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Original Research

Analyzing Urban Centers' Vulnerability to Climate Change Using Livelihood Vulnerability Index and IPCC Framework Model in Southwest Ethiopia

Tesfaye Dessu Geleta[1,*], Diriba Korecha Dadi [2], Weyessa Garedew[3], Adefires Worku[4], and Gemechu Debesa[5]

[1]Ethiopian Meteorology Institute, P.O. Box 1090, Addis Ababa, Ethiopia

[2]Famine Early Warning Systems Network, P.O. Box 17413, Addis Ababa, Ethiopia

[3]College of Agriculture and Veterinary Medicine, Jimma University, P.O. Box 307, Jimma, Ethiopia

[4]Ethiopian Forestry Development, P.O. Box 24536, Code 1000, Addis Ababa, Ethiopia

[5]Department of Geography and Environmental Studies, College of Social sciences and Humanities, Jimma University, Jimma, Ethiopia

Abstract

This research examines the state of climate change vulnerability on urban households' using the Livelihood Vulnerability Index (LVI) and LVI-Intergovernmental Panel on Climate Change (IPCC) approach using 17 components in the four urban centers of southwest Ethiopia. Across-sectional study design was employed to collect both quantitative and qualitative data. A semi-structured questionnaire for 384 households, focus group discussions, key informant interviews, and field observation were used in Jimma, Bedelle, Bonga and Sokorru. The data were analyzed using SPSS version 21, R version 4.31, ArcGIS 10.2 Origion 2019 and MS-Excel 2016. The results showed that the four urban centers were vulnerable to climate disasters due to the increment of temperature, flooding, and landslides. The majority (60%) of the respondents disclosed that emergency support was not provided during the occurrence of climate-related extreme events. The results revealed that the four urban centers household communities experienced distinct degrees of climate vulnerability spatially and temporally due to differences in their exposure, sensitivity, and adaptive capacity. The results of the urban households' livelihood vulnerability index analysis showed that all urban centers were found to be vulnerable with the least at Jimma (0.40) and the highest observed at Sokorru (0.44). While the LVI-IPCC index value implied the least at Bedelle (0.01), the highest was observed at Sokorru (0.09) due to lower income, infrastructure and adaptive capacity. This calls for policy interventions that improve the community's adaptive capacity through local level resilience-building adaptation strategies that curb the vulnerability of urban centers to climate change variability and extremes.

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***Corresponding Author:**
E-mail:
tesfayegyana@gmail.com

INTRODUCTION

The great impacts of extreme weather on many urban centers each year calls for authorities' attention that the risks and vulnerabilities have to be addressed (UNISDR, 2009; IFRC, 2010). Strengthening the capacities of national, institutions, civil society, the private sector, indigenous peoples, and local communities can support the implementation of ambitious actions of limiting global warming to 1.5°C where international cooperation is a critical (IPCC, 2018). The increased concern about global warming and climate change need scientific understanding of the level of vulnerability impacts in urban areas calls for special attention (Raihan & Said, 2022; Raihan & Himu, 2023; Raihan & Bijoy, 2023) to reverse the adverse effects through devising appropriate adaptation and mitigation strategies (IPCC, 2022). Global population is expected to reach 8.5 billion in 2030, 9.7 billion in 2050, and 10.9 billion at the end of twenty-first century (UN, 2006; UN, 2019). Urban areas today are home to 55% of the world's population (UNFPA, 2018) among which more than 80% in the Latin American and Caribbean population, which will continue to grow in the next decades. The advantages of city-scale assessments are potentially significant because climate change impacts are either unique to urban areas or exacerbated in urban areas (Lindley et al., 2006; IPCC, 2022). Flood events are examples of impacts that are potentially more severe in urban areas simply because of the relatively high density of population and poor infrastructures (IPCC, 2014; 2022), more exaggerated in the impervious area due to heavy rainfall and extreme climatic events (Douglas et al., 2008).

Although climate change is expected to have adverse impacts on socio-economic development globally, the degree of the impact varies across nations. Africa, due to its low adaptive capacity and high sensitivity of socio-economic systems, is one of the most vulnerable regions highly affected by the impacts of climate change (IPCC, 2014; 2022). For each of the direct and indirect impacts of climate change, there are groups of urban dwellers that face higher risks like; illness, injury, mortality, damage of homes and assets, disruption of incomes (Hardoy and Pandiella, 2009; Mitlin and Satterthwaite, 2013). The vulnerable group people of urban poor live in locations facing greater risks for instance, on coasts or nearby rivers with increased flood risks, landslides or flash floods which occurs in hazard prone areas (Mavromatidi et al., 2018). According to IPCC (2014), the most vulnerable groups, notably, low-income groups in general; women, children, the elderly and disabled are vulnerable to direct climate change impacts actually poses a risk. Women may face higher risks in their work and constraints on adaptation (IPCC, 2014:2022) and Infants may face serious health risks when water supplies are contaminated by flooding (Bartlett, 2008). Also, elders and disables face challenged during the risks occur because of their inability to withdraw from prone places.

"Climate change assessments, including the vulnerability of low-income groups to stresses and shocks (Chambers, 1989; Pryer, 2003) and to disasters (Cannon, 1994; Manyena, 2006) have been carried out". The success of early warning systems, the speed of response, and the effectiveness of post-disaster response that have to focus an understanding of the specific vulnerabilities, needs, and priorities of different income groups, age groups, and vulnerable groups like women, marginalized ethnic groups (UN-HABITAT, 2011).

"In Africa, Ethiopia is among the most vulnerable countries to the adverse effects of climate change; mainly due to its high dependence on rain-fed agriculture, low adaptive capacity, and a higher reliance on natural resources base for livelihood" (NMA, 2007; EPCC, 2015). Also, Ethiopia frequently faced climate-related hazards commonly by drought and floods (Burnett, 2013). Ethiopia is the least urbanized countries in Africa; only 20 percent of the population resides in cities (Gebre-Egziabher, 2019). By 2030, a one third of Ethiopia's population will live in cities, placing huge burden on urban service delivery and governance systems with such Ethiopia's projected population growth (Cities Alliance, 2017). Long-term climate change in Ethiopia is related to changes in temperature, rainfall patterns, and variability derived the increase in frequency of both droughts and floods (Below et al., 2010). Vulnerability to climate change is due to inter-annual climate variability and an economy that is highly dependent on agriculture (Byerlee et al., 2007) as well as institutional factors that can create socio-economic crises (Simane et al, 2016; Smakhtin and Schipper, 2008). A major challenge is that vulnerability varies spatially based on differences in agro-ecological context, socio-economic factors, climatic impacts, and existing infrastructure and adaptive capacity that vulnerability is defined differently for different disciplines (Gallopin, 2006; Fussel, 2007).

Vulnerability defines as "the degree to which a system is susceptible to and unable to cope with, adverse effects of climate change, including climate variability and extremes (IPCC, 2007; 2014). Vulnerability is a function of the character, magnitude, rate of climate change and variation to which a system is exposed, its sensitivity, and its adaptive capacity" (Parry et al., 2007) and as an inability to cope with external changes (Hardoy and Pandiella, 2009). The urbanization that results in urban environmental changes through unplanned urban expansion for diverse use of socio-economic activities can potentially intensify cities' vulnerability to climate change impacts (Apreda et al., 2019; Revi et al., 2014). There is recent consensus that livelihood vulnerability to the changing climate varies with the scale of analysis and noted that vulnerability assessed at the national level can conceal variations in local vulnerability (Brooks et al., 2005).

Previous studies have been undertaken to assess climate change vulnerability at a national level and district level whereas failed to address local context (Amare and Simane,2017; Brooks et al., 2005; Deressa et al., 2008; Gebrehiwot et al., 2013; IPCC, 2014 and NAPA, 2019). The type of analysis that often overlooks local variations is unable to capture the full range of climate vulnerabilities across urban centers that vary with the level of socio-economic, infrastructure development, households' access to resources, and coping ability. Unlike the studies undertaken mostly on agricultural and hydrological sectors, while climate change vulnerability research in urban centers in Ethiopia is not widely available and not focused well (Feyissa et al., 2018).

Climate change vulnerability researches at the town/city level are few and scant. In particular, there is limited empirical evidence so far in the study urban centers of southwest Ethiopia thereby this study bridge the research gap in this regard. Therefore, the main objective of this research is to assess the state or the level of vulnerability of urban centers households to climate change in southwest Ethiopia as well as determine which areas are more or less exposed to sources of disaster. The empirical results of this research assist in identifying level of urban dwellers/residents' vulnerability to climate change or its extremes at the town level so that alerts concerned bodies to reduce climate induced catastrophes. Also, the findings of this research will give insights to urban actors and policy makers in devising policies that effectively promote sustainable development by taking climate change vulnerability into account in the study urban centers context.

MATERIALS AND METHODS

Description of the study Area

This study was conducted in the southwest Ethiopia's urban area, which lies between $7^0$22'N to 8^0 45'N and 36^0 23'E to 37^0 40'E. The three study urban centers Jimma, Bedelle, and Sokorru situated in Oromia Regional State and Bonga is located in the Southern Nations Nationalities and Peoples (SNNP) region as depicted in Figure 1. The altitude of southwest Ethiopia ranges from low-lying plains of 600 meters to the high plateaus of over 2000 meters to flat. The altitude of Jimma City ranges from 1720 meters above mean sea level (m.a.s.l) of the Jimma Abba Jifar Airport (Kitto) to the highest 2010 m.a.s.l of Jiren, where Abba Jifar Palace (Masara) is situated. Whereas, Bonga, Bedelle, and Sokorru lay at an elevation of 1,779, 2,011 and 1,928 m.a.s.l, respectively (Jimma Town Administration, 2019; NMA, 2019; Dessu et al., 2020; Figure 1). Jimma, which is the biggest City in southwest Ethiopia was founded in the 1830s, with the Municipality was established in 1942. According to the City's revised master plan 2019, the total area of Jimma City is about 100.2 km^2 (10,200 hectares). While, the total areas of Bonga, Bedelle, and Sokorru towns are 8,846, 2,878, and 300 hectares, respectively, with the major parts of the land is used for residential, infrastructure, and green areas based on their recent master plan.

The current city administration of the urban centers is structured from Town level to kebeles with decentralized functions of a municipality at Kebele level (the lowest administrative body in Ethiopia). The total population of Jimma City was 120,600 in 2007, which is projected to be over 265,000 by 2024 with diverse ethnic compositions in the city; the total population of Bonga Town was 20,858 in 2007, projected to be 44,046 by 2024; the total population of Bedelle Town was 19,517 in 2007, projected to reach 40,500 in the year 2024, whereas Sokorru's Town total population was 6,233 in 2007 and projected to be 25,617 by 2024 (CSA, 2007 and 2017). Each of the four towns included in this study has its own historical establishment; land uses types, structural plan, or master plan to guide development while none of them was established in the planned manner at the beginning.

Climatically, this area experienced a mean annual temperature of 14-20°C and a mean annual rainfall of 1,700-2,000mm. The study area is characterized by mono-modal type of rainy season, with the long rainy season often from March through the mid of November (Funk and Rowland, 2012). The southwest Ethiopia (Figure 1) is considered as one of the country's highest rainfalls receiving regions (Getinet and Woldeamlak, 2009) and an observed decline of rainfall total trend after 1950's onwards (Korecha, 2013, Gemeda et al, 2021). The significant business activity is contributed by local urban-rural exchanges in the study towns. Commerce is the main economic activity in the study urban centers with small manufacturing enterprises. Also, the livelihood of households depends on surrounding natural resources and urban agriculture as well as employments in in different enterprises. Except the Industrial Park established by 2018 in Jimma City, there is no large-scale industrial activity was found in the study urban centers, with the exception of small–scale cottage industries that have recently been expanded. The infrastructure development of each urban centers spatially differs, but low infrastructural development in Sokorru, Bonga, Bedelle and Jimma from low to high, respectively comparing their current development status.

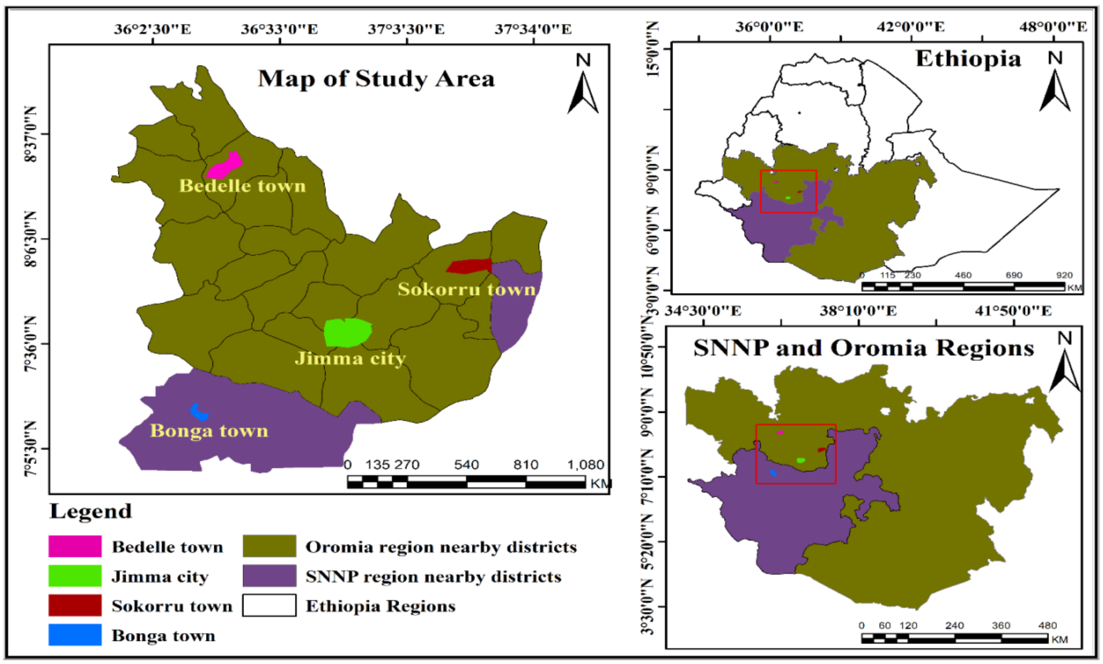

Figure 1. Map of the study area.

Sampling methods and sample size determination

This study employed a cross-sectional survey study design to conduct the assessment of the state of vulnerability due to climate change impacts was surveyed in the urban centers of Jimma, Bedelle, Bonga, and Sokorru using research methodology documented by Shajahan (2005). Accordingly, multi-stage stratified sampling methods were used to identify samples of the study. First, the four study urban centers were selected purposively from two regional states (Oromia and the new SNNP regions) in Southwest Ethiopia taking the Jimma City as the center hub of urban centers under study. Secondly, the study seven kebeles were selected by using a simple random sampling technique from each town proportional to the size of the population. Thirdly, the households from each kebeles were included in the study sample proportional to the size of households using Kebele household's registration as a sample frame. Fourth, the first households were selected by simple random sampling in each Kebele and then the next household following at skip interval or sample interval using systematic sampling.

The sample was obtained by taking the n [th] unit defined as sampling ratio or skip interval, the total household population divided by the size of the sample K= N/n or P=N/n the skip interval (Elizabethann et al, 2000; Kothari, 2004). The skip interval of this study was computed by dividing the total of urban centers households by required sample which is 10772÷ 384 =28 and the first household for each Kebele is selected randomly and then at intervals of every 28[th] household sample study was taken. The study includes identification of the research site, preliminary field visit, formulating questionnaires, focus group discussions, key informant interviews, and final visit for data collection.

$$n = \frac{Z^2 pq}{d^2} \quad \text{.. (1)}$$

Where- n = the desired sample size

Z= the standard normal variable at a required level of confidence (standard normal deviation)

P= proportion in the target population estimated to have characteristics being measured (If no estimate 50% should be used)

q= 1-p d= the level of statistical significance set

Where, the value Z = 1.96 at 95 % confidence level, p= 0.5, q = 1-0.5 =0.5 and d is sampling error 5% = 0.05. For the present study, the sample size n was determined as;

$$n = \frac{Z^2 pq}{d^2} = \frac{(1.96)^2 \times 0.5 \times 0.5}{(0.05)^2} = 384.16 \approx 384$$

The total numbers of households were 10772 and the sample size included in the study was 384. Based on Kothari (2004) sample size for each town/Kebele was calculated using Eq. 2 below.

$$ni = \left(\frac{Ni}{N}\right) n \quad \text{..(2)}$$

Where: N=Total Size of population/Household, Ni=Population Size/Household in each kebele, n=Total sample, ni =sample Size from each Kebele/stratum, the sum of the total size of n drawn from each Kebele. Thus, the total number of urban households which were included in the sample size from each of the four towns randomly included were 384 households (192 from 3 kebeles of Jimma, 41 from 2 kebeles of Bonga, 85 from 1 kebeles of Bedelle, and 66 from 1 kebeles of Sokorru towns) proportional to each town population size.

Data sources and data collection techniques

The main sources of data for this research were primary and secondary sources. The study population for this study was the total number of households of Jimma, Bedelle, Bonga, and Sokorru urban centers. Thus, the sampling unit of this study was the household of urban dwellers. The primary data were collected from 384 sample urban households, 55 key informants purposively selected public officials of four urban centers (15 from Jimma, 14 from Bonga, 13 from Bedelle, and 13 from Sokorru). A total of four focus group discussions including 40 participants, ten participants from each urban center, were conducted for a period of 60-90 minutes. The field observation was conducted using checklists about households' vulnerability to climate change related problems. Secondary data were collected from documents, books, the internets, journals, and reports of the study Towns /Municipality as well as their master plan/structural plan of the town to supplement the primary data. Data was collected from households of study urban centers by using semi-structured survey questionnaires to collect detailed information, about the relevant issues of climate change vulnerability in each of the four towns. The focus group discussion, key informant interviews and field observation were carried out to supplement and substantiate the quantitative data of the household survey.

Before the commencement of actual data collection, the study questionnaire was tested on five percent of the sample in urban households not included in the study by the trained data collectors. This approach was intended to evaluate the appropriateness of the instrument for use, reactions of respondents, the time required and finally, the correction was done. The training was given for interviewers or enumerators, close follow-up by the principal investigator and supervisors during data collection, and the filled collected data in order to check for completeness and consistency before analysis. For ethical considerations, before commencing the actual study or data collection support letter was sent from Jimma University by the principal investigator so as to have good relationships and trust among the public officials and households to be studied. Also, prior to data collection, verbal consent from urban households, willingness to participate in the study was ensured. The interviewer continued with due respect to community norms, beliefs, values, culture and ensuring confidentiality throughout the study.

Livelihood Vulnerability Index (LVI) analyses

The LVI model used in this study was based on previous research scholars by Hahn et al. (2009), Shah et al. (2013), and Iwan and Dony (2020). Following these three studies, with some modification, seven main components for livelihood vulnerability assessment were selected. These include; socio-demographic profiles, livelihood strategies, social networks, health, water resources, housing and natural disaster, and climate variability as described in Table 1. Although infrastructure conditions and level of development may also significantly influence the vulnerability of a household's community, our aim is solely to describe the level of livelihood vulnerability in the four urban centers by assessing livelihood vulnerability from the household perspective.

Table 1. Design of Livelihood Vulnerability Index (LVI) components assessment

Major component	Sub-components	Measuring unit	Explanation of sub-components
Socio-demographic profile	1) Dependency ratio	ratio	The ratio of population < 15 and > 65 years of age to the population between 19 and 65 years of age
	2) Percentage of female-headed households	percent	Household percentage of an adult female. If the head of her family had no home > 6 months a year
	3) Percentage of households where the head of household did not attend school	percent	Percentage of heads of households who do not attend schools
Livelihood strategy	4) Percentage of households that depend on farming and natural resources for their income	percent	Percentage of households that engaged on farming and natural resources as their primary income.
	5) Percentage of households that have livelihood alternatives	percent	Percentage of households that have livelihood alternatives to support their main income, in the coastal sector or other.
	6) Percentage of households that have saving ability	percent	Percentage of households that have saving ability to cope with hazard events.
Social networks	7) Percentage of households who asked for help from their neighborhood or local government in the previous 12 months	percent	Percentage of households who asked for help from their neighborhood or local government in the form of financial aid or other.
Health	8) Average time needed to reach a health facility	minutes	Average time needed to reach the closest health facility, such as the local public health center or hospital.
	9) Percentage of households that do not have health insurance	percent	Percentage of households that do not have health insurance to cope when they become ill.
Water	10) Percentage of households that use natural water resources	percent	Percentage of households that obtain their clean water from a source other than a local water company, i.e. from a well, river, rainwater harvesting, or other.
Housing	11) Percentage of homes that are vulnerable to disasters	percent	Percentage of dwellings that are vulnerable to disasters, such as tidal floods or local floods.
	12) Percentage of homes that did not raise their floor to prevent flood hazard	percent	Percentage of dwellings that are not able to keep out tidal floods or local floods because of failure to raise the floor.
	13) Percentage of households that do not have access to sanitation	percent	Percentage of households that do not have access to sanitation in their building.
Natural disaster and climate variability	14) Average number of disaster events	total number of events	The average number of disaster events, such as local floods in the last three years.
	15) Percentage of households that lost their physical assets because of flood	percent	Percentage of households that lost their physical assets because of natural disasters and climate variability to an extent that their livelihood strategies are impacted.
	16) Percentage of households who respond warming of temperature in past decades	percent	Percentage of households who perceive warming of temperature impact in the past decade.
	17) Average distance to the nearest river	km	Average distance to the nearest river. The closer the river, the higher the risk of local flooding because of river overflow

Source: Modified by authors from the substantial number of scientific literatures (Hahn et al., 2009; Shah et al., 2013; Ahsan and Warner, 2014; Fang et al., 2014; Morzaria et al., 2014; Donohue and Biggs, 2015; Liu and Liu, 2016; Iwan and Dony, 2020).

Methods of data analysis

Qualitative and quantitative analytical methods were applied in the analysis of the data. The collected data were checked for completeness and consistency before analysis. The quantitative data were analyzed with relevant computing packages such as SPSS version 21, R software, Origion 2019 b/MS-Excel 2016 software to generate spider diagrams of LVI and IPCC framework model in order to facilitate the analysis and interpretation. Descriptive statistics were used for the livelihood vulnerability index (LVI) and the LVI-Intergovernmental Panel on Climate Change's (IPCC) index calculation. The ArcGIS 10.2 package of Geographical Information System software was used to generate maps of the study area and spatial distribution of households included in the study. The quantitative data analyzed statistically were presented using tables, figures, charts, photographs, and other displaying schemes. The qualitative data were organized and summarized in descriptive form. The justification for the data collected and analyzed in numerical values was described in words to be meaningful and compared with findings of other researchers to make the conclusion.

2.5.1 Calculating the livelihood vulnerability: Livelihood Vulnerability Index approach

The Livelihood Vulnerability Index (LVI) was originally designed to provide development organizations, policymakers, and planners with a practical tool to understand the contributions of demographic, social, and physical factors to climate vulnerability. In addition to the overall composite index, sectorial vulnerability indices can be segregated to identify potential areas for intervention (Hahn et al. 2009). Descriptive statistics were used for the livelihood vulnerability index (LVI) and the LVI-Intergovernmental Panel on Climate Change's (IPCC) index calculation.

For this study, the livelihood vulnerability analysis technique developed by Hahn et al. (2009), with replacements of some indicators to suit the local context was used. These include socio-demographic profile, livelihood strategies, social networks, health, and housing, access to water, natural disaster risks, and climate variability. Many authors (Aryal et al. 2014; Etwire et al.2013; Shah et al. 2013) have used a similar approach in various contexts because this assessment tool is accessible to a diverse set of users in resource-poor settings through applying equal weights to all major components and each of the sub-components are measured on a different scale which first demands to standardize them for comparability. The standardized values were ranged from 0 to 1 for sub-component indicators. The equation for standardizing numerical values is the same as that used in constructing the Human Development Index-HDI (UNDP 2007) as formulated in Eq.3;

$$Index\ Sd = \frac{Sd - Smin}{Smax - Smin} \quad \text{———} \quad (3)$$

Here, Sd is the original sub-component for Town/district d, and S min and S max are its minimum and maximum values reflecting low and high vulnerability, respectively. An index for each major component of vulnerability was created by averaging the standardized sub-components most related to it using Eq. 4.

$$Md = \frac{\sum_{i=1}^{n} indexSdi}{n} \quad \text{———} \quad (4)$$

Here, Md is one of the major components for district d, the Sdi represents the sub-components, indexed by i, that make up the major component, and n is the number of sub-components in each major component. Once values for each of the major vulnerability components for a towns/district are calculated, they were averaged and compared each other using Eq. (5and 6) to obtain the town /district-level LVI:

$$LVId = \frac{\sum_{i=1}^{7} WmiMdi}{\sum_{i=1}^{7} Wmi} \quad \text{———} \quad (5)$$

Equ. 5 above can be expressed in expanded form as

$$LVI_d = \frac{W_{SDP}\ SDP_d + W_{LS}\ LS_d + W_{SN}\ SN_d + W_H\ H_d + W_W W_d + W_H H_d + W_{NDCV}\ NDCV_d}{W_{SDP} + W_{LS} + W_{SN} + W_H + W_W + W_H + W_{NDCV}} \quad \text{.......} \quad (6)$$

SDP=socio-demographic profile, LS=livelihood strategy, SN=social network, H=health, W=water, H= Housing, NDCV =natural disasters and climate variability.

Here, LVI_d is the LVI for town/district d, equal to the weighted average of all major components. The weights of each major component, Wmi, are determined by the number of sub-components that make up each major component and are included to ensure that all sub-components contribute equally to the overall LVI (Sullivan et al. 2002; Shah et al 2013). Different researchers used different scales of LVI but this research uses the relevant few studies of vulnerability index scales used in urban centers or cities than the mostly studied over rural areas. By employing (Food Agriculture and Natural Resources Policy Analysis Network (FANRPAN, 2011), which was also used by recent study (Phuong Tran et al, 2022) the value of the calculated *LVI* is scaled to range from 0 to 1 classifies as follows: 0.00 - 0.30 as "not vulnerable" ; 0.31 - 0.46 as "slightly vulnerable" ; 0.47 - 0.51 as "moderately vulnerable"; 0.52 - 0.60 as "highly vulnerable"; 0.61 - 1.00 as "extremely vulnerable.

Calculating the livelihood vulnerability: IPCC framework approach

The other analysis is by calculating the livelihood vulnerability: IPCC framework approach is an alternative method developed by Hahn et al. (2009) also documented in (IPCC, 2014; Nguyen et al., 2018). For calculating the LVI based on the IPCC vulnerability definition which highlights exposure, adaptive capacity, and sensitivity. The index diverges from the LVI in how the major components are combined. Rather than merging the major components into the LVI in one step, they are first combined according to the categorization into exposure, sensitivity and adaptive capacity as indicated in Eq. 7.

$$CFd = \frac{\sum_{i=1}^{n} WmiMdi}{\sum_{i=1}^{n} Wmi} \quad \text{-----------} \quad (7)$$

Here, CFd is one of the contributing factors to VI-IPCC for town/district d, Wmi is the weightage of one of the major contributing factors and Mdi is the major component for town/district d indexed by i. For this study, equal weight is given to all the components since we do not have detailed information to justify assigning different weights. After calculating the contributing factors, once the three categories of exposure, sensitivity, and adaptation capacity were calculated, the three contributing factors were combined to calculate the vulnerability index of IPCC using Eq. 8.

$$LVI\text{-}IPCC_r = (e_r - a_r) * s_r \quad \text{-----------} (8)$$

Or LVI-IPCC = (Exposure- Adaptive Capacity) x Sensitivity

Where $LVI\text{-}IPCC_r$ is the LVI for urban center/town r expressed using the IPCC vulnerability framework, e_r is the calculated exposure score for town r (equivalent to the natural disaster and climate variability major component), a_r is the calculated adaptation capacity score for town r (weighted average of the socio-demographic, livelihood strategies and social networks), and s_r is the calculated sensitivity score for town r (weighted average of the health, water and housing) as shown in Table 2. Finally, this research was framed in the sense of vulnerability framework developed by Turner et al. (2003). Based on the IPCC definition, a system's vulnerability is divided into three major components; exposure, sensitivity, and adaptive capacity (Table 2). Exposure considers the frequency, magnitude, and duration to which a system is subject to hazards. We used the term "climate-related hazards" to cover both climate-related shocks, such as floods and droughts, and longer-term climate stresses, such as increasing rainfall variability and increasing temperature. The sensitivity of a system is determined by both the environmental and human characteristics that contribute to how a system responds to exposures. Finally, the adaptive capacity of a system refers to actions that can improve a system's ability to cope with outside hazards. The LVI-IPCC index ranges from-1 (least vulnerable) to +1 (most vulnerable). The scale of LVI-IPCC ranges between -1 and -0.4 is not vulnerable; between -0.41 and +0.3 is vulnerable or moderate and between +0.31 and +1 is very vulnerable.

Table 2. Mapping LVI Categories of major components contributing to the IPCC model

IPCC vulnerability components	LVI Major components
Exposure	Natural disaster and climate variability
Adaptive capacity	Socio-demographic profiles
	Livelihood strategies
	Social networks
Sensitivity	Health
	Water resources
	Housing

RESULTS

Demographic and socio-economic characteristics of the respondents

The demographic and socio-economic characteristics of the household respondents in the four towns (Jimma, Bedelle, Bonga, and Sokorru's) were summarized in Table 3 below. About 54% of the respondents were males while 46% were females. The age of the respondents ranges from 15-65 with the majority (29%) were from 45-54, whereas 5% above 65 years. Of the total respondents, about 28% attended their elementary education -less than grade 10 while 30% secondary education (Table 3). With regard to income, the majority (51%) of the respondents have a monthly income of less than 2000 Ethiopian birr whereas only 49% earned greater than 2000 birr (Table 3). The main economic activity of the respondents is trade followed by employment (Table 3)

Table 3. Socio-demographic characteristics of study urban centers in southwest Ethiopia based on a field survey conducted during the period from 2019 to 2021

Background information	Descriptions	Number of respondents of each urban center/ town					
		Jimma	Bedelle	Bonga	Sokorru	Total	%
Sex	Male	71	63	30	45	209	54
	Female	121	22	11	21	175	46
Age group	15-24 years	5	7	1	1	14	4
	25-34	18	32	14	13	77	20
	35-44	49	14	16	31	110	28
	45-54	68	20	7	15	110	29
	55-64	38	9	2	4	53	14
	65 and above	14	3	1	2	20	5
Educational status	<grade 10	60	13	4	32	109	28
	10+1	19	3	5	0	27	7
	10+2	14	2	5	7	28	8
	Certificate	42	4	9	3	58	15
	Diploma	26	19	3	7	55	14
	1st degree	24	38	14	17	93	24
	2nd degree	7	6	1	0	14	4
	PhD and above	0	0	0	0	0	0
Place of birth	In the Town	68	14	21	23	126	33
	Rural areas of the Town	84	38	16	38	176	47
	Outside of the zone	28	33	4	5	70	20
Housing type							
	Wooden and thatch	127	23	32	58	240	63
	stone and mud	29	49	6	8	92	25
	stone and cement	26	13	3	0	42	12
Housing tenure	own house	103	32	20	51	206	53
	rented house	46	42	16	14	118	31
	kebele house	43	11	5	1	60	16
Monthly Income (in Birr)	< 300	28	6		5	39	10
	301-1000	32	14	15	9	70	18
	1001-2000	40	13	11	22	86	23
	≥ 2001	92	52	15	30	189	49

The spatial distribution of households that were included in the study towns was depicted in Figure 2 and annexed as supplementary with x, y coordinates of their location as per the sample size of each urban center and respective kebeles included in the study. The coordinates of surveyed households that participated in four study towns were taken and documented for the validity of the study using a geographic position system (GPS).

Perception of the impacts of climate change

The majority of the respondents (83%) disclosed that climate change was observed in the past three decades in the urban centers of Southwest Ethiopia. Most of the respondents were explained its causes as both natural and human (59%) effects, followed by human/anthropogenic activity (36%) due to unplanned urban expansion and development activities in urban centers (Table 4). The majority of household respondents (90%) in the four study towns agreed that the temperature hotter days have increased and changed during the past thirty years (Table 4).

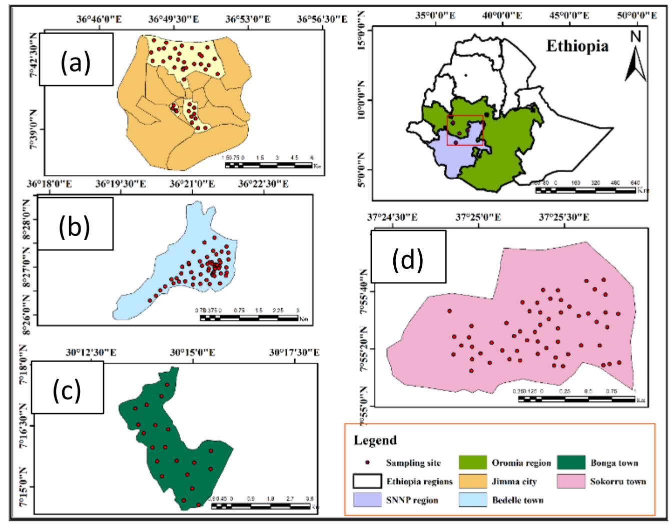

Figure 2. Study area map of household survey samples a) Jimma city b) Bedelle town c) Bonga town d) Sokorru town.

Table 4. Responses of urban households' perception and observation on climate change variability and trends based on field Survey conducted during the period from 2019 to 2021

		Number of respondents from each urban center/ town					
Variables	Perceptions	Jimma	Bedelle	Bonga	Sokorru	Total	%
Does climate change in your local area in the past 30 years?	1. Yes	160	71	24	63	318	83
	2. No	22	6	14	0	42	11
	3. I do not know	10	8	3	3	24	6
In your opinion what do you think is the cause of climate change?	1. Human actions	70	32	7	29	138	36
	2. Natural process	6	2	2	6	16	4
	3. Both human and natural process	116	48	32	31	227	59
	4. I don't know	0	3	0	0	3	1
Do you feel the temperature of the area is changing?	1. Yes	178	69	39	60	346	90
	2. No	12	14	2	3	31	8
	3. I do not know	2	2	0	3	7	2
What is your observation/opinion on the trends of hot days over the last 30 years?	1. Increase	162	36	16	42	256	67
	2. Decrease	9	15	6	14	44	11
	3. The same	1	3	1	0	5	1
	4. fluctuated	19	28	16	8	71	18
	5. I don't know	1	3	2	2	8	2
Was the amount of rainfall increased or decreased?	1. Increased	87	35	0	22	144	38
	2. Decreased	96	41	39	38	214	56
	3. No change	7	6	2	2	17	4
	4. I do not know	2	3	0	4	9	2
Increase problem of heavy rain and hail?	1. Yes	176	66	29	9	280	73
	2. No	16	14	12	53	95	25
	3. I do not know	0	5	0	4	9	2
Is there drought experienced in the past 30 years?	1. Yes	114	62	31	38	245	64
	2. No	68	11	9	15	103	27
	3. I do not know	10	12	1	13	36	9

Regarding the amount of rainfall trends, more than half of the respondents (56%) said rainfall has been decreased while 38% of respondents said increased. On the other hand, the majority (73%) of the respondents indicated the problem of heavy rainfall or hail due to frequent occurrence of extreme rain events which result in flooding occurrence in towns (Table 4). Similarly, the majority of the respondents (64%) reported the occurrence of recurrent drought in the past three decades in urban centers of Southwest Ethiopia (Table 4).

The majority of the respondents (90%) agreed upon the impacts of climate change at the local scale of each town in the past three decades (Table 5). As a result, most of the residents informed the occurrence of warm temperature (84%) with heat, and flooding due to extreme rainfall in order of the magnitude from highest to the lowest in Jimma, Bedelle, Bonga and Sokorru, respectively with the evident occurrence of catastrophes in urban centers of southwest Ethiopia (Table 5). Landslides were also mentioned as a common problem with variable magnitude in the study towns. During the occurrence of extreme events, the majority of the residents (60%) said they do not get support but a few (33%) get support. In the study area, there is no well-established emergency and disaster risk management (Table 5).

Table 5. Climate change impacts, extreme events, and support in study urban centers based on field Survey conducted during the period from 2019 to 2021

Variables	Descriptions	Number of respondents of each urban center/ town					
		Jimma	Bedelle	Bonga	Sokorru	Total	%
Do you think climate change has an impact on your Town?	1. Yes	175	75	35	60	345	90
	2. No	13	1	6	5	25	6
	3.I do not know	4	9	0	1	14	4
Which extreme climatic events have frequently occurred in your urban areas over the past 3 decades?							
Warm temperature with heat	1. Yes	175	66	32	50	323	84
	2. No	15	8	5	9	37	10
	3. I do not know	2	11	4	7	24	6
Flooding due to extreme rainfall	1. Yes	182	71	35	34	322	83
	2. No	5	9	6	24	44	12
	3. I do not know	5	5	0	8	18	5
Landslides	1. Yes	124	63	30	21	238	62
	2. No	47	11	7	39	104	27
	3. I do not know	21	11	5	6	43	11
Does any support provided during such events occur?	1. Yes	46	50	12	19	127	33
	2. No	120	22	29	44	215	60
	3. I do not know	26	13	0	3	42	11

Assessment on impacts of temperature and precipitation changes

Climate change challenged the residents of study towns through inducing illnesses, food security, and price rise, and triggered migration to the urban centers (Table 6). According to the respondents, high-density buildings and residential areas were reported as areas that are most susceptible to extreme events of temperature and precipitation changes followed by office, commercial and industrial areas of the study area (Table 6).

Climate change impacts vary spatially and among people in urban areas. The most affected people were children, women, elders, and disabled/ distributes (Table 6). The majority of the residents prioritized the natural resources (22%), built up the environment (21%), and agriculture (20%) sectors are more vulnerable to climate change (Table 6). The majority of the respondents said the rise of the temperature has an impact on people including being inactive at the workplace, accidental fire, skin irritations whereas the occurrence of lower temperatures also has a negative impact on the systems such as the death of animals and respiratory diseases (Table S1). The impact of high precipitation is more identifiable and visible than temperature. During extreme rainfall, high flooding problem was common. The frequent flooding is common in the summer season mainly for people living along the river banks and flash flooding which overflows on some streets as well as filling drainage channels. Awetu river in Jimma and stormwater coming from hills of Jiren where frequently over floods the residents at its lower courses during the summer season. The flooding by Awetu river is serious when the heavy rainfalls in the upper catchment of Limmu with peak rainy season which result in loss of property and livestock. In Bonga, Bedelle, and Sokorru flooding problem was also raised in focus group discussions and key informant interviews as a common challenge during summer with the loss of livestock life, assets, damage on infrastructure due to overflow of the river and surface runoff stormwater.

Table 6. Climate change impacts on buildings, people, and sectors vulnerability in urban centers based on a field survey conducted during the period from 2019 to 2021.

Variables	Descriptions	Number of respondents of each urban center/ town					
		Jimma	Bedelle	Bonga	Sokorru	Total	%
Which areas are most susceptible to extreme events of temperature and precipitation change in urban areas?	1.Low-density Residential Areas	6	14	4	2	26	6
	2.Medium-density residential areas	1	14	0	14	29	8
	3.High-density building areas and residential areas	136	53	26	34	249	71
	4. Office, commercial and industrial	17	4	22	16	59	15
	5. Others (specify)	0	0	0	0	0	0
Who are the most affected people by climate change impacts?	1. Children	135	48	13	36	232	19
	2. Women	94	37	0	15	146	12
	3. Elders	85	18	2	21	126	10
	4. Disables	70	11	26	0	107	9
	5. All	384	114	41	72	611	50
On which sector do climate changes impose impacts in urban Areas (multiple answers possible underline it)?	1. Agriculture	121	40	28	13	202	20
	2. Health	119	18	22	26	185	19
	3. Natural resources	122	44	28	23	217	22
	4. Infrastructure	90	13	30	44	177	18
	5.Built-up environment (residences, buildings, etc).	92	37	25	53	207	21
	6. Others	0	0	0	0	0	0

Analysis of Livelihood Vulnerability Assessment

Socio-demographic profile

The computed standardized values of each sub-component result in the value of each main component in the LVI model described as follows. The socio-demographic profiles in the urban centers of Southwest Ethiopia have values of 0.38, 0.29, 0.18, and 0.33 for Jimma, Bedelle, Bonga, and Sokorru respectively (Table 7 and S2-6). The dependency ratio and percentage of households where the head of the household do not attend primary school has values of 0.34 and 0.36 in Sokorru and the least values of 0.04 and 0.10 in Bonga respectively (Table 7 and S2-6). The dependency ratio measures the number of family members who are non-productive age with those of productive age while productive-age members of a family have a duty to support the non-productive ones. However, when the head of a household has not attended primary school, the family has limited knowledge and is less adaptive to climate change impacts which vary inter towns spatially. Household livelihood strategies in the four urban centers have a value range of the least in Sokorru (0.47) to the highest (0.54) in Bedelle, the percentage of households that have the saving ability which explains financial adaptive capacity with a value range of the least 0.31, 0.53 the highest in Jimma and Bedelle, respectively (Table 7 and S2-6).

Social net works

Regarding social networks, the LVI index shows a value ranging from the least 0.24 to 0.59 over Jimma and Bedelle respectively which represents the percentage of households that asked for help from their local government or neighborhood in the last 12 months (Table 7 and S2-6). Thus, the number of neighborhoods that have the ability to provide a helping of their inhabitants implies the existence of social networks that foster adaptive capacity.

Health

The health main component has an LVI value of the least (0.45) in Bedelle and Sokorru to the highest (0.52) in Bonga based on spatial distance and size of each town., Its highest contribution comes from the average time needed to arrive at a health center which is the average travel time to a health center which explains accessibility of health facilities in study towns, indicating health insurance opportunity to get health services during the households exposed to climate-related disasters (Table 8 and S2-6).

Water resources

With regard to the water resources component, the least value (0.35) was recorded in Jimma while the highest value (0.50) was recorded at Bonga and Sokorru towns, indicating that some households still use natural water resources (wells, rain, and rivers) which has a greater sensitivity level due to their exposure to pollutants from climate-related disasters with lower water quality (Table 8 and S2-6). The housing main component has the least value (0.25) in Bedelle and the highest value (0.47) in Sokorru, with the greatest contribution coming from the percentage of households that are vulnerable to disasters by floods (Table 8 and S2-6).

Natural disasters and climate variability

Natural disasters and climate variability describe how great is the stress of climate-related disasters on four study town's environments. The value of the average number of disaster events makes the largest contribution, with a value of the least LVI index 0.47 over Bonga and the highest value 0.57 over Sokorru which indicates that the urban centers in Southwest Ethiopia are highly exposed to the impacts of climate-related disasters. Households' distance to the river can raise the district's exposure level because proximity to a river can raise exposure to riverine floods due to river overflow as raised by households in all study towns (Table 7and S2-6).

Table 7. Computed results of components Livelihood Vulnerability Index in urban centers of Southwest Ethiopia based field survey conducted during the period from 2019 to 2021

Major component	Sub-components	Composite index values					Component value index				
		Jimma	Bedelle	Bonga	Sokorru	Areal	Jimma	Bedelle	Bonga	Sokorru	Areal
Socio-demographic profile	1) Dependency ratio	0.13	0.14	0.04	0.34	0.16	0.38	0.29	0.18	0.33	0.24
	2) Percentage of households where the head of household did not attend school	0.30	0.12	0.10	0.36	0.20					
	3)Average number of family members in the household	0.7	0.60	0.40	0.30	0.36					
Livelihood strategy	4) Percentage of households that depend on trade for their income	0.85	0.8	0.87	0.79	0.80	0.49	0.54	0.49	0.47	0.49
	5) Percentage of households that have livelihood alternatives	0.32	0.31	0.15	0.11	0.26					
	6) Percentage of households that have saving ability	0.31	0.53	0.44	0.52	0.41					
Social networks	7) Percentage of households who asked for help from their neighborhoods or local government in the previous 12 months	0.24	0.59	0.29	0.29	0.33	0.24	0.59	0.29	0.29	0.33
Health	8) Average time needed to reach a health facility	0.5	0.45	0.63	0.55	0.5	0.46	0.45	0.52	0.45	0.46
	9) Percentage of households that do not have health insurance	0.42	0.45	0.45	0.35	0.42					
Water	10) Percentage of households that use natural water resources	0.35	0.40	0.50	0.50	0.30	0.35	0.40	0.50	0.50	0.30
Housing	11) Percentage of homes that are vulnerable to disasters	0.67	0.14	0.13	0.15	0.63	0.39	0.25	0.44	0.47	0.46
	12) Percentage of homes that did not raise their floor to prevent flood hazard	0.20	0.27	0.78	0.85	0.40					
	13) Percentage of households that do not have access to sanitation	0.30	0.35	0.40	0.40	0.35					
Natural disaster and climate variability	14) Average number of disaster events	0.5	0.5	0.5	0.5	0.5	0.52	0.5	0.47	0.57	0.49
	15) Percentage of households that lost their physical assets because of flood or tidal flood	0.20	0.25	0.13	0.20	0.15					
	16) Percentage of households who respond warming of temperature in past decades	0.91	0.78	0.78	0.91	0.84					
	17) Average distance to the nearest river	0.47	0.47	0.47	0.68	0.47					

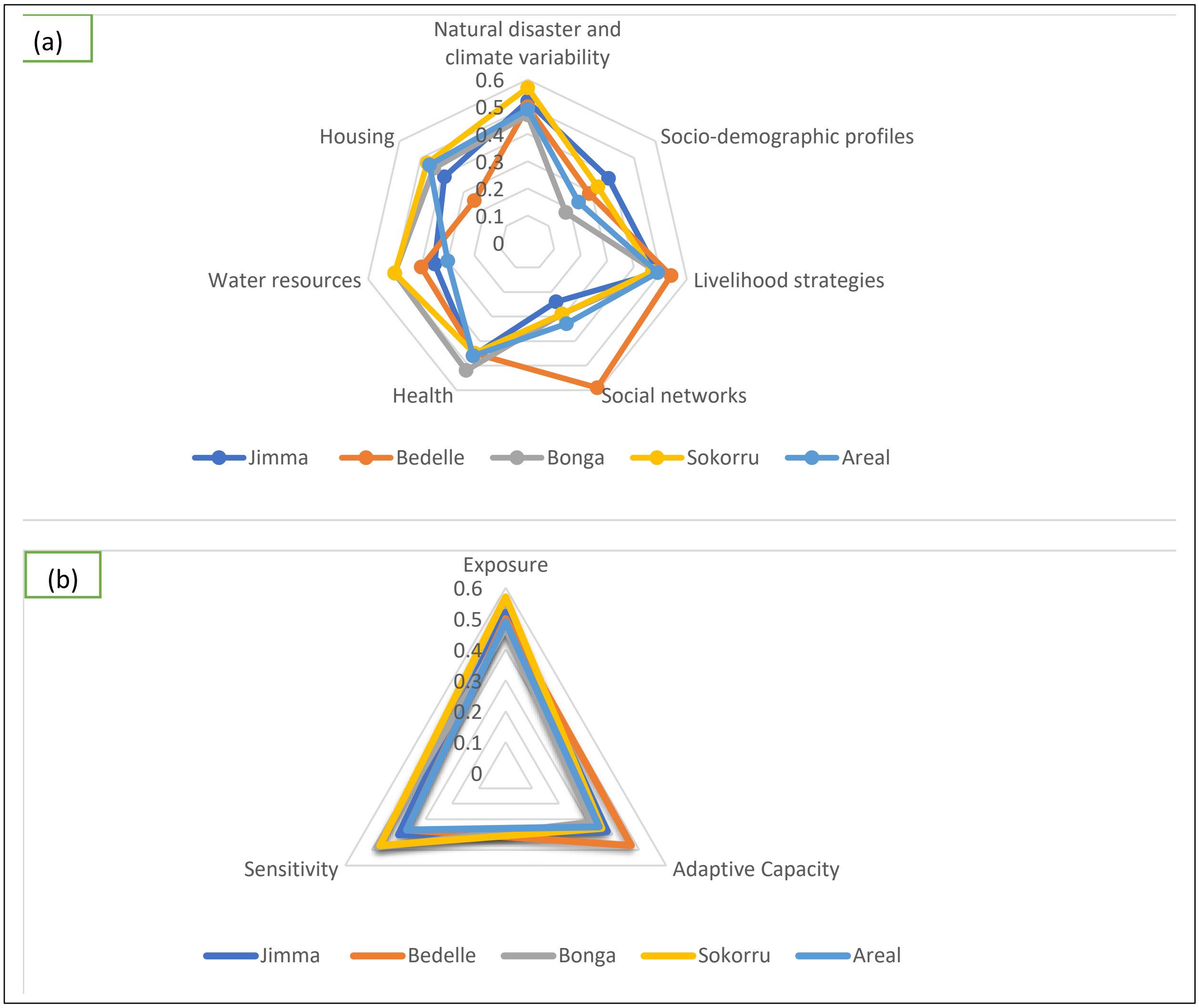

Figure 3. Distribution diagram of vulnerability for (a) the LVI components (b) LVI–IPCC model

The analysis performed in this study, for components, computed Livelihood Vulnerability Index were grouped into three main categories of vulnerability (adaptive capacity, sensitivity, and exposure), which turned into a spider diagram that shows the vulnerability level of each component (Figure 3), that depicts the contribution of each main component to the livelihood system vulnerability. Natural disaster and climate variability is the main component with the largest contribution to the vulnerability index which explains that the urban centers of southwest Ethiopia are vulnerable to climate-related disaster variability.

Analyzed result of LVI- IPCC framework model in urban centers

The major livelihood vulnerability components are grouped in to three major LVI-IPCC components exposure, sensitivity and adaptive capacity as depicted in Table (8) below. The LVI-IPCC calculation result shows that the urban centers of southwest Ethiopia's community livelihood system are vulnerable to climate-related disasters. Based on the computed value of the vulnerability index using the LVI and the LVI–IPCC models the four urban centers are categorized as highly vulnerable by areal LVI index value (range, 0.40 to 0.44). The calculation made using the LVI–IPCC model results in a value range of about (0.011 to 0.099) which is closer to +1 than -1, making the study area vulnerable with varying degrees of vulnerability (Figure 3; Table 7, 8 and S2-6).

The highest vulnerability value (0.44) was recorded at Sokorru while the least vulnerability value (0.40) was recorded at Jimma using LVI value analyses. However, all towns score above the areal average aggregate score of 0.39. On the other hand, the LVI-IPCC model value shows the highest vulnerability was scored by Sokorru with an index value of 0.099 while the least scored by Bedelle with the value of 0.011, which is the only scored below the areal value of 0.052 (Fig. 3; Table 7, 8 and S2-6). An adjustment to local conditions is needed to determine the sub-components to enrich the more adaptable method, as LVI and LVI–IPCC are more locally specific.

Table 8. Computed summary result of LVI major components, and LVI-IPCC model across urban centers of Southwest Ethiopia on a field survey conducted during the period from 2019 to 2021.

IPCC vulnerability components	Livelihood vulnerability Major components	The index value of each town				
		Jimma	Bedelle	Bonga	Sokorru	Areal Aggregate
Exposure	Natural disaster and climate variability	0.52	0.50	0.47	0.57	0.49
Adaptive capacity	Socio-demographic profiles	0.38	0.29	0.18	0.33	0.24
	Livelihood strategies	0.49	0.54	0.49	0.47	0.49
	Social networks	0.24	0.59	0.29	0.29	0.33
Sensitivity	Health	0.46	0.45	0.52	0.45	0.46
	Water resources	0.35	0.40	0.50	0.50	0.30
	Housing	0.39	0.25	0.44	0.47	0.46
Overall LVI index		0.40	0.43	0.41	0.44	0.39
Overall LVI-IPCC		0.056	0.011	0.074	0.099	0.052

***** *The analyzed vulnerability index value of the LVI–IPCC model range is 0.011 (least) to 0.099 (highest), which is in a vulnerable category. The LVI–IPCC model is scaled between -1 (least vulnerable) to +1 (most vulnerable).*

DISCUSSIONS

The demographic and socio-economic characteristics of the household respondents in the four urban centers (Jimma, Bedelle, Bonga and Sokorru's) were assessed. The income of the respondents is highly varied and the majorities (51%) of the respondents have a monthly income of less than 2000 Ethiopian birr whereas only 49% of the respondents earned greater than 2000 birr. The findings showed that income of household served for many other family members, especially dependents children, and elders impact the adaptive capacity of households. The findings comparable with Tizale (2007) explained that many family members can raise the opportunity of other family members to support family incomes, both from primary sectors in their household community and others. The study revealed that most of the households in the urban centers depend on available local resources, so the disturbance of these resources directly influences their income generation which hampers household's savings also documented by Rudiarto et al. (2020). Households that have no access to sanitation in their residents or building have a greater sensitivity to climate change thereby increasing access to sanitation is an important strategy for climate change adaptation (McGranahan et al., 2007; Kundzewicz et al., 2008).

Regarding exposure, similarly, Barbier (2015) and IPCC (2014) documented that urban areas and coastal areas are on the front lines of climate change exposure and their communities are vulnerable, especially low-income poor people. The main component which social networks contribution is the highest comparing inter towns understudy (Feyissa et al., 2018), which are known to play a pivotal role in developing social resilience in another research (Adger et al., 2005).

The findings indicate that the livelihood system in the study urban centers of Southwest Ethiopia is vulnerable due to a low adaptive capacity at the household level. Hence, they cannot cope with exposure to disasters such as riverine and splash floods, warm temperatures with heat, and landslides. A study conducted by Handayani et al. (2017) revealed similar results that vulnerability in a small city/town was due to its lack of adaptive capacity than exposure or sensitivity. These research findings are also in line with the research done by Buchori et al. (2018) and Rudiarto et al. (2020) in the coastal areas of Semarang, Central Java., which raised that role urban government actions to increase household adaptive capacity is a crucial factor in reducing vulnerability. Also, Huoang et al. (2018) reported that lower adaptive capacity and sensitivity resulted in high exposure comparison through vulnerability level compared to two other communes in Northwest Vietnam, lack of adaptive capacity was found as the major provider to vulnerability in some parts of rural Nepal (Pandey and Bardsley, 2015; Panthi et al., 2016). Lower adaptive capacity is believed to be the principal cause of vulnerability in most of developing countries (Füssel, 2010). Furthermore, according to Wisner et al. (2004), the main issue with vulnerability is not the hazard but the critical state of livelihood conditions that affect the ability of an individual person, household, or community to respond to hazardous conditions. Moreover, despite the predominance of adaptive capacity raised in this study, exposure and sensitivity play critical contributors to vulnerability.

The most vulnerable groups of people identified was similar to the findings of the study in Ambo town which reveal that climate change the most vulnerable social groups to the negative impacts of climate change are old people, the urban poor, children, the urban handicaps, and women (Gemechu, 2013) and climate vulnerability findings in Addis Ababa revealed that similar vulnerable groups (Feyissa et al., 2018).

The findings of climate hazards identified in urban centers were warming temperature, floods, landslides, and climate-related disasters threaten 32.20% of the sampled household's community. This calls appropriate policy interventions to enhance the community's adaptive capacity and reduce its exposure level as documented in previous studies (Iwan and Dony, 2020). Also, the finding is comparable to other studies conducted in Metropolitan Addis Ababa capital reported that rise in temperature, extreme rainfall, heatwaves and others have been reported as environmental problems in Addis Ababa (Birhanu et al., 2016; CLUVA, 2011), different climate-related impacts were also reported in Addis Ababa, mainly flooding (Feyissa, 2018) and large-scale urbanization and population increases have led to large numbers of people, especially the poor settling and living in flood plains in and around urban areas outskirts (CLUVA, 2015; Dessu et al., 2020). Moreover, similar to the study documented in Ambo Town that climate hazards identified in Ambo town are flash floods, water stress, urban heat waves, wind storms, and dust storms (Gemechu, 2013).

Vulnerability varies spatially based on topographic and agroecological differences. The results of the study conducted on ten sub-cities in metropolitan Addis Ababa were indicated not similar levels of vulnerability to climate change intra city, while Gulelle, Bole, and Arada sub-cities are better compared to others (Feyissa et al., 2018). The findings of the urban centers LVI index value of three towns (Bedelle, Bonga, and Sokorru) is greater than 0.4 except Jimma which is equally as well due to the difference in adaptive capacity, exposure, and sensitivity which result in a difference of vulnerability between inter-urban centers and intra town of the same territory. This result is comparable with the study of Addis Ababa by Feyissa et al. (2018) and their agro ecological differences of the highest in Kolla and the least vulnerability in Dega due to its higher adaptive capacity (Amare and Simane, 2017).

The level of vulnerability is significantly related to the sub-components or indicators used in the primary survey (Hahn et al., 2009). The sub-components used in this study are directly associated with the livelihood values and assets of the households sampled with regard to vulnerability assessment. Therefore, livelihood diversifications would substantially improve the community's adaptive capacity and reduce its vulnerability. This study suggests that a more local approach of framework should be created for the human-environment nexus biophysical and social environments (Dolan and Walker, 2006), which depends on the understanding of how the four urban centers communities are vulnerable. The participation of the four study urban centers community in a survey, where urban residents responded the factors that are more closely linked to their livelihood vulnerability, based on their perception and understanding makes the assessment more reliable and accurate.

As policy recommendations, the study findings implies that urban centers vulnerability could be curbed by the adaptation strategies set at national level as "National Adaptation Plan" should be devised in suitable manner to curb the livelihood vulnerability of the urban households to climate change related disasters and risks through devising municipal adaptation plan that considers urban centers context (NAP, 2019). Furthermore, cost effective and innovative adaptation solutions of grey and green infrastructural development through inclusion of local knowledge in participatory manner as a significant climate action through improving adaptive capacity of urban households and institutions of study urban centers of southwest Ethiopia. The collaboration of all urban actors will also be effective for minimizing of household livelihood vulnerability to climate-induced disasters and variability as well as proactive adaptation measures by creation of climate smart urban centers of the future.

CONCLUSION

Understanding utmost vulnerable communities to climate variability and its extremes, has become a growing concern for policymakers in order to develop area-specific adaptation strategies for sustainable development. The findings of livelihood vulnerability and IPCC model index result indicated that the four urban centers of southwest Ethiopia are vulnerable to climate change which varies spatially across inter-study urban centers due to exposure, sensitivity and adaptive capacity. The crucial factors determining the vulnerability of the four urban communities were related to the adaptive capacity that households including social networks, livelihood strategies, and their household demographics in the study urban centers. This indicates that urban households are prone to variability of climate-related disaster variability, which impact their livelihood and quality of life. The results of the study show that women, children, elders, disabled and low-income groups or the urban poor are the most vulnerable groups of people in urban areas of Southwest Ethiopia. The study urban centers have a high level of exposure and sensitivity to climate-related disasters with a low level of adaptive capacity. The urban household community can hardly cope with climate change impacts such as riverine and splash floods, as well as warming heat during winter in urban cores where high-density buildings and residents are congested.

The urban household community in Jimma, Bedelle, Bonga, and Sokorru could raise their adaptive capacity through increasing their social networks, enhancing community-based associations, income-generating activities; improve of social insurance and social values at the local level. The city administrations or Municipalities should focus on building communal infrastructure which can improve access to sanitation, services, and social infrastructure to benefit low-income urban residents. The application of the LVI and LVI–IPCC models is useful in understanding the major components and sub-components of vulnerability which shows how socioeconomic and physical environments can shape vulnerability at town or the local level which identified directly. The finding showed Bedelle (highland) which is located in Dega agroecology is less vulnerable and Sokorru town is the most vulnerable which is located near to lowland Gibe Catchment (kola) agroecology with low adaptive capacity. The urban local-level assessment findings alert local administrators, stakeholders, and other urban actors to devise a more adaptive livelihood system and coping adaptation strategies as policy recommendation to curb the inevitable climate change. The results are helpful in identifying determinants of livelihood vulnerability to climate change by urban communities in the study area in particular and may be applicable to other similar urban centers in general. Furthermore, we recommend that more urban level studies should be carried out to explore the links between socio-economic development, urban planning, and future vulnerability that integrate urban planning and adaptation governance climate actions as a future line of study.

Conflicts of Interest:

The authors declare that they have no conflicts of interest.

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Author Contributions

TD was responsible for all activities of the research process such as the design, data compilation and entry, data analysis, and interpretation of results as well as writing up of the manuscript. The three authors DK, AW, and WG were involved in supervising from design to data collection, contributed to framing the manuscript, made valuable inputs and comments in improving the quality of the manuscript during the write-up of the manuscript. GD encode the GPS collected fieldwork, technical expertise contribution during the field survey, generate maps using household geolocation coordinate points in four towns to process using ArcGIS 10.2 software version. All authors contributed to the manuscript, read and approved the final submitted version.

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Data Availability Statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation based on reasonable request.

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