010). In the third stage, a sample of households in each target *kebele* was identified, and the sample size was determined by the sample size determination formula of Yamane (1967), which is suitable for a finite population. The formula employed was:

$$n = \frac{N}{1 + N\left(e^{2}\right)} \qquad \text{………………………………………………………………………….. (1)}$$

Where ‘n’ is the sample size and ‘N’ represents the total households. ‘e^2’ is the precision level (0.05%), and ‘1’ is the odds of an event occurring. To allocate the calculated households proportionally into the study *kebeles*, the use of the lottery method was carried out (Table 1). To show the sampling procedure more clearly based on the total households, sample size was calculated by using Yemane's sample size calculation framework as follows:

3553/1+3553 (0.0025) =3553/9.98825=360………………………………………………. (2)

The goal was to enable the research to focus on similarities and differences in exposure, sensitivity, and adaptation strategies, depending on local context and circumstances, to climate variability and change in a specific climate zone.

Table 1. Study *Kebeles*, sampling frame and sample households

No	Name of *kebeles*	Total households			Sample households		
		M	F	T	M	F	T
1	Kolla Shara	988	97	1,085	100	10	110
2	Chano Chalba	827	223	1,050	84	22	106
3	Kolla Shelle	1,279	139	1,418	130	14	144
Total		3,094	459	3,553	314	46	360

3.3. Instruments and Sources of Data Acquisition

In order to collect the required data to attain the set objectives, different tools were employed. A structured household survey questionnaire was used to collect the primary data. The household survey questionnaire was given to sampled household heads in order to gather comprehensive data on household demographics, assets, and sources of livelihood, as well as perceptions of the local climate, the effects of climate variability or change on household livelihood, and household-level adaptation responses.

Moreover, the key informant interview was conducted with the interview respondents (experts) selected from the office of agriculture in the study district with relevant positions to the current investigation and backgrounds such as disaster risk management, food security, and livelihood security-related profiles. six (6) development agents' (DA), two (2) respondents from each *kebeles*, four (4) experts with specialization positions in rural extension development, development studies, agricultural business and economics, and an agronomist, totalling ten (10) agricultural sector experts, in order to collect qualitative primary data and triangulate the survey data. Key informant interviews and semi-structured open-ended questions were raised and administered by the researchers. The biophysical secondary data, like climate data and GIS (shape file of administrative boundary) data, were collected from the National Meteorological Agency (NMA), the National Aeronautics and Space Administration (NASA), and the Central Statistical Agency (CSA). The researchers have also accessed different secondary data from written, published, and unpublished sources like literature, websites, and government reports to carry out smallholders' vulnerability analysis.

Table 2: Sources of Biophysical Data and Processing

No	Variables	Resolution Scale(m)	Resample (m)	Data source
1	Meteorological or grid data (rainfall and Temperature) (1991-2020)	5km	30*30	NMA & CRU
2	Elevation	30*30	Original	USGS
3	Shape files (administrative boundary)	-	30*30	CSA, 2011
4	Field data	digital camera, and field observation		

3.4 Methods of Data Analysis

In this research, the researchers utilized both qualitative and quantitative (mixed approaches) data analysis. Triangulation was employed to validate the survey questionnaire findings by using key informant interview inputs on issues such as socio-economic and biophysical data assessments concerning the vulnerability of smallholders to climate vulnerability and variability. Descriptive statistics are used to characterize and explain the socio-economic, demographic, exposure, sensitivity, and adaptation capacities of the smallholders. Descriptive statistics like percentages, tabulations, summary statistics, and diagrams were utilized. The analysis and triangulation of livelihood vulnerability based on similarities and differences among three (3) selected *kebeles* were performed. Exposure, sensitivity, and adaptation strategies depending on local context and circumstances, to climate variability are assessed.

The secondary (biophysical) data like shape files, the Digital Elevation Model (DEM), rainfall, and temperature were also analysed using the ARC-GIS 10.8.1 version, the Stata 14 version, and Excel. The qualitative data inputs accessed through key informant interviews and field observations were used to substantiate the quantitative data outputs where necessary.

While analysing the data quantitatively, the Livelihood Vulnerability Index (LVI) and Livelihood Vulnerability Index-Intergovernmental Panel on Climate Change (LVI-IPCC) values were used to quantify smallholders' vulnerability to climate change. Accordingly, the descriptions and procedures for LVI and LVI-IPCC employment are presented as follows:

Vulnerability in the indicator method is quantified based on selecting indicators from the potential set of indicators and then combining them analytically to identify the levels of vulnerability (Hahn et al., 2009). In this study, all indicators of vulnerability are assumed to have equal importance, so giving them equal weight (Cutter et al., 2000) was found to be imperative. Different scholars (Aryal et al., 2014; Mohan & Sinha, 2010; Panthi et al., 2015; Simane et al., 2014) also used a similar approach in various contexts. In order to construct the LVI, Sullivan et al. (2002) noted that each main profile is composed of many indicators or subcomponents, yet each indicator contributes equally to the overall index. Standardization for each index is required because each of the indicators or subcomponents is measured on a different scale.

A profile average value is calculated as follows:

$$P= \frac{\Sigma Iv}{N} \quad (3)$$

Where P is the value for one of the described major profile and N is the number of variables in the profile. Values for each of the described profiles then combined to obtain the level LVI:

$$\mathbf{LVI}= \frac{\sum_{p=1}^{E} Np}{\sum_{i=1}^{E} N} \quad (4)$$

Where LVI is the Livelihood Vulnerability Index and Np is the number of indicators in each profile. The described profiles are combined according to the IPCC categorization scheme as follows:

$$\mathbf{CF} = \frac{\sum_{p=1}^{F} \mathbf{Np}}{\sum_{i=1}^{E} \mathbf{N}} \quad (5)$$

Where CF is an IPCC contributing factor exposure (E), sensitivity (S), or adaptive capacity (A), f is the number of profiles associated with the contributing factor, and P is the indexed value to the profiles associated with the CF.

Finally, the LVI-IPCC for the study area district was calculated as follows:

$$LVI-IPCC= (E-A) * S \quad (6)$$

The LVI-IPCC is scaled from -1 (least vulnerable) to 1(most vulnerable) and is best understood as an estimate of the relative vulnerability of compared populations.

4. RESULTS AND DISCUSSIONS

4.1. Socioeconomic Profile of the Respondent Households

Based on demographic data obtained from the sample frame, women headed 13% of households, while men headed the remaining 87%. The average age of household heads was 39 years, and the average household size was 4.5, with ranges from 1 to 9 members per household. Regarding marital status, 73% of the respondents were married, 8% were unmarried, and others were either widowed or divorced. Out of the total 228 respondents, 33% were illiterate with no formal education of any kind and thus were unable to read and write (Table 2). At the research sites, raising indigenous-breed livestock is one of the primary means of subsistence for the farmers. Due to the shortage of fodder and water, the production and productivity of the local breeds have declined from time to time. In the *Kolla* agroecology, bananas and other fruits are highly produced. On the other hand, vegetables such as tomatoes are also widely cultivated.

Table 3: Main Characteristics of the Respondents

Characteristics of respondents		Frequency	(%)
Sex	Male	314	87
	Female	46	13
Age	18-35	194	54
	36-63	129	36
	>63	37	10
Marital status	Single	29	8
	Married	263	73
	Divorced	43	12
	Widowed	25	7
Educational level	Illiterate	118	33
	Read and write	81	22
	Formally educated	161	45
Household size	1-3	116	32
	4-6	107	30
	7-9	137	38
Health status	Healthy	240	66
	Sometimes feel pain	60	17
	Chronic health problem	60	17
Occupation	Farmer	202	56
	Merchant	76	21
	Employed	63	18
	Other	19	5

4.2 Trends of Major Climatic Attributes: Implications for Variability and Change

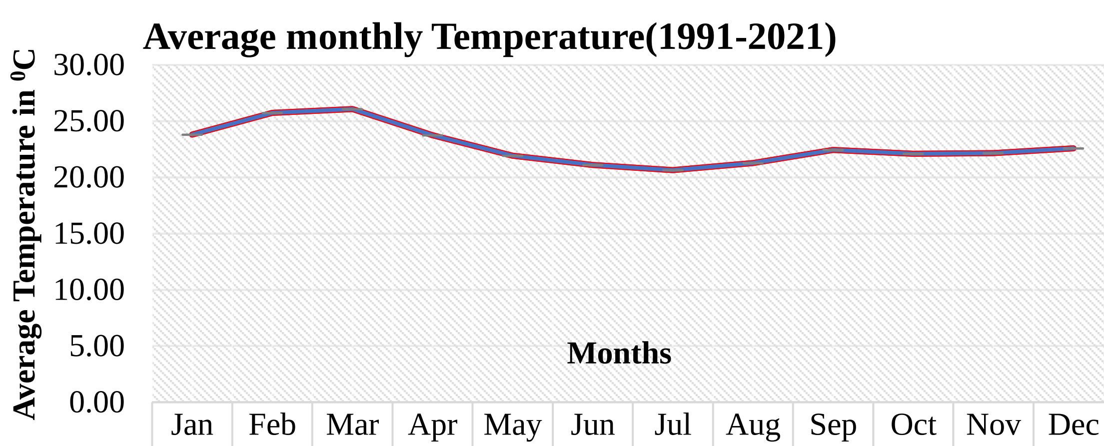
4.2.1 Trends of Rainfall and Temperature

According to data obtained from the Arba Minch and *Zuriya* District meteorological stations and extrapolated to the recently revised political boundaries, the annual rainfall in the Arba Minch and *Zuriya* District varies between 800 mm and 1200 mm, while the mean temperature is 22.75°C, fluctuating between 21.5°C and 24°C. According to the meteorological records, the district is characterized by a bimodal rainfall pattern with two rainy seasons, traditionally named Meher *(Kiremit*, June, July, and August*)* and *Belg* (February to May, long rainy season*)* (Tesfayesus, 2011*)*. The bimodal nature (having double wet and dry characteristics) of the rainfall has also been verified by other investigators (Tefera & Murty, 2016). In the following figures (3-6), the temperature and rainfall trends for the study district are presented.

4.2.2 Climate Change and Variabilities

Key informants were interviewed if they had observed variations in the weather, including rainfall and temperature. As a result, the majority of experts and households saw trends in rising temperatures and decreasing irregular rainfall patterns. Nearly all farmers believed they were facing unpredictable trends in the Belg and Bega rains, which are crucial for the growth of crops and cattle. Except for Kiremit rainfall, which shows a statistically significant increasing trend, farmers' perceptions of diminishing trends in yearly and seasonal rainfall are congruent with findings from meteorological data. Most farmers noticed a rising trend in the temperature, which was corroborated by meteorological information.

Temperature Trends



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chano Chalba	23.82	25.75	26.07	23.76	21.94	21.11	20.64	21.26	22.44	22.10	22.16	22.59
Kolla Shelle	23.82	25.75	26.07	23.76	21.94	21.11	20.64	21.26	22.44	22.10	22.16	22.59
Kolla Shara	23.82	25.75	26.07	23.76	21.94	21.11	20.64	21.26	22.44	22.10	22.16	22.59

Figure 2: Average Temperature Trends among Months in Three *Kebeles* (source NASA, 2021)

In the study area, the highest temperature was recorded in the early spring seasons (February to April) which coincides the time of equinox or over heading of sun’s angle in it shift from southern to the northern hemisphere. The lowest temperature was measured during June, July and August (summer season).

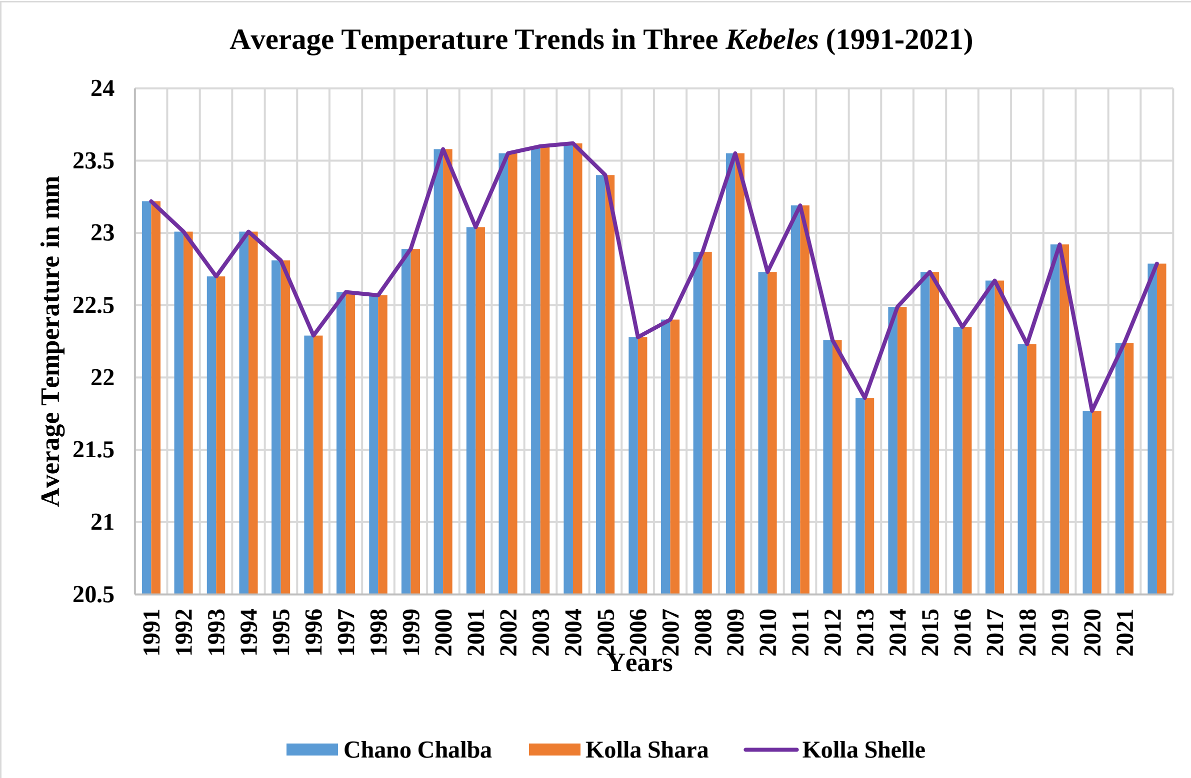
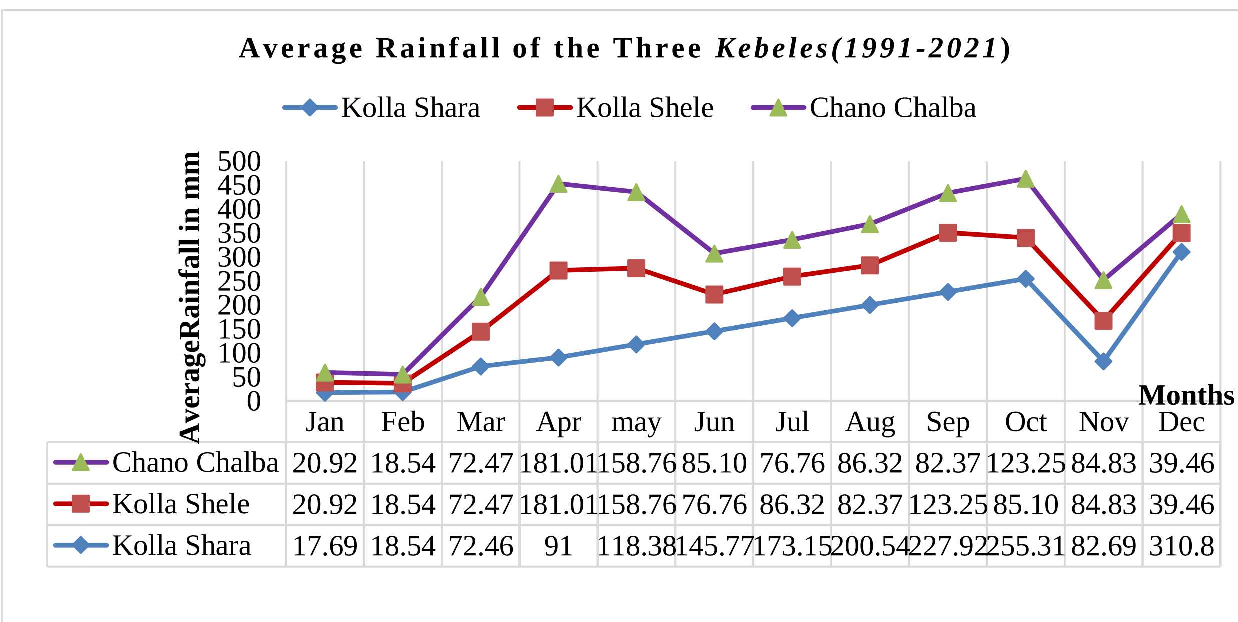


Figure 3: Mean Annual Trends of Temperature for Three *Kebeles from 1991-2021(NASA, 2021)*

Figure 3 shows that there is great variation of average temperature records in different season in the year.

Rainfall Trends



	Jan	Feb	Mar	Apr	may	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Chano Chalba	20.92	18.54	72.47	181.01	158.76	85.10	76.76	86.32	82.37	123.25	84.83	39.46
Kolla Shele	20.92	18.54	72.47	181.01	158.76	76.76	86.32	82.37	123.25	85.10	84.83	39.46
Kolla Shara	17.69	18.54	72.46	91	118.38	145.77	173.15	200.54	227.92	255.31	82.69	310.8

Figure 4: Average Rainfall Variability among the Months (NMA, 2020; NASA, 2021)

Figure 4 shows the variability pattern of rainfall measure across months in the year. Bimodal type of rainfall with two maximum rainfall record season characterizes the study area. During spring season highest amount of average rainfall in millimetre (mm) was recorded.

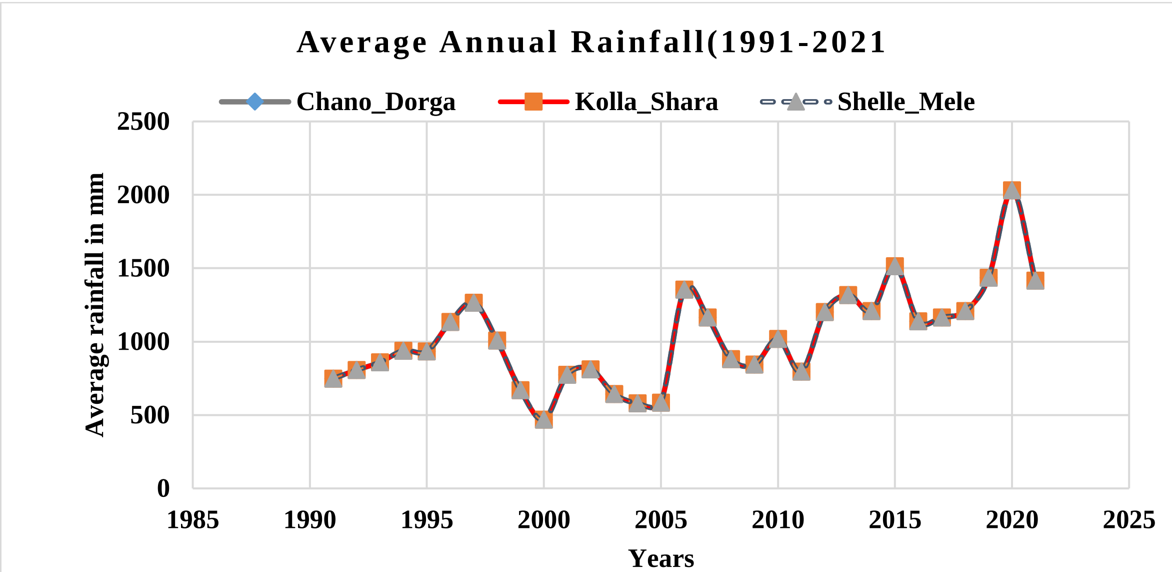


Figure **5.** Mean Annual Precipitation Trend of the Three *Kebeles* (Source: NASA, 2021)

As can be seen in Figure 5, there has been a minor upswing and downswing in average rainfall records during the past 31 years. This shows that there was a wide range in the region's average annual rainfall, making small farmers' livelihoods susceptible to variations in the climate.

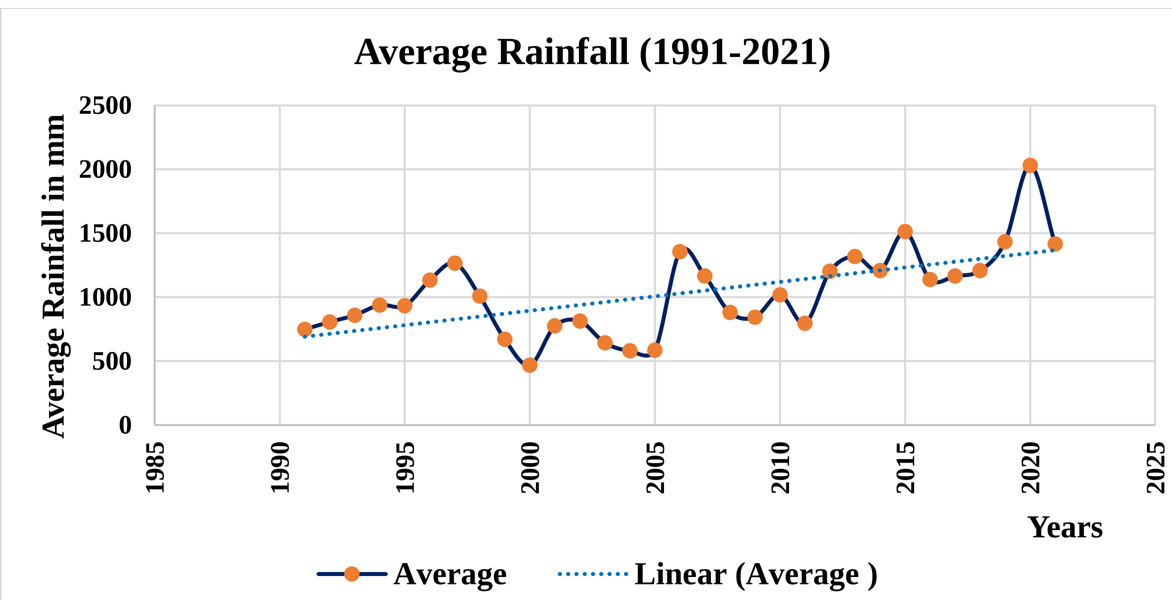


Figure 6: Rainfall Trends (Source: NASA, 2021)

4.2.3 Climate Change: Causes and Impacts from the Perspective of the Respondents

The key informant interview respondents mentioned their perceptions that rainfall intensities have been varying in the district. The temperature has increased in the past 10 years. The rainfall was characterized by a late onset and early termination for both the spring and autumn seasons. The causes of climate change showed that it could happen due to different factors. According to the key informants, deforestation, conversion of the wetlands into farmlands, emissions from tilling, cultural disobedience, and uncontrolled grazing were mentioned as the major causes of climate change and variability. The changing climate affects society and ecosystems in diverse ways. As explained by the key informants and respondent households, the following are major impacts that occurred due to climate change in the last 10 years in all study sites: In this regard, the result of house head survey data identified the following: loss of crop and livestock production and productivity; decline in water resources; loss of biodiversity (crops, animals, tree species); food insecurity and poverty; migration to other areas for seeking alternative livelihoods; increased prevalence of human, crop, and livestock diseases; and increased resource use conflict due to shortages (e.g., water).

4.3 Quantifying Smallholders' Vulnerability Extent

The LVI Results

The LVI results are shown in the following sections, demonstrating household vulnerability, which is described using the primary components (Table 4; Figure 7 & 8). As a result, implications for the vulnerability of smallholders' livelihoods are drawn. The demographic, livelihood, infrastructure, social networks, and water resource components comprise the adaptive capacity; the sensitivity and exposure components each of which has its own sub-component, provide the final score of vulnerability to varying or changing climates based on smallholders' basic capital asset components.

Table 4 summarizes the major and subcomponent LVI score comparison results for three *kebeles*.

Table 4: The Results Summary of LVI Scores

Major Components	**Subcomponents**	***Kebeles &Mean scores***		
		Kolla Shara	Chano Chalba	Kolla Shelle
Demographic Profile	Age of Household Head	0.5	0.55	0.65
	Sex Household Head	0.83	0.75	0.80
	Educational Level HH	0.3	0.50	0.6
	Family Size	0.4	0.15	0.40
	Occupation	0.1	0.20	0.3
	Mean Score	**0.42**	**0.43**	**0.55**
Livelihood Strategies	Land Size	0.65	0.35	0.25
	Access Credit services	0.80	0.5	0.55
	Practice of Livestock Rearing	0.65	0.75	0.50
	Crop Production-Based Livelihood	0.45	0.75	0.9
	Government and NGOs Provide Aid	0.5	0.65	0.80
	Access to Credit and Saving Service	0.8	0.7	0.90
	Mean Score	**0.642**	**0.616**	**0.6**
Infrastructure and social networks	Access Veterinary Service	0.85	0.3	0.45
	Average Time to Health Centre	0.65	0.2	0.2
	Access to school	0.60	0.2	0.45
	Access to Media (Tv/Radio/telephone)	0.85	0.95	1
	Access to Clean Drinking Water	0.25	0.75	0.7
	Mean score 3.2/5	**0.64**	**0.48**	**0.56**
Water resources	Availability of Irrigation Water	0.25	0.45	0.55
	Average Time to Water Source	0.3	0.6	0.1
	Water is Always Available	0.7	0.2	0.5
	Mean Score	**0.416**	**0.416**	**0.3833**
Adaptive capacity		**0.5285**	**0.4856**	**0.5233**
Degree of sensitivity	Food Insecurity/Shortage	0.95	1	1
	Death of Livestock	0.35	0.55	0.25
	Decline in Crop Yield/Livestock Productivity	1	0.95	1
	Loss of Assets	0.95	0.95	0.95
	Increasing Sickness of Family Members	0.533	0.50	0.25
	Decline in consumption	0.2	0.65	0.35
	Increasing of Crop/ Livestock Disease	0.55	0.85	0.25
	Mean score	**0.647**	**0.778**	**0.507**
Level of Exposure	My Farm/Grazing Plot Exposed to Erosion	0.45	0.50	0.45
	Death of Family Members	0.3	0.2	1
	Shifting the Time/Season of Cultivation	0.85	1	0.65
	Mean Score	**0.5333**	**0.566**	**0.7**
	LVI-IPCC= (E-A)*S)	**0.0031**	**0.0630**	**0.0895**

(Source: House Hold Survey, 2022)

In the context of the studied lowland agroecological sites, the LVI results were found to be supportive indicators of the differences in vulnerability from household to household. This condition was conformal to the findings of Thomas et al. (2021), which divulge the context of the Gamo lowland communities' vulnerability to drought hazards and other sorts of vulnerability. Besides, an attempt was made to summarize the smallholders' vulnerability with a radar chart (Fig. 7). In the diagram, the scale goes from the center (0), which is less vulnerable, to 0.8 (most vulnerable) for the exposure and sensitivity components, and the inverse is true for the adaptive capacity components.

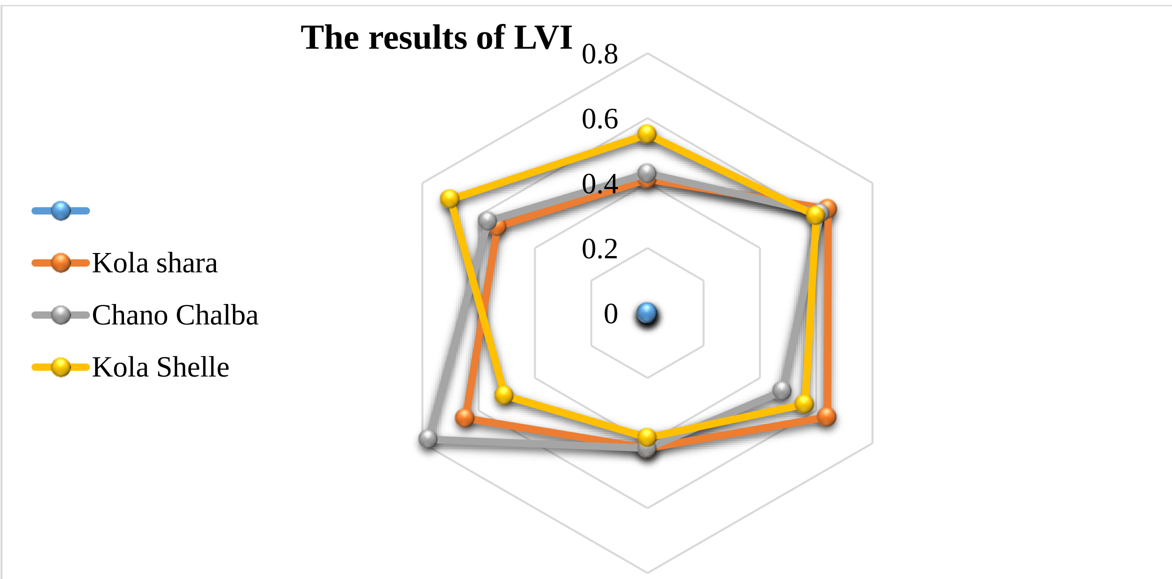


Figure 7. The Spider Diagram of LVI Results

The major components that yielded the LVI scores are elements of the four capital forms (natural, physical, human, and social) and are grouped into the contributing factors, namely, exposure, sensitivity, and adaptive capacity in order to compute the level of households' vulnerability (Table 4, Fig. 8).

Table 4. Categorizations of the Effect Dimensions by LVI Indicators

Indicators	Effect Dimensions
Human Capitals	Health
	Food
	Education
Natural Capitals	Water
	Natural Vulnerability and Climate Variability
Social Capitals	Socio-Demographic
	Social Networks
Physical Capitals	Livelihood Strategies

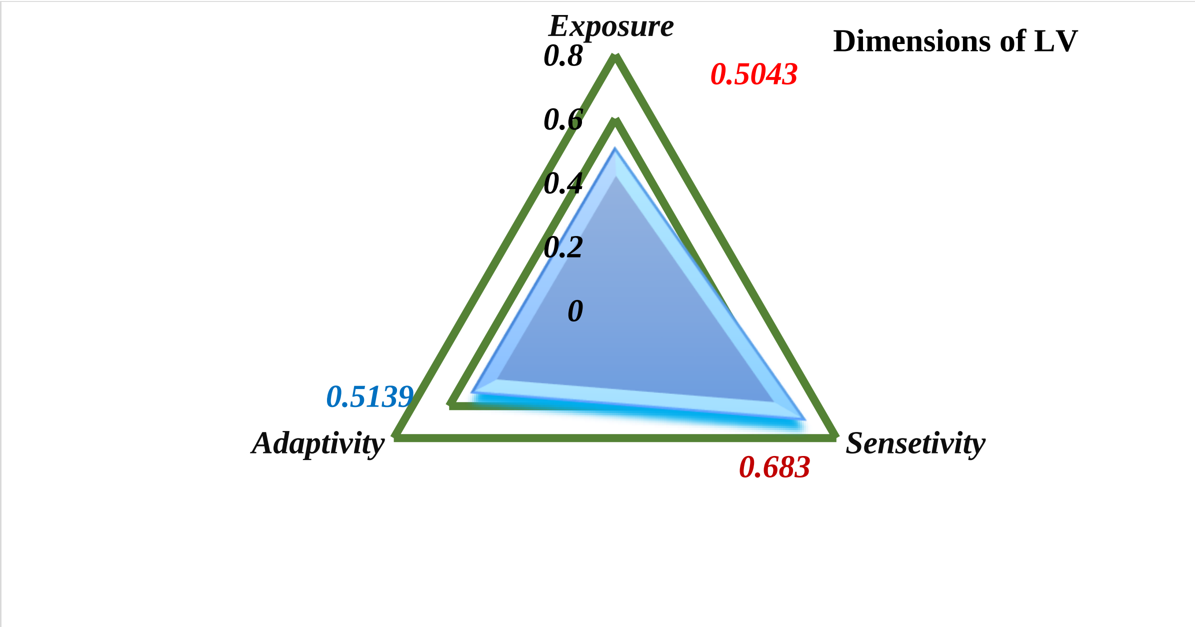


Figure 8. Summarized Contributing Factors (CF) for LVI Computation

The LVI-IPCC on Climate Variability/Change Results

The LVI-IPCC is computed by grouping the major components into three categories, namely, exposure, sensitivity, and adaptation capacity. Exposure has consisted of a score for only one major component; sensitivity and adaptation capacity are made up of aggregated scores for three major components each. The IPCC definition of vulnerability takes into consideration exposure, sensitivity, and adaptation capacity, which are represented in the vulnerability triangle as shown in Figure 9. Based on the survey data collected from the studied lowland smallholders, the analysis output reveals that there is a wide variation in vulnerability among the communities. This is observed in varying responses for exposure, sensitivity, and adaptive capacity. As the LVI-IPCC outcomes reveal, all of the indices have positive values. In general, the index ranges from -1 (the least vulnerable) to 1 (the most vulnerable) to climate change and variability (Panthi et al., 2015). Per the major components and contributing factors (CF), the vulnerability condition of the study area is identified as 0.700 for exposure, 0.507 for sensitivity, and 0.5233 for adaptive capacity, wherein the more comprehensive framework of the LVI-IPCC was found to be 0.089. This circumstance showed that the areas were most vulnerable to the varying or changing states of climate.

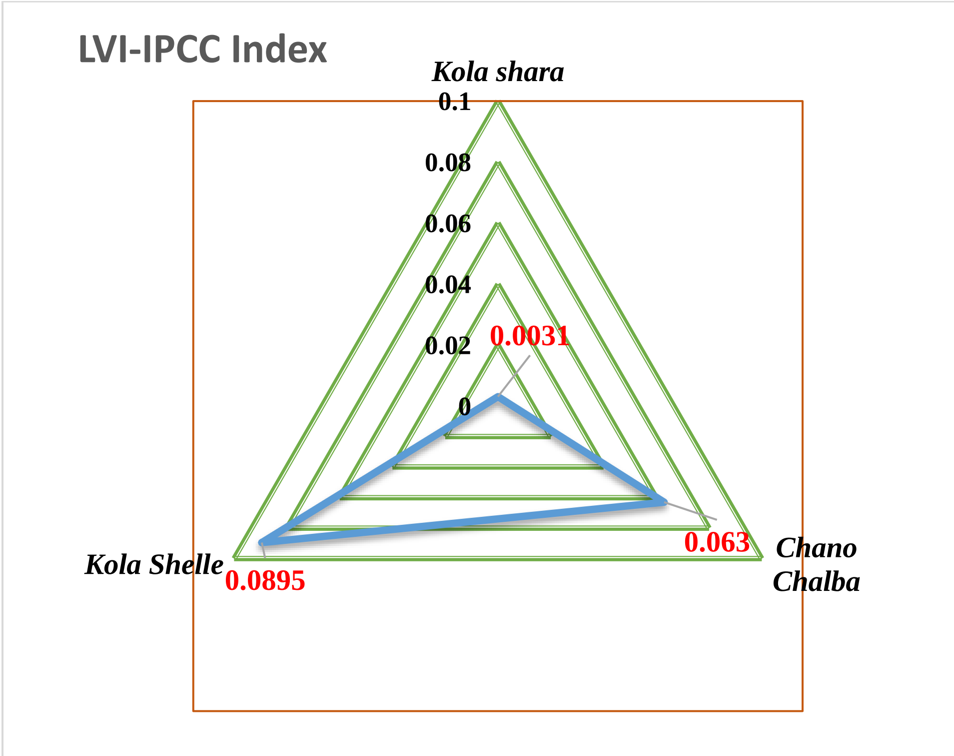


Figure 9: Vulnerability Triangle Diagrams Dimensions

The vulnerability triangle indicates that the study Kebeles are exposed to climate change. The district is moderately sensitive to climate change taking into consideration the water, health, and food status of the adaptation capacity of households, taking into account the sociodemographic profile, social networks, and livelihoods of households in the district. The LVI-IPCC is on a scale from -1 (least vulnerable) to + 1 (most vulnerable). Based on the result of the calculation of LVI-IPCC, high values of exposure relative to adaptive capacity yield positive vulnerability scores, while low values of exposure relative to adaptive capacity yield negative vulnerability scores. The sensitivity factor acts as a multiplier, such that high sensitivity for which exposure exceeds adaptive capacity resulting in a large positive (i.e., high vulnerability) LVI-IPCC score of 0.056, which is moderately vulnerable. The LVI-IPCC is the vulnerability index using the IPCC vulnerability framework, E is the calculated exposure score, A is the adaptive capacity score and S is the sensitivity calculated score. The scaled range from LVI-IPCC is from -1 (negative to value one which is least vulnerable or adaptive capacity greater than exposure) to 1 (positive value one which is most vulnerable, exposure greater to adaptive capacity). A value of 0 denotes a moderate vulnerability (exposure and adaptive capacity are equal).

5. CONCLUSIONS AND RECOMMENDATIONS

This investigation attempted to assess the smallholders' livelihood vulnerability to climate change and variability in the Arba Minch Zuriya district. Data collected through survey questions, key informants, and observation were analyzed and discussed. LVI was used to analyze smallholders' livelihood vulnerability under climate change and variability by taking the major and subcomponents of livelihood capital. The result revealed that exposure is high and adaptive capacity is low for the investigated Kolla agro-ecological households. The results call for the necessity of resilience-building adaptation strategies to reduce the vulnerability of smallholder farmers. As input for policymakers and decision-makers, the measures taken should consider site-specific mechanisms to manage the vulnerability of smallholders. The study, hence, suggests the need for tactical planning and implementation of area-specific climate change adaptation strategies.

In addition, it is crucial to integrate activities that can moderate climate variability and increase awareness of climate change impacts, climate data and information, and preparedness for climate-driven hazards among different stakeholders, including vulnerable farmers, experts, and decision-makers. This would be achieved by designing and encouraging the substitution of farming systems through skill gap pieces of training, implementing effective preparedness, and building resilience. Since the climate state of the area across months and years is not promisingly predictable, smallholder farm households are advised to diversify their livelihood strategies.

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