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Measuring Climate Change Vulnerability in Rural Northern Laos

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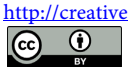

Abstract

Climate change poses a growing threat to rural livelihoods in Lao PDR, particularly in upland areas where socio-economic vulnerabilities and limited adaptive capacity heighten risks. Despite this, localized assessments of livelihood vulnerability remain limited, hindering the development of targeted adaptation strategies. This study applies the Livelihood Vulnerability Index (LVI) and the LVI-IPCC framework to assess household-level vulnerability to climate variability in 15 villages across Beng District, Oudomxay Province. Drawing on quantitative data from 450 households collected under the Mekong Sentinel Landscape Project, the analysis integrates 22 sub-indicators across seven domains: socio-demographic profile, livelihood strategies, health, social networks, food security, water access, and climate-related shocks. Mang village recorded the highest vulnerability score (LVI = 0.476), associated with low education levels, a high proportion of female-headed households, and heavy reliance on agriculture. Namtouy village exhibited the lowest score (LVI = 0.327), reflecting stronger adaptive capacity and improved water access. The LVI-IPCC framework underscores the combined influence of high exposure and low adaptive capacity in shaping vulnerability outcomes. Gender consistently emerged as a critical factor, with female-headed households showing elevated vulnerability across multiple domains. The findings underscore the importance of integrating gender-responsive, locally tailored, and inclusive approaches into climate adaptation planning. Strengthening education, diversifying livelihoods, enhancing water and health infrastructure, and improving disaster preparedness are essential for building resilience in vulnerable upland communities. The LVI and LVI-IPCC frameworks offer practical tools to support evidence-based policy and investment decisions for climate adaptation in Lao PDR.

Keywords

Livelihood Vulnerability, Climate Change, Northern Laos

1. Introduction

Climate change poses an immediate and escalating threat to sustainable development, particularly in climate-vulnerable nations such as the Lao People's Democratic Republic (Lao PDR). As ASEAN countries intensify their commitments to regional frameworks like the ASEAN Working Group on Climate Change and the ASEAN Agreement on Disaster Management and Emergency Response (AADMER), national efforts must align with shared priorities on resilience, adaptation, and risk reduction. Lao PDR's own National Adaptation Plan (NAP) and Nationally Determined Contributions (NDCs) emphasize the importance of localized, evidence-based approaches to safeguard livelihoods and ecosystems (Lao PDR, 2021). Addressing climate vulnerability especially among rural, agriculture-dependent populations, therefore, not only a national imperative but also a key contribution to ASEAN's collective climate resilience agenda. In this context, it is crucial to understand the broader impacts of climate change and their implications for vulnerable communities. Climate change has emerged as one of the most pressing challenges of the 21st century, exerting far-reaching impacts on ecosystems, human health, and global economies (IPCC, 2007; IPCC, 2022a). Primarily driven by human activities such as fossil fuel combustion and deforestation, climate change has disrupted natural systems and intensified weather-related hazards including floods, droughts, heatwaves, and sea level rise (Pachauri et al., 2014; Hoegh-Guldberg & Poloczanska, 2017). These impacts not only threaten biodiversity and environmental stability but also severely affect human livelihoods, particularly in developing regions where socio-economic vulnerabilities are pronounced (Adger, Arnell & Tompkins, 2005; Stern, 2006; Haines et al., 2006).

In the context of Southeast Asia, countries like the Lao People's Democratic Republic (Lao PDR) face heightened vulnerability due to their economic dependence on climate-sensitive sectors such as agriculture and forestry (Yusuf & Francisco, 2009; Beirne et al., 2021). Home to over 7 million people, Laos is predominantly rural, with around 60% of the population engaged in subsistence agriculture (World Bank, 2022). Climate variability, including erratic rainfall, extreme temperatures, and floods, has been shown to significantly reduce crop yields, threaten food security, and undermine community resilience (Rosenzweig et al., 2014; IPCC, 2022b). In particular, communities with limited access to health services, infrastructure, and education—especially in mountainous and remote areas—are disproportionately impacted (ADB, 2021; Nigatu, 2019). Oudomxay province in northern Laos is a case in point, having experienced over 326 documented climate-related hazards in recent years, including floods, droughts, and forest fires that have disrupted thousands of lives and livelihoods (Laodi, 2023; Laotian Times, 2022). These recurring events

highlight the urgent need to understand livelihood vulnerability at the local level, particularly in the face of increasing climate variability.

Vulnerability in the climate change context refers to the degree to which individuals or systems are exposed, sensitive, and lack the capacity to cope with or adapt to adverse climate impacts (IPCC, 2007; Smit & Wandel, 2006). Multiple frameworks have emerged to assess vulnerability, notably the Sustainable Livelihoods Framework (Chambers & Conway, 1992; Scoones, 1998; DFID, 1999), which considers the interaction of human, natural, physical, financial, and social capital in shaping livelihood outcomes. Scholars emphasize the need for multidimensional and context-specific vulnerability assessments to guide effective adaptation and disaster risk reduction (Birkmann & Pelling, 2006; Eriksen & Kelly, 2007). In response to these needs, the Livelihood Vulnerability Index (LVI), developed by Hahn, Riederer, and Foster (2009), offers a quantitative, integrative approach to assess community vulnerability. The LVI combines indicators of exposure, sensitivity, and adaptive capacity, making it a useful tool for guiding targeted policy interventions and resource allocation (Adu et al., 2017; Madhuri et al., 2014). Despite its wide application in other developing countries, its use in Laos remains limited. While past studies in Laos have assessed vulnerability in sectors such as energy (Stout et al., 2020), forestry (Cleetus, 2005), and land use planning (Hearn & Pongpanya, 2021), there is a notable gap in community-based livelihood vulnerability assessments.

To address this gap, the present study applies the LVI framework to assess the vulnerability of livelihoods to climate variability in Beng district, Oudomxay province. By identifying the most vulnerable populations and underlying drivers of vulnerability, the research aims to support climate adaptation planning and inform national efforts such as the National Adaptation Plan.

2. Methodology

2.1. Study Area

This study was conducted in Beng district, located in Oudomxay province, northern Lao People's Democratic Republic (Lao PDR), as shown in **Figure 1**. The province is mountainous, with altitudes ranging from 300 to 1800 meters, and comprises seven districts and 471 villages over an area of 15,370 km^2. It has a population of approximately 308,000 people, most of whom rely on subsistence agriculture as their primary livelihood. The main crops include upland and lowland rice, supplemented by maize, vegetables, and non-timber forest products. Oudomxay is prone to climate-related hazards such as droughts, flash floods, and erratic rainfall, which increasingly threaten agricultural productivity, food security, and household income. The climate profile includes a warm temperate climate with distinct wet and dry seasons. The rainy season spans May to October, while the dry season lasts from November to February. Rainfall patterns in the past decade have shown increased variability, with significant dry spells and extreme precipitation even during the dry season—demonstrating clear signs of cli-

mate change impacts on local ecosystems and communities. Given these conditions, Beng district was selected as the study area for assessing household-level vulnerability to climate change, using the Livelihood Vulnerability Index (LVI) and its adaptation based on the IPCC framework (LVI-IPCC).

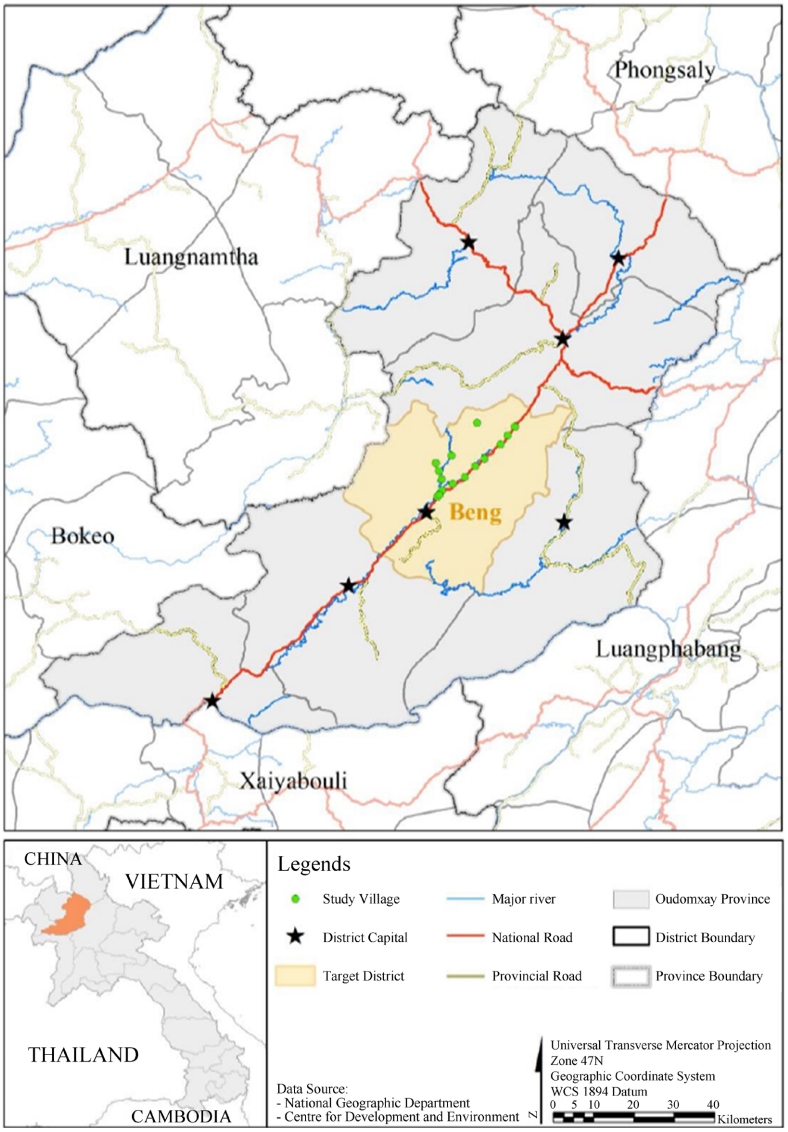

Figure 1. Map of case study area.

2.2. Data Source and Sampling Design

The data used in this study were obtained from the Mekong Sentinel Landscape Project, an initiative of the World Agroforestry Centre (ICRAF), which aimed to understand socio-economic and environmental dynamics across the Mekong region. The project collected household-level data from Laos, China, and Thailand between 2014 and 2016. This study specifically focused on the 2016 dataset for Lao PDR, from which 450 households were selected across 15 villages in Beng district (30 households per village). The selected villages were: Huaylor, Lai Gna, Mang,

Muangho, Nalai, Namet, Namtouy, Nangoua, Napa, Pangtho, Phiahua, Phonsa, Siengle, Tharmun, and Yor. The data were originally collected using a structured household questionnaire covering livelihood activities, resource access, health, education, social capital, and exposure to climate hazards. For the purpose of this study, 22 relevant sub-indicators were extracted from the dataset to construct both the LVI and LVI-IPCC metrics.

2.3. Analytical Framework

The Livelihood Vulnerability Index (LVI) provides a composite measure of household vulnerability by aggregating multiple indicators into a single index. This index captures the multidimensional nature of vulnerability through seven major components, each composed of several sub-indicators (22 in total). These components were selected based on their theoretical relevance, empirical validation in previous vulnerability assessments (Hahn et al., 2009), and contextual applicability to rural communities in northern Laos. The rationale for the selection and structuring of indicators is shown in **Table 1**.

2.3.1. LVI: Composite Index Model

LVI aggregates indicators into a single index, reflecting the degree of livelihood vulnerability. It consists of seven major components, each comprising multiple sub-indicators (22 in total):

Modifications and Implications

During the operationalization of the LVI in this study, minor contextual adaptations were made to certain indicators to reflect local realities. For instance:

The "access to health care" indicator was modified to include both distance to the nearest clinic and availability of traditional healers, as these are widely used in remote Lao villages.

"Migration support" was expanded to include seasonal labor migration to neighboring countries, reflecting a significant coping mechanism in northern Laos.

"Access to safe drinking water" was further disaggregated into dry-season and wet-season availability to better represent seasonal vulnerabilities.

While these modifications enhance the cultural and geographical relevance of the indicators, they may slightly affect comparability with LVI studies conducted in other regions or countries. However, transparency in indicator definitions and consistent internal methodology ensure that results remain internally comparable across villages in the study area and valid for cross-sectional analysis. Importantly, these adjustments allow for more accurate interpretation of results and the formulation of context-specific adaptation strategies.

Each sub-indicator was standardized using min-max normalization:

$$Index_{sv} = \frac{S_v - S_{\min}}{S_{\max} - S_{\min}}$$

where: S_v is value for the sub-indicator in village *v.*

$S_{\max}$, $S_{\min}$ is minimum and maximum values of that sub-indicator across all villages.

Each major component score M_v was calculated by averaging its normalized sub-indicators:

$$M_v = \frac{1}{n}\sum_{i=n}^{n} Index_{svi}$$

Finally, the overall LVI was calculated as a weighted average of all seven components:

$$LVI_v = \frac{\sum_{i=1}^{7} W_i * M_{vi}}{\sum_{i=1}^{7} W_i}$$

where: W_i is weight of each component (equal for all components);

M_{vi} is score of the i component for village v;

LVI scores range from 0 (least vulnerable) to 0.5 (most vulnerable).

Table 1. Major indicator.

Major Component	Description	Justification
Socio-Demographic Profile	Age, gender, and education characteristics of household heads	Demographic characteristics influence household adaptive capacity. For example, elderly or less-educated household heads may face greater barriers to adaptation.
Livelihood Strategies	Sources of income, employment, and migration support	A diverse livelihood portfolio reduces dependency on climate-sensitive sectors such as agriculture, thereby lowering exposure and sensitivity.
Health	Illness occurrence and access to healthcare services	Health status directly affects a household's capacity to respond to stressors and shocks, making it a critical element of vulnerability.
Social Networks	Support received from relatives, government, and financial institutions	Social capital and institutional support serve as buffers during crises and are essential for resilience-building and post-disaster recovery.
Food Security	Food access, income for food, and reliance on external food inputs	Food security is a key outcome affected by climate-induced stress, especially among subsistence farmers in drought- or flood-prone regions.
Water Access	Sources of water and shortages	Water availability is a core determinant of agricultural productivity, health, and daily living, particularly in regions facing seasonal drought.
Natural Disasters and Climate Variability	Exposure to floods, droughts, crop loss, and adaptive measures	Directly captures household exposure and sensitivity to climatic shocks and their readiness to respond, aligning closely with IPCC vulnerability dimensions.

2.3.2. LVI-IPCC: IPCC Vulnerability Framework

The LVI-IPCC adapts the LVI to align with the IPCC's definition of vulnerability as a function of Exposure (E), Sensitivity (S), and Adaptive Capacity (A):

$$Vulnerability = (E - A) \times S$$

Each of the 7 LVI components was assigned to one of the three IPCC contributing factors as illustrated in Table 2.

Table 2. IPCC framework component.

IPCC Factor	Contributing Components
Exposure (E)	Natural disasters and climate variability
Sensitivity (S)	Health, Food Security, Water Access
Adaptive Capacity (A)	Socio-demographic profile, Livelihood strategies, Social networks

For each IPCC factor, component scores were averaged using:

$$CF_v = \frac{\sum_{i=1}^{n} W_i * M_{vi}}{\sum_{i=1}^{n} W_i}$$

where CF_v is the value of Exposure, Sensitivity, or Adaptive Capacity for village v.

Adaptive capacity indicators were inverted (where appropriate) to reflect that higher values indicate lower vulnerability (e.g., education level, income diversity).

The resulting LVI-IPCC score ranged from −1 (least vulnerable) to +1 (most vulnerable).

2.4. Gender-Based Crosstab Analysis

To explore gender-specific patterns of vulnerability, the study performed a crosstab analysis using SPSS. The LVI scores and select sub-indicators were disaggregated by the gender of the household head (male vs. female), allowing for an assessment of differences in exposure, sensitivity, and adaptive capacity between male- and female-headed households. This analysis complemented the main findings and supported the study's aim of identifying vulnerability disparities across demographic groups.

3. Results

This section presents the findings from the Livelihood Vulnerability Index (LVI) and the Livelihood Vulnerability Index-IPCC (LVI-IPCC), based on data from 450 households across 15 villages in Beng district, Oudomxay province. The results are structured around the seven major LVI components and disaggregated further into three contributing factors under the IPCC framework: adaptive capacity, sensitivity, and exposure. A gender-disaggregated analysis is also included to explore differential vulnerability among male- and female-headed households.

3.1. Livelihood Vulnerability Index (LVI)

Overall LVI Scores

The overall LVI scores ranged from 0.327 to 0.476, with Mang village showing the

highest vulnerability (0.476), followed by Huaylor (0.465) and Napa (0.448) as demonstrated in Table 3. In contrast, Namtouy exhibited the lowest vulnerability (0.327). Figure 2 presents a spider diagram comparing the most and least vulnerable villages.

- Socio-demographic profile: Mang village (0.845) had the highest vulnerability due to a high dependency ratio, large number of female-headed households, and low education levels. Namtouy (0.222) had the lowest score in this domain.
- Livelihood strategies: Huaylor recorded the highest vulnerability (0.978), reflecting heavy reliance on agriculture and high household unemployment. Namtouy again showed the lowest vulnerability (0.344).
- Health: Muanghom had the highest vulnerability (0.500), attributed to long distances to health services and presence of severe illness. Yor (0.009) was the least vulnerable.
- Social networks: Nalai had the highest vulnerability (0.556), while Nangoua, Napa, and Muanghom shared the lowest (0.422), reflecting better support systems.
- Food security: Phiahuanam and Phonsa At recorded the highest vulnerability (0.711), with widespread food shortages and reliance on purchased inputs. Yor (0.411) was least affected.
- Water access: Thamun was the most vulnerable (0.356), lacking tap water and relying on natural water sources. Sienglea (0.033) was least vulnerable.
- Natural disasters and climate variability: Muanghom (0.500) showed the highest vulnerability due to crop loss, pests, and absence of mitigation strategies. Napa (0.320) was least vulnerable.

Table 3. LVI index.

Villages	Sociodemographic profile	Livelihood strategies	Health	Social Network	Food Security	Water Access	Natural disasters and climate variability	Overall LVI
Huaylor	0.455	0.978	0.1	0.5	0.533	0.256	0.373	0.465
Lai Gnai	0.333	0.667	0.242	0.456	0.678	0.033	0.413	0.411
Mang	0.845	0.7	0.173	0.433	0.633	0	0.46	0.476
Muanghom	0.333	0.678	0.5	0.422	0.567	0	0.5	0.432
Nalai	0.267	0.578	0.017	0.556	0.489	0.178	0.467	0.389
Namet	0.511	0.544	0.318	0.511	0.5	0.267	0.393	0.437
Namtouy	0.222	0.344	0.117	0.467	0.556	0.067	0.4	0.327
Nangoua	0.3	0.567	0.136	0.422	0.489	0.089	0.447	0.368
Napa	0.489	0.644	0.426	0.422	0.589	0.322	0.32	0.448
Pangthong	0.478	0.544	0.173	0.467	0.444	0.289	0.36	0.401
Phiahuanam	0.4	0.6	0.239	0.456	0.711	0.022	0.347	0.399
Phonsa At	0.267	0.667	0.189	0.478	0.711	0.044	0.413	0.407
Sienglea	0.278	0.622	0.036	0.456	0.622	0.033	0.38	0.364
Thamun	0.333	0.722	0.279	0.511	0.556	0.356	0.353	0.444
Yor	0.344	0.556	0.009	0.344	0.411	0.222	0.387	0.345

The Livelihood Vulnerability Index (LVI) scores across the 15 surveyed villages in Beng District ranged from 0.327 (least vulnerable) in Namtouy to 0.476 (most vulnerable) in Mang, within the possible scale of 0 (least vulnerable) to 0.5 (most vulnerable). This distribution indicates a moderate to high level of vulnerability across all villages, with some variation in the magnitude and drivers of vulnerability. Mang exhibited the highest LVI score (0.476), primarily due to a critically high sociodemographic profile score (0.845), suggesting an aging or less-educated population with reduced adaptive capacity. Elevated scores in natural disasters and climate variability (0.460) and food security (0.633) further contributed to Mang's high vulnerability. Huaylor (LVI = 0.465) also ranked among the most vulnerable, driven by extremely high livelihood strategies vulnerability (0.978), indicating poor income diversification and a dependence on climate-sensitive livelihoods. Meanwhile, Phiahuanam, Phonsa At, and Lai Gnai exhibited moderate vulnerabilities (LVI ≈ 0.399 - 0.411), but with distinct patterns such as high food insecurity and limited water access. At the lower end of the spectrum, Namtouy (0.327), Sienglea (0.364), and Nangoua (0.368) displayed comparatively lower vulnerability levels. These villages had consistently low scores in key components such as water access, health, and social networks, reflecting relatively better access to services and support. However, even these villages exhibited moderate exposure to natural disasters and climate variability, indicating district-wide climatic sensitivity. Component-level analysis revealed that livelihood strategies, natural disasters and climate variability, and food security were the most influential contributors to overall vulnerability. Conversely, water access and health generally presented lower vulnerability scores across the sample. These findings underscore the multidimensional and spatially variable nature of livelihood vulnerability, and suggest that targeted interventions such as improving income diversification, strengthening disaster preparedness, and enhancing food security are essential to building resilience in Beng District.

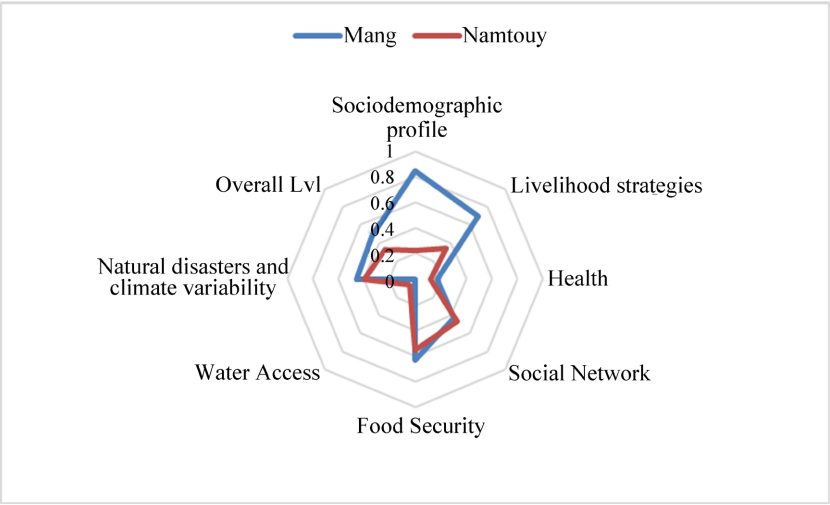

Figure 2. Vulnerability spider diagram of major indicators of livelihood vulnerability for highest and lowest vulnerable villages.

3.2. Livelihood Vulnerability Index (LVI)-IPCC

The Livelihood Vulnerability Index-IPCC (LVI-IPCC) was calculated by regrouping the seven primary indicators into three IPCC-defined components: adaptive capacity, sensitivity, and exposure.

To align with the IPCC framework, sub-indicators under adaptive capacity were inverted, for instance, female-headed households were recoded as male-headed, and similar adjustments were made for all relevant variables as shown in Table 4.

Table 4. LVI-IPCC indicators.

Primary Indicator	Original Sub-Indicator (LVI)	Modified Sub-Indicator (LVI-IPCC)
Socio-demographic	Percent of households with members under 15 or over 60	Percent of households without members under 15 or over 60 (inverted)
Livelihood Strategies	Percent of households headed by females	Percent of households headed by males
	Percent of households where head did not attend school	Percent of households where head attended school
	Percent of households receiving help from non-resident family	Percent not receiving help from non-resident family
	Percent relying on agriculture income	Percent not relying solely on agriculture income
	Percent with unemployed household members	Percent with no unemployed household members
Social Network	Percent receiving money/food/assistance from relatives	Percent not receiving assistance from relatives
	Percent borrowing money from an institution	Percent not borrowing money from an institution

Livelihood Vulnerability Index (LVI)-IPCC Index

According to the calculation of vulnerability based on the Intergovernmental Panel for Climate Change (IPCC), contributing factors (Adaptive capacity, Sensitivity and Exposure as shown in Table 5 and Figure 3) show that Mang village demonstrated the highest vulnerability score (0.033), followed by Huaylor (0.006).

Table 5. LVI-IPCC result.

Village	Adaptive Capacity (A)	Sensitivity (S)	Exposure (E)	LVI-IPCC
Huaylor	0.356	0.321	0.373	0.006
Lai Gnai	0.515	0.327	0.413	−0.033
Mang	0.341	0.281	0.46	0.033

Continued

Muanghom	0.522	0.338	0.5	−0.008
Nalai	0.533	0.254	0.467	−0.017
Namet	0.478	0.367	0.393	−0.031
Namtouy	0.656	0.263	0.4	−0.067
Nangoua	0.57	0.251	0.447	−0.031
Napa	0.481	0.448	0.32	−0.072
Pangthong	0.504	0.318	0.36	−0.046
Phiahuanam	0.515	0.335	0.347	−0.056
Phonsa At	0.53	0.331	0.413	−0.039
Sienglea	0.548	0.255	0.38	−0.043
Thamun	0.478	0.412	0.353	−0.051
Yor	0.585	0.24	0.387	−0.047

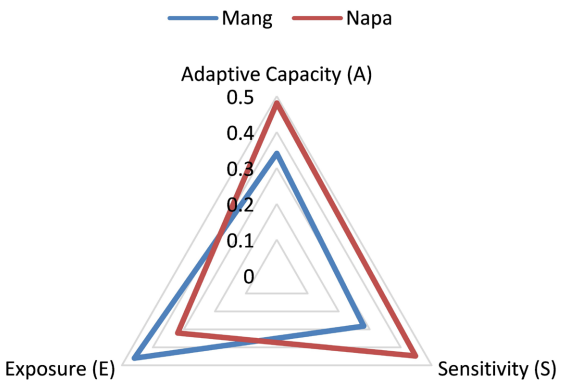

Figure 3. Vulnerability triangle diagram of the contributing factors to the Livelihood Vulnerability Index-IPCC for highest and lowest vulnerable villages.

3.3. Gender-Based Vulnerability Analysis

Crosstab analysis reveals that female-headed households consistently face higher levels of vulnerability compared to male-headed households across multiple indicators as illustrated in **Table 6**. Notably, 26.1% of female-headed households experienced food shortages in the past year, compared to 16.2% of male-headed households. Female-headed households were also more likely to receive government assistance (12.4% vs. 7.2%), borrow from microfinance institutions (42% vs. 38.9%), and purchase agricultural seeds (32.2% vs. 18%). Furthermore, 18.8% of female heads reported facing rising food prices, significantly more than the 4.8% of male heads. In terms of climate impact, 43.5% of female-headed households reported crop loss due to drought, compared to 28.7% of male-headed households. These findings underscore the heightened vulnerability of female-headed households to food insecurity, financial stress, and climate-related shocks.

Table 6. Result of Crosstab analysis.

Indicator	Male (%)	Female (%)
Food shortage experience	16.29	26.1
Received government assistance	7.2	12.4
Borrowed from micro-finance	38.9	42
Bought seed for agriculture	18	32.2
Faced rising food prices	4.8	18.8
Lost crops due to drought	28.7	43.5

4. Discussion

This study assessed the vulnerability of rural communities to climate change using the Livelihood Vulnerability Index (LVI) and the Intergovernmental Panel on Climate Change (LVI-IPCC) frameworks across 15 villages in Beng District, Oudomxay Province, Lao PDR. The findings highlight a high degree of heterogeneity in vulnerability across villages, influenced by socio-demographic, economic, environmental, and institutional factors. A key emphasis of this discussion is the role of gender, integrated within the socio-demographic profile, which emerged as a critical dimension influencing livelihood vulnerability.

Socio-demographic Profile and Gendered Vulnerability

The socio-demographic characteristics of households—including age structure, education level of the household head, and gender—substantially influenced vulnerability levels. Villages with a high proportion of households with dependent members (under 15 or over 60 years of age) showed increased vulnerability, consistent with literature indicating that dependency burdens reduce a household's adaptive capacity (Bryant et al., 2022; UEPA, 2022). Households led by individuals with no formal education were also significantly more vulnerable, supporting findings by Hoffman and Blecha (2020) and Muttarak and Lutz (2014), who argue that education enhances resilience by fostering disaster preparedness and informed decision-making.

Integrating gender into this profile further revealed that female-headed households exhibited consistently higher levels of vulnerability than male-headed households. Crosstab analysis demonstrated that female-headed households were more likely to report food shortages, reliance on purchased agricultural inputs, lack of access to adaptive resources, and loss of crops due to drought. These findings are in line with studies highlighting how socio-cultural roles, limited access to resources, and exclusion from decision-making disproportionately affect women during climate-related shocks (Habtezion, 2016; Brody et al., 2008; Rahman, 2013). The feminization of poverty, particularly in rural and resource-dependent settings, exacerbates this disparity. Pangthong, Huaylor, and Namet, which had the highest proportions of female-headed households, also recorded high overall vulnerability scores, emphasizing the gendered dimension of climate risk.

Livelihood Strategies and Economic Exposure

Agriculture was the primary livelihood source across all surveyed villages, indicating strong dependence on climate-sensitive natural resources. Villages such as Huaylor and Mang, where households derived nearly all income from agricultural activities, were especially exposed. Previous studies (De Silva & Kawasaki, 2018; Abeygunawardena et al., 2009) emphasize that such reliance heightens sensitivity to climate variability, particularly when compounded by unemployment, limited livelihood diversification, and weak market access. A significant proportion of households in Mang village identified as the most vulnerable overall were entirely reliant on agriculture, received remittances from absent family members, and lacked employment diversity. These factors collectively point to economic fragility, undermining resilience in the face of floods, droughts, and crop diseases. As Vinke et al. (2017) suggest, livelihood diversification and non-farm income sources are essential in buffering against climate shocks.

Social Networks and Institutional Support

Social networks measured by households' access to informal (relatives) and formal (government or microfinance) support played a dual role. On one hand, assistance from relatives provided a short-term buffer against economic shocks. On the other, heavy dependence on remittances or microfinance borrowing signaled underlying vulnerability and financial stress. Namet and Nalai had the highest proportion of households receiving family assistance, reflecting both strong social ties and limited self-sufficiency. Notably, formal institutional support was limited across all villages. Fewer than 30% of households in any village reported receiving government assistance, and some villages (e.g., Yor and Nalai) had none. This suggests a gap in state-led climate adaptation support and highlights the need for inclusive risk reduction and resilience programming, particularly for rural and remote communities.

Health, Food Security, and Water Access

Health infrastructure, food security, and water access were also major determinants of vulnerability. Villages farther from district health centers, such as Muanghom (35 km), had higher health-related vulnerability, confirming that geographic isolation limits access to essential services during climate-related emergencies (Adu et al., 2017; Syed et al., 2013).

Food insecurity was pervasive. A large proportion of households, especially in Phiahuanam and Phonsa At, reported not having enough money to buy food. The widespread use of firewood and purchase of agricultural seeds underscored continued reliance on natural ecosystems and out-of-pocket farming inputs, both of which are sensitive to market volatility and environmental change (Pasanen et al., 2017; Vatthanatham et al., 2018). Water insecurity was not uniformly severe but still notable. In villages such as Thamun and Napa, a significant share of households relied on natural water sources (creeks, rivers), increasing sensitivity to seasonal droughts. Although tap water access was more common in some areas, reliability and climate resilience of these sources remain uncertain. Given Oudomxay's vulnerability to hydrological extremes (UN-Habitat, 2019; Pink, 2016), water security must remain a policy priority.

Natural Hazards and Community Preparedness

Natural disasters—including droughts, floods, and crop diseases—were widespread, particularly in Muanghom and Nalai. The impact of the 2016 flash flood, which affected over 1,900 people in Beng District (IFRC, 2016), was still evident in the vulnerability scores. Despite this exposure, the majority of villages lacked effective mitigation or prevention plans, especially for droughts. This suggests limited risk awareness, insufficient early warning systems, and low investment in preparedness—issues also flagged in Laos' National Adaptation Programs (Lao PDR, 2009; WHO, 2019). Mitigation and adaptation planning is further hindered by low levels of community awareness. As Ratinen (2021) and Surminski & Oramas-Dorta (2014) emphasize, integrating local knowledge, building capacity, and fostering inclusive participation in climate policy are key to reducing long-term vulnerability.

5. Conclusion

This study assessed the vulnerability of rural communities to climate change in 15 villages of Beng District, Oudomxay Province, Lao PDR, using the Livelihood Vulnerability Index (LVI) and LVI-IPCC frameworks. The analysis revealed that livelihood vulnerability is shaped by multiple, interdependent factors, most notably socio-demographic conditions, livelihood strategies, social networks, health, food security, water access, and exposure to natural hazards. Among the surveyed villages, Mang exhibited the highest overall vulnerability due to a combination of structural and environmental disadvantages. These included a high proportion of uneducated and female-headed households, strong dependence on climate-sensitive agricultural livelihoods, widespread unemployment, weak adaptive capacity, and limited disaster preparedness. In contrast, Namtouy showed relatively low vulnerability, underpinned by stronger adaptive capacity, reliable water access, and lower exposure to climate-related hazards. A key finding across the sample was the role of gender as a cross-cutting factor. Female-headed households consistently scored higher on vulnerability indicators, including food insecurity, limited access to financial services, and inadequate disaster preparedness. This underscores the need to incorporate gender equity as a foundational element of climate adaptation and rural development strategies. The use of both LVI and LVI-IPCC frameworks adds analytical robustness and enhances validation of results. While the LVI offers a composite measure of overall vulnerability, the LVI-IPCC disaggregates vulnerability into adaptive capacity, sensitivity, and exposure, consistent with the conceptual foundations of the IPCC framework. The convergence of results from both methods lends credibility to the findings and confirms the utility of these frameworks for field-based assessments in data-scarce contexts. These findings are significant in both academic and policy terms. Academically, they contribute to a growing body of evidence that highlights the spatial and social differentiation of climate vulnerability within rural communities. From a policy perspective, they identify specific vulnerability drivers that can be targeted through

local interventions. Villages such as Mang and Huaylor, which combine high exposure and low adaptive capacity, should be prioritized for place-based, socially inclusive, and gender-responsive adaptation planning. Moreover, the study demonstrates that standardized, indicator-based assessments when grounded in local data can provide actionable insights for development practitioners and policymakers. As vulnerability continues to evolve under changing climate and socioeconomic conditions, regular updates to such assessments, alongside the integration of qualitative methods and longitudinal data, will be crucial for tracking adaptation progress and informing responsive strategies.

6. Limitation and Recommendation

6.1. Limitation

This study utilized secondary data from the Mekong Sentinel Landscape household survey to calculate the Livelihood Vulnerability Index (LVI). While the dataset offered a useful basis for analysis, the selection and adaptation of indicators were constrained by data availability, limiting comparability with other LVI studies. Key variables such as income trends, land tenure, and local adaptation practices were either absent or insufficiently detailed, affecting the comprehensiveness of the vulnerability assessment. Sampling bias is a further concern. As noted by Hahn et al. (2009), a survey may underrepresent households with migrant or working adults, skewing results toward more sedentary populations. This could distort indicators related to livelihood strategies and adaptive capacity. Future studies should consider randomized sampling, follow-up visits, and oversampling of vulnerable groups to improve representativeness. Moreover, the cross-sectional nature of the data limits insights into temporal dynamics. Longitudinal studies and repeated surveys are essential to track changing vulnerability and adaptation over time. Finally, combining quantitative assessments with qualitative methods—such as key informant interviews and focus group discussions—would enrich context-specific understanding and improve the relevance of policy recommendations.

6.2. Recommendation

Based on the study's findings, the following recommendations are proposed for policymakers, development partners, and local stakeholders:

- Gender-responsive adaptation should be strengthened by targeting female-headed households with livelihood support, social protection, and skills training, while ensuring their active participation in community planning and disaster risk reduction.
- Educational and awareness initiatives should promote adult literacy and localized climate education, including campaigns on flood and drought preparedness in high-risk areas.
- Livelihood diversification can be supported by investing in alternative income sources such as agro-processing, small enterprises, and ecotourism, alongside

vocational training for youth and women.

- Access to basic services should be improved by upgrading health and transport infrastructure in remote villages and expanding resilient water supply systems.
- Community-based disaster preparedness should be enhanced through support for local risk mapping, early warning systems, preparedness planning, and infrastructure for drought and flood mitigation.
- Financial inclusion and safety nets can be strengthened by increasing access to microfinance, insurance, emergency assistance, and expanding public works programs tailored to climate-affected households.

Given that this study employed the LVI-IPCC framework, a widely recognized tool that synthesizes elements of the Sustainable Livelihoods Framework with the IPCC's earlier conceptualization of vulnerability as a function of exposure, sensitivity, and adaptive capacity, it is important to acknowledge recent developments in climate risk assessment. The IPCC's Sixth Assessment Report (AR6) advances a more integrated risk-based framework, emphasizing the interaction of hazards, vulnerability, and exposure within broader socio-ecological systems. While the LVI-IPCC continues to offer practical utility for community-level, indicator-based vulnerability assessments, future research would benefit from aligning with the AR6 paradigm. This includes incorporating a more nuanced analysis of socio-institutional drivers of risk, accounting for non-linear and compounding effects of climate hazards, and recognizing feedbacks between system components. Such integration would enhance the conceptual robustness and policy relevance of LVI-based assessments in the context of evolving global climate frameworks.

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Conflicts of Interest

The authors declare no conflicts of interest regarding the publication of this paper.

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