VULNERABILITY ASSESSMENT OF HOUSEHOLDS TO NATURAL HAZARDS: A CASE STUDY OF AN ETHNIC COMMUNITY IN LAO CAI PROVINCE, VIET NAM

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Abstract: *This study presents an indicator-based assessment of household vulnerability to natural hazards among H'Mong communities in Lao Cai Province, Viet Nam. The assessment used the IPCC AR4 framework with three components: Exposure (E), Sensitivity (S), and Adaptive Capacity (AC), and a set of 19 indicators was used to assess the vulnerability. Household data were collected through in-depth and semi-structured interviews with 70 H'Mong households in 2026. Flash floods and landslides are the most frequently experienced hazards in the study area, with percentages of 67% and 80%, respectively. 100% of interviewed households rely on agriculture. Approximately 73% of households reported having no savings or access to credit and 68.5% lived in wooden, grade-IV (lowest-grade) houses. The calculated assessment results for E, S, and AC were 0.46, 0.57, and 0.44, respectively, resulting in an overall vulnerability index of 0.59. Financial limitations, inadequate housing, and weak institutional support were identified as the main constraints to household resilience. These findings provide evidence to support targeted disaster risk reduction and climate change adaptation policies for ethnic minority communities in mountainous regions.*

Keywords: *Vulnerability, household vulnerability, indicator-based assessment, natural hazards, mountainous areas, Viet Nam.*

1. Introduction

Natural hazards have become a growing global concern due to climate change (CC) and environmental degradation [1]. Viet Nam is one of the countries most vulnerable to climate change and faces many natural hazards, including floods, landslides, storms, droughts, and heatwaves. Demonstrating this trend, Typhoon Yagi hit Northern Viet Nam in September 2024, resulting in an estimated USD 1.6 billion in damage across the country; within the two provinces included in the current study area, the storm caused damage to around 5,000 homes in Lao Cai and 23,400 homes in Yen Bai, with a single landslide in Lao Cai's Bao Yen district completely wiping out a hamlet [2].

Reducing the impacts of climate change and strengthening resilience to natural hazards have become significant priorities in Viet Nam [3]. Therefore, vulnerability assessment plays a key role in identifying the populations and areas that are most at risk. It also provides a scientific foundation for disaster risk reduction, climate change adaptation, and sustainable development planning in Viet Nam [4]. Although efforts in disaster risk management have increased in recent years, important research gaps remain. Firstly, most existing studies assess vulnerability to individual hazards, while comprehensive multi-hazard assessments are still limited [5]. In particular, there is a lack of understanding of how hazard characteristics,

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exposure, vulnerability, and adaptive capacity interact to influence disaster risk across different regions or communities [5].

More recent studies (2023-2025) extend this line of research to other ethnic minority groups in Viet Nam. Bui et al. applied the same framework to Tay and Thai households in Yen Bai province [6], while Tran et al. examined the Pa Co and Co Tu communities in Thua Thien Hue province using the LVI-IPCC framework [7]; both studies similarly found that livelihood diversification and adaptive capacity remain the primary drivers of differential vulnerability among ethnic groups, reinforcing the relevance of the present study's focus on H'Mong households.

Mountainous regions in Northern Viet Nam are particularly vulnerable due to steep terrain, unstable geological conditions, and limited infrastructure, all of which increase both hazard occurrence and potential losses [8]. Vulnerability is also influenced by socioeconomic conditions, including dependence on agriculture, limited access to public services, and low adaptive capacity. Ethnic minority communities, such as the H'Mong, Tay, Dao, and Nung, often face higher levels of vulnerability because they live in remote areas and experience social and economic disadvantages [9]. Among these groups, the H'Mong usually live in high-altitude areas where they are more exposed to landslides, flash floods, and extreme weather. Their vulnerability is exacerbated by limited access to transportation, education, healthcare, early warning information, and official support [5], [9]. However, previous studies have provided limited insight into how multiple hazards and socio-cultural factors interact to shape the vulnerability of H'Mong households.

Lao Cai Province, located in Northern Viet Nam, is one of the country's most hazard-prone mountainous regions due to its steep terrain, complex river systems [10], and diverse ethnic populations [11]. Within the province, Van Chan commune is characterized by steep slopes, fragmented terrain, and livelihoods that mainly depend on upland agriculture. Frequent flash floods, landslides, and other climate-related hazards, together with limited infrastructure and livelihood diversification, make local communities particularly vulnerable. H'Mong households, which make up a large part of the commune's population, face additional challenges because of their remote location and limited adaptive capacity, making them more vulnerable to natural hazards [9], [12]. Therefore, this study evaluates the vulnerability of H'Mong households to natural hazards in Lao Cai province using a composite Vulnerability (V) index based on Exposure (E), Sensitivity (S), and Adaptive capacity (AC) indicators. The study has three objectives: (1) To assess the overall level of household vulnerability, (2) To identify the main factors affecting vulnerability, and (3) To provide recommendations for improving the resilience of H'Mong households and reducing their vulnerability to natural hazards.

2. Materials and methods

2.1. Indicator-based assessment of vulnerable households to climate change

This study assesses household vulnerability based on three components: E, S, and AC [13]. A total of 19 indicators were selected and developed to assess the vulnerability of ethnic minority households in Lao Cai province (Table 1).

2.2. Social survey

In-depth and semi-structured interviews using questionnaires were conducted from January to February 2026 through face-to-face surveys in Van Chan commune, Lao Cai province. The questionnaire was developed based on the vulnerability indicator framework, covering household characteristics, socio-economic conditions, housing conditions, hazard experiences, and adaptive strategies. A total of 70 households were selected using random sampling from different hamlets. The sample size was determined using Slovin's formula (1):

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

Where, n is the sample size, N is the total number of households in Van Chan commune (N = approximately 19,000 following the 2025

administrative merger), assuming a confidence level of 90% and a margin of error of 10%. In-depth interviews were conducted with one local authority representative, two local police (public security) officers, three former local officials, and elderly residents to obtain additional information on local hazards and livelihood conditions.

Table 1. Indicators for household vulnerability assessment

Dimension	Code	Indicators	Description	References
Exposure (E)	E1	Number of natural hazards affected households	Percentage of households affected by natural hazards in the last 10 years (2015-2025)	[14]
	E2	Frequency of natural hazards	Frequency of natural hazards experienced by the household in the last 10 years (2015-2025)	[1]
	E3	Damage level of agricultural land by natural hazards	Level of damage to agricultural land caused by natural hazards within 2015-2025	[15]
	E4	Damage level of housing by natural hazards	Households experiencing damage to housing caused by natural hazards within 2015-2025	
Sensitivity (S)	S1	Gender of household head	Household is headed by male/female	[16]
	S2	Household dependency	Presence of vulnerable household members (children, elderly, persons with disabilities)	[17]
	S3	Housing condition	Traditional H'Mong housing type	[14]
	S4	Livelihood diversity	Number of household livelihood activities	[18]
	S5	Reduced agricultural production due to natural hazards	Reduction in crop/livestock production due to natural hazards	[18]
	S6	Insufficient food produced from own farm	Degree of insufficiency of food produced from own agricultural activities to meet household needs	[18]
	S7	Water access	Degree of difficulty accessing domestic water during natural hazards	
Adaptive Capacity (AC)	AC1	Education	Education level of respondent	[18]
	AC2	Health care/Health insurance	Ability to afford healthcare costs	[18]
	AC3	Preparedness measures	Financial resources for recovery, medicine, food, water storage, alternative lighting tools	[18]
	AC4	Awareness/Capacity	Household participation in training courses and workshops on disaster mitigation	[18]
	AC5	Disaster warning information	Number of households receiving disaster warning information	

Dimension	Code	Indicators	Description	References
	AC6	Household adaptation measures	Degree of adoption of measures to reduce impacts of natural hazards (reinforced housing, crop adjustment, food storage, etc.)	[18]
	AC7	Accessibility to Infrastructure	Accessibility to infrastructure/support during natural hazards occurring	[18]
	AC8	Participation in local social organizations	Financial support or access to credit for post-disaster recovery	[18]

2.3. Data analysis

The dataset was first coded and subsequently standardized to a range of 0-1 using the min-max normalization technique [19]. For indicators showing a positive relationship with E, S, and AC, normalization was carried out using Equation (2):

$$x_{ij} = \frac{X_{ij} - MinX_{ij}}{MaxX_{ij} - MinX_{ij}} \quad (2)$$

For indicators that were inversely related to *E, S*, and *AC* the normalization process followed Equation (3):

$$x_{ij} = \frac{MaxX_{ij} - X_{ij}}{MaxX_{ij} - MinX_{ij}} \quad (3)$$

Where, x_{ij} is the normalized value, and X_{ij} is the original value of indicator *i* for household *j*.

Following the normalization process, the indicators within each component *E, S*, and *AC (R)* were calculated to have the average value in order to find the scores. The specific calculations for each component are described as follows in Equation (4):

$$R = \frac{\sum_{i=1}^{n} R_i}{n} \quad (4)$$

Where, *n* represents the number of indicators within each component. This method is used in indicator-based vulnerability assessments due to its simplicity and transparency [20], [21].

V was calculated following the conceptual framework of the IPCC [13], using the following formulation:

$$V = E + S - AC \quad (5)$$

In this study, three component indicators, including *E, S*, and *AC* are normalized to a range between 0 and 1. Based on the linear formulation as presented above, the theoretical range of the vulnerability index extends from −1 to 2 [13], [22].

3. Results and discussion

3.1. Vulnerability assessment of households to natural disasters

3.1.1. Exposure

Exposure is evaluated by the intensity and frequency of various hazards that households experienced within the last 10 years (E1, E2), as well as the damage to agriculture, forestry, livestock, and local people's houses (E3, E4). The survey indicated that landslides are the most frequently reported hazard, with 80%, followed by heavy rain and flash floods with 67.1%, drought and water shortages, and hail with approximately 60%. Storms and tropical depressions also affect a considerable number of households, accounting for 47.1%, while unpredictable weather is reported by 18.6%. In contrast, only 5.7% and 2.9% of households experienced severe cold and reported no hazard occurrence, respectively (Figure 1). Especially, most of the points of flash floods and landslides are concentrated in the Suoi Giang area and the former Son Thinh Town where most of the H'Mong people live, and then exhibits quite high exposure.

For frequency of these hazards (E2), heavy rainfall, floods/flash floods, and landslides are the most prevalent hazards in the study area. Approximately 35.7% of households reported experiencing heavy rainfall and floods more than three times per year. Similarly, 57% of households experienced landslides 1-2 times

per year, and around 29% reported occurrences more than three times per year. Hail, drought, and water shortage were recorded, with about 61% and 40% of households experiencing these hazards 1-2 times per year. In contrast, storms, tropical depressions, and severe cold and frost were less frequently reported, with 50% of households indicating no occurrence.

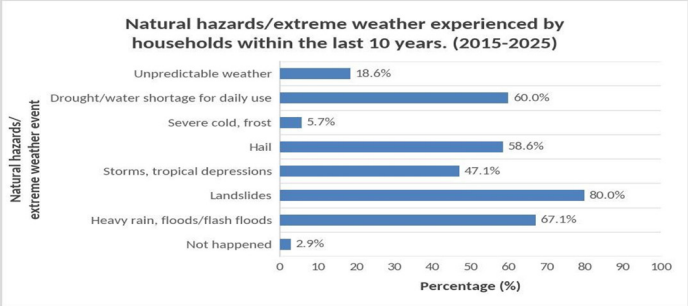


Figure 1. Natural disasters experienced by households within the last 10 years (2015-2025)

Table 2. Normalized values of Exposure (E), Sensitivity (S), and Adaptive Capacity (AC) indicators

Code	Indicator	Normalized value (0-1)
Exposure (E)		
E1	Number of natural hazards affecting households	0.40
E2	Frequency of natural hazards	0.77
E3	Damage level of agricultural land by natural hazards	0.50
E4	Damage level of housing by natural hazards	0.19
—	**Mean Exposure (E)**	**0.46**
Sensitivity (S)		
S1	Gender of household head	0.37
S2	Household dependency	0.67
S3	Housing condition	0.72
S4	Livelihood diversity	0.90
S5	Reduced agricultural production due to natural hazards	0.56
S6	Insufficient food produced from own farm	0.20
S7	Water access	0.56
—	**Mean Sensitivity (S)**	**0.57**
Adaptive Capacity (AC)		
AC1	Education	0.21
AC2	Health care/Health insurance	0.60
AC3	Preparedness measures	0.49
AC4	Awareness/Capacity	0.52
AC5	Disaster warning information	0.76
AC6	Household adaptation measures	0.22
AC7	Accessibility to Infrastructure	0.45
AC8	Participation in local social organizations	0.27
—	**Mean Adaptive Capacity (AC)**	**0.44**

The survey results also indicate that the impacts of these natural hazards on agriculture, forestry, and livestock (E3) vary across households. 60% of households reported experiencing minor and moderate damage, while 26% reported significant damage. Only 14% of households reported no damage. For house damage (E4), 37% experienced minor damage.

The overall exposure score is 0.46 on a scale of 0-1, indicating a moderate level (Figure 2). The frequency of hazard occurrence (E2 = 0.77) contributes the most to overall exposure, indicating that households are commonly exposed to multiple hazards. This is followed by damage to agriculture and livestock (E3 = 0.50) and the number of natural hazard types affecting households (E1 = 0.40). In contrast, damage to housing contributes the least (E4 = 0.19), suggesting that physical damage to housing is limited compared to other exposures (Table 2).

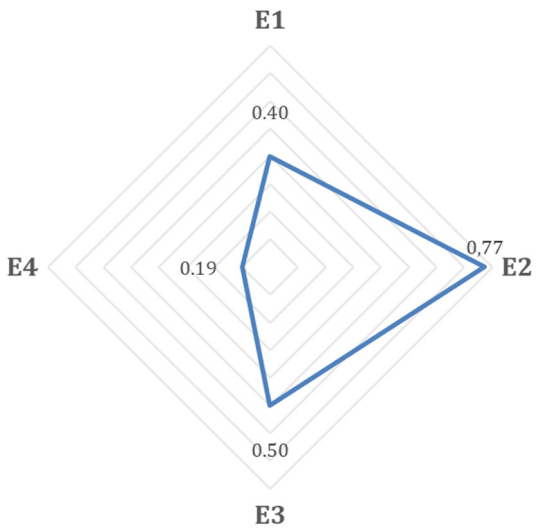


Figure 2. Exposures of ethnic households to natural disasters

3.1.2. Sensitivity

Females, children, the elderly, and the disabled persons and people with long-term illness (S1, S2) are highly vulnerable groups when exposed to natural hazards. The study area is generally characterized by these groups, with almost 80% of households containing at least one vulnerable member, indicating a high level of social sensitivity. In particular, 37% of households are headed by women, which may increase social sensitivity, as female-headed households often face greater socioeconomic challenges in disaster preparedness and recovery. About 52% of households have children under 11 years old, 23% have elderly members over 65, and 5% include disabled or chronically ill members. 20% of households have multiple types of vulnerable members simultaneously. The presence of multiple vulnerable groups in one-fifth of households further underscores the need for targeted disaster risk reduction and social protection measures.

Housing condition (S3) represents the sensitivity of households to natural disasters; for example, a considerable proportion of semi-permanent and temporary houses indicates increased sensitivity, as these structures are more susceptible to damage during floods and landslides. Wooden houses are the most common, accounting for 45.7% of households, followed by 24.3% of concrete houses and 17.1% of grade IV houses. A smaller share of 7.1% live in permanent houses, whereas 5.7% reside in temporary houses (Figure 3).

The interview showed that all surveyed households are engaged in crop cultivation, making agriculture the primary livelihood activity (S4). A smaller proportion of 7%

supplement their livelihoods through wage labor alongside farming activities. Within this main livelihood, approximately 83% of households reported a reduction in agricultural output due to natural hazards (S5), with 24% experiencing a slight reduction, 31% a moderate reduction, and 27% a significant reduction. Only about 17% of households reported no reduction in agricultural production.

Moreover, access to food and water annually (S6, S7) reflects the sensitivity of households. The results show that most households are generally able to meet their annual food needs, with 66% reporting sufficient food. However, around 28% of households experience food shortages for 1-2 months per year, and about 6% face shortages for more than 3 months per year. For water access, approximately 56% of households reported experiencing water shortages for domestic use. Especially in the dry season, 86% of households reported difficulty accessing water, with 27% facing significant difficulties .

Quantitative assessment of the sensitivity component is presented in Figure 4. The average sensitivity score is 0.57 on a scale of 0-1, indicating a moderate level. Livelihood dependence (S4 = 0.90) shows the highest sensitivity, followed by housing condition (S3 = 0.72) and presence of vulnerable members (S2 = 0.67). In contrast, gender of household head (S1 = 0.37) and food shortage (S6 = 0.20) contribute less to the sensitivity (Table 2). Overall, sensitivity in the study area is primarily driven by livelihood dependence and housing condition.

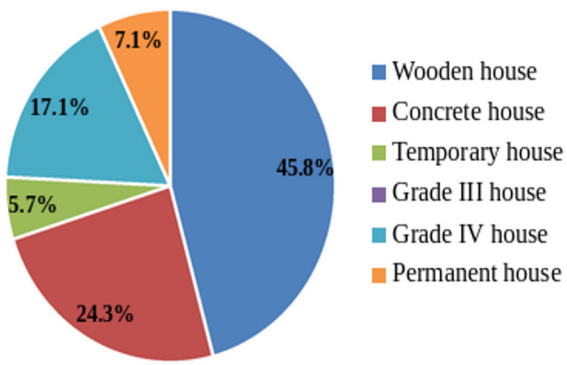


Figure 3. Housing conditions of interviewed households

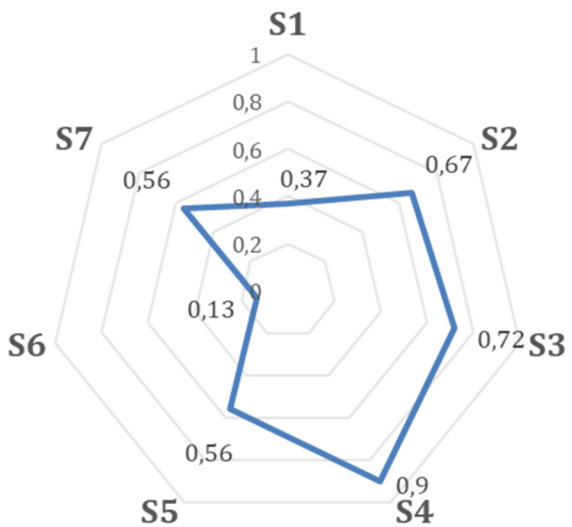


Figure 4. Sensitivity of ethnic households to natural disasters

3.1.3. Adaptive capacity (AC)

Education level (AC1) and health insurance (AC2) can enhance access to information and strengthen households' ability to prepare for, respond to, and recover from natural hazards. The results show that only 7% reached high school, and approximately 1% attained college or higher education. Otherwise, about 33% and 39% of households reported that the household head has no formal education or is illiterate, and completed primary school, respectively. Especially, around 60% of households reported having health insurance coverage.

For adaptation at the household level, the preparedness of equipment (AC3) becomes relatively important. The most common measures include mobile phones (94%), water storage tanks, and lighting equipment (83%). In addition, 30% of households reported keeping medical supplies, while only 10% had access

to water pumps, and 4% reported owning power generators. Also, for participation in local training courses (AC4), only 23% of these households reported having participated in local training programs. For receiving the disaster warning system (AC5), 37% of the interviewed households reported not receiving disaster warnings. For those who received disaster warnings, they received information only 1-2 times per day, indicating limited real-time communication during emergencies. In terms of information channels, the most common sources the households accessed were local authorities about 79%, followed by mobile phones or text messages about 59% and community loudspeakers. Fewer households received information via neighbors or relatives (21%), radio (10%), and television (9%), while none reported receiving information from civil society organizations (Figure 5). Especially, the households adopt several adaptation measures (AC 6). The most common strategies include food storage (79%) and water storage (77%), reflecting a focus on securing basic needs during emergencies.

Adaptation during (AC6, AC7) and after (AC8) disasters plays an important role in increasing households' AC. For accessibility during natural hazard events, there is limited or very limited/ no access to stable income sources (~89%) and clean water sources outside the community (76%). Otherwise, full and moderate access to government aid/loans, stored food/essentials, health service, drainage 47%, 64%, 84%, and 66%, respectively (Figure 6). For financial capacity for post-disaster recovery, approximately 73% of households reported having no savings or access to credit for recovery after natural hazards.

The overall adaptive capacity (AC) score is approximately 0.44, indicating a moderate level of adaptive capacity among households in the study area (Figure 7, Table 2).

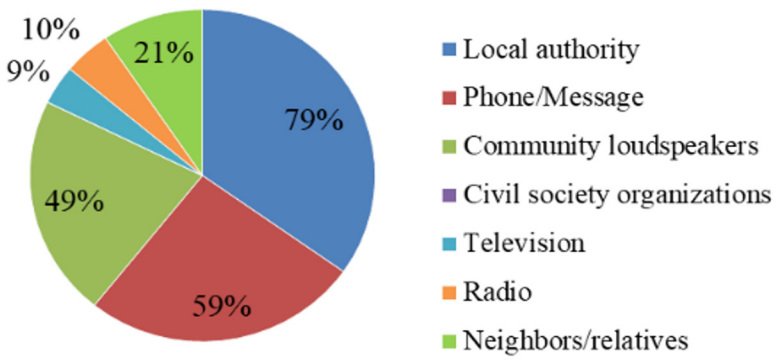


Figure 5. Communication channel for natural hazards information

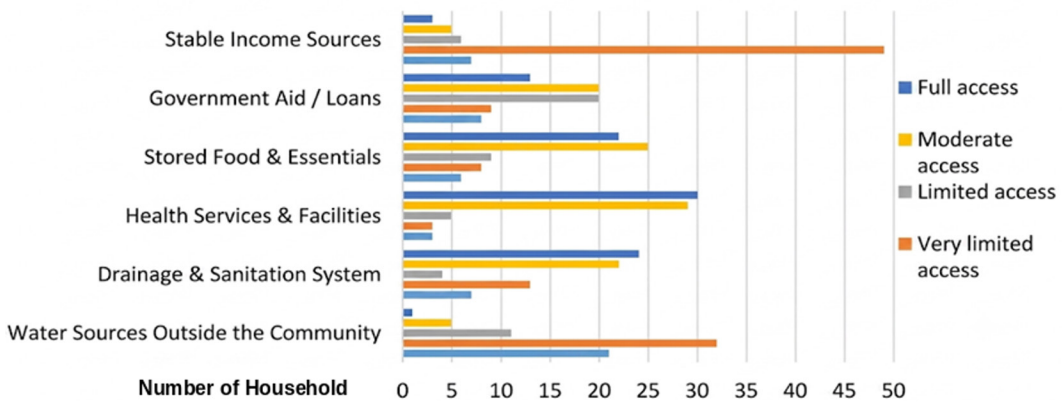


Figure 6. Accessibility of households within natural hazard occurrences

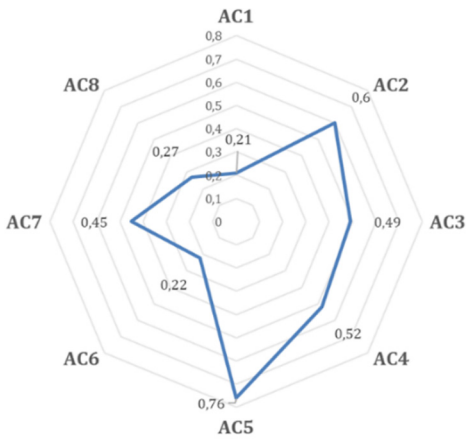


Figure 7. Adaptive capacity of ethnic households to natural disasters

3.1.4. Vulnerability assessment of households to natural hazards

Following the IPCC framework, the vulnerability was determined using Equation (5). Thus, the vulnerability (V) obtained the value of 0.59 on a scale of -1 to 2 (Figure 8). This result is consistent with previous studies in Viet Nam. For example, Nga et al. [5], assessed household vulnerability to flash floods and landslides in the upland regions of Viet Nam and reported that ethnic minority households were highly vulnerable due to strong dependence on agriculture and forestry, with low livelihood diversification and poor infrastructure. Likewise, Huong et al. [23] reported a vulnerability index of 0.63 (-1 to 2 scale), close to the 0.59 (-1 to 2 scale) obtained in this study.

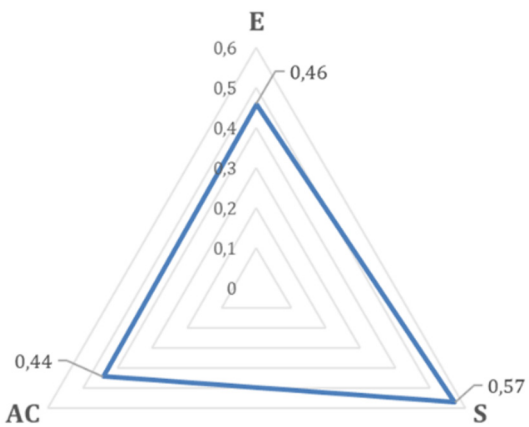


Figure 8. Vulnerability of ethnic households to natural disasters

3.2. Key factors influencing household vulnerability to natural disasters and reduction solutions

3.2.1. Key factors influencing household vulnerability to natural disasters

The vulnerability of ethnic households to natural disasters in Lao Cai province is primarily driven by some main factors:

Multi-hazard exposure remains a critical contributing factor, as households are frequently affected by multiple types of natural hazards. The survey results demonstrated that the multi-hazard context is further intensified by the relatively high frequency of hazard occurrence in the period of 2015-2025. This aligns with findings from other studies in Southeast Asia, which highlight that cumulative exposure to

multiple hazards tends to amplify vulnerability and complicate recovery processes [24].

The results indicate that household vulnerability in the study area is strongly influenced by high dependence on agriculture. This high level of dependence (100%) makes household income highly sensitive to climate variability and natural hazards. As a result, extreme weather events often translate directly into income loss, reduced productivity, and increased food insecurity. Notably, 83% of interviewed households reported a decline in agricultural output due to natural hazards. These findings are similar to Harvey et al. [25], who showed that farmers in Madagascar were highly vulnerable in the context of climate change because they depended mainly on agriculture and had few other income sources.

In addition, housing conditions represent another critical determinant of vulnerability of the ethnic households to natural disasters. The survey results indicate that housing quality remains relatively limited. Specifically, 68.5% of interviewed households live in wooden or lower-quality housing structures. This type of houses often lack adequate resilience features, making them more susceptible to partial or complete destruction during hazards such as landslides in Northern provinces such as Yen Bai and Lao Cai [26].

Although adaptive capacity provides some degree of buffering-particularly through access to disaster warning information and relatively high participation in health insurance. Key constraints include low education levels, weak financial capacity, and limited adoption of long-term adaptation measures. This pattern is also commonly reported in vulnerability studies in Viet Nam, where improvements in awareness and short-term coping strategies have not yet translated into stronger long-term adaptive capacity [5].

3.2.2. Solutions to reduce vulnerability of households to natural disasters

Based on the earlier mentioned key factors influencing household vulnerability, the following solutions are proposed. First, livelihood diversification and economic support should be promoted. Vocational training programs and small business/ cooperatives in other sectors should be expanded and facilitated. Also, local authorities and development organizations should encourage the adoption of climate-resilient crop varieties and sustainable farming techniques. Second, it is essential to strengthen early warning systems and community communication. Local authorities should collaborate with meteorological agencies and social organizations to establish multi-channel warning systems, ensuring most households receive warnings one or two days in advance. Implementation measures include installing warning signs at high-risk locations, establishing community rapid response teams, and training local volunteers. Third, improving essential infrastructure and promoting resilient housing is critical to reducing sensitivity. Authorities should prioritize investments in roads, bridges, and drainage systems in hazard-prone areas. In parallel, households should be supported in upgrading houses using more durable and hazard-resistant materials. Finally, enhancing adaptive capacity through social services and institutional support. Policies should aim to expand access to health insurance as well as support for participation, improve disaster preparedness training, and provide financial assistance mechanisms.

4. Conclusions

This study achieved its three research objectives. First, applying the IPCC (2007) AR4 framework, the overall vulnerability of H'Mong households in Van Chan commune, Lao Cai Province was assessed at V = 0.59 (−1 to 2). Second, the main factors underlying this vulnerability were identified: strong dependence on agriculture, poor-quality housing, the presence of vulnerable household members (children, elderly, and disabled or chronically ill people), low livelihood diversification, limited education, and inadequate financial support and access to credit, combined with only moderate adaptive capacity. Thirdly, to reduce vulnerability, key

priorities are diversifying livelihoods, promoting climate-resilient agriculture, improving disaster preparedness and early warning systems, upgrading housing and infrastructure, and strengthening education, disaster awareness, and financial support.

While the study provides useful insights, its findings are limited by the sample size and cross-sectional data. Future research should cover larger areas, use more advanced methods, and compare different ethnic groups and regions to better inform policy.

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