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Flood Vulnerability-Rural Poverty Nexus: Implications for Disaster Risk Reduction and Sustainable Rural Development in Vietnam

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Abstract Floods are the most dreaded danger for household livelihoods, particularly those in coastal and estuary regions, due to their tremendous destruction. Proper assessment of the livelihood vulnerability of these communities thus becomes imperative for prioritizing policies. Applying the LVI-IPCC framework, this study investigates the flood-induced vulnerability of two coastal communities in Hai Duong and Vinh Hien communes of Thua Thien Hue province, Central Vietnam, and their vulnerable index's determinants. Data were obtained through three focus group discussions, twelve key-informant interviews, and a cross-sectional survey of 360 households between September and December 2021. The results disclosed that coastal fishery communities are highly vulnerable to flood risks due to their high exposure and sensitivity. Further analysis revealed that floods are an extra burden to impoverished fishermen and have sealed the poor into endless poverty traps and thus could reverse the poverty reduction efforts. Therefore, poverty alleviation should be integrated and prioritized in capacity-building programs to adapt to flood risks. Attention to issues that assist the resilience of poor populations, specifically allocating resources to vulnerable groups, strengthening access to information for hard-to-reach households, and well cognizance of the floods-relative poverty and inequality nexuses should be future priorities.

Keywords Climate Change, Central Vietnam, Flood Risks, Livelihood Vulnerability, Poverty

1. Introduction

The global climate is markedly changing, threatening millions of human well-being worldwide. Climate change (CC)-induced phenomena can impact coastal rural communities in various ways, such as causing floods, sea level rise, or tropical storms. Flooding is among the most destructive natural hazards, resulting in fatalities and considerable damage to private property and public infrastructure. Annually, floods kill around 6,000 people and cause 19 billion dollars in damages worldwide [1].

Major flood-related calamities have been fourfold in almost three decades since the 1980s [2], [3]. Floods have afflicted estimated 2 billion people globally during the last 20 years [4]. Asia seems to be the region most afflicted by natural disasters [5]. In 2018, over 45% of catastrophic incidences, 80% of fatalities, and 76% of the affected population occurred in Asia. The majority of the population (50%) was impacted by flooding, followed by storms (28%) [1].

Given its long coastline and dense population in riverine and coastal areas, Vietnam is one of the country's most severely impacted by floods, accounting for an estimated 97% of average annual losses from natural hazards [6], [7]. Flooding-related incidents between 1989 and 2015 resulted in 14,927 fatalities, 16,829 injuries, and 3.7 billion USD in direct damages [8]. Nearly a million people in this country are thought to be impacted by floods every year, particularly in deltas, coastal regions, and low-lying areas [9]. According to estimates from international agencies, CC is anticipated to increase the number of low-lying and coastal populations impacted by fluvial flooding, which is expected to reach 9 million by 2044, depending on the emissions pathway [6]. Key factors increasing the susceptibility to flooding include insufficient resources, poor infrastructure, and a lack of adaptive and protective measures [10], [11]. Along with the disadvantages of geographical features, human-induced activities such as human encroachment on rivers and unsustainable practices —have significantly raised the flood danger [12], [13]. Unsurprisingly, flood studies have been carried out more often in Vietnam at different levels, contributing to global temporary CC literature and insights. Some make policy suggestions at the macro level (e.g., [9], [14]), while others seek to understand floods at the micro level, such as looking at the adaptation patterns of households to floods and examining their recovery from floods [7], [10], [11].

However, assessments of household vulnerability to CC, particularly flooding vulnerability, appear to be underreported in Vietnam [15], albeit with recent efforts [7], [8], [15]. This could hinder planners and decision-makers in identifying who is most vulnerable to flooding, which communities, and, more importantly, what constitutes their vulnerability. Insufficient knowledge of these aspects may reduce the effectiveness of adaptive resource allocation and public policy interventions [16], [17]. Additionally, the existing literature often overlooks the intersection between flood hazards and the vulnerability of small-scale fishery households, particularly in the context of rural development and poverty alleviation. Given that poverty reduction is a key strategy for low- and middle-income economies and a United Nations Millennium Development Goal, it is imperative to discuss this topic in greater detail.

This study, with specific reference to two flood-prone communities in Central Vietnam, aims to fill these knowledge gaps through three specific objectives: (1) to estimate the vulnerability of fishery households to flooding using the livelihood vulnerability index referring to the Intergovernmental Panel on Climate Change (IPCC) framework (LVI-IPCC) tool; (2) to identify the determinants of household flood vulnerability; and (3) to propose policy implications to reduce flood risk for low-lying estuary populations and sustainable rural development. In so doing can enable us (policymakers, development practitioners, and scientists) to provide a more overview of the prevalence of flood risk in a specific context of rural poverty. We argue that such contributions are essential in the growing CC-related literature in Vietnam and serve as references in mitigating and adapting to natural hazards efforts for other communities around the world, especially where share similar geographical features and are heavily influenced by floods.

2. Research Framework

The definition of vulnerability initiated by the IPCC (2007) stated that "the degree to which a system is susceptible to and unable to cope with adverse effects of CC, including climate variability and extremes." In this vein, vulnerability refers to the function of a climate-related extreme event's character, magnitude, and rate and variation to "which a system is exposed, its sensitivity, and its adaptive capacity." In the context of flooding, the socioeconomic vulnerability of a community influences its capacity to prepare for, respond to, and recover from a flood hazard event. Thus, vulnerability assessment for a region to floods serves as a planning tool in decision-making on environmental issues and disaster risk reduction programs. Among the livelihood vulnerability assessment methods, the LVI-IPCC tool developed by [18] seems to be the most popular applied due to its convenience. First, it can systematically incorporate many indicators (called sub-components) ranging from socioeconomic demographics to capital sources, income, social networks, and climate-related reports as well [15], [16], [19], [20]. Second, this method is resourceful in allowing primary data from household surveys, particularly in the absence of reliable secondary data in developing countries [15], [21]. Finally, the results of the LVI-IPCC provide an impartial estimation of the vulnerability of fishermen's livelihoods in the context of climate shocks.

The LVI-IPCC is formed by three main contributors: exposure, sensitivity, and adaptive capacity. Exposure is defined as "the nature and degree to which a system is exposed to significant climate variations" (IPCC, 2007). In this study, the exposure component is formed by sub-components of flood risks and damages (e.g., the total number of flooding events in the last 10 years and the amount of damage at the household level) (Figure 1). Following Nguyen and Leisz [17], a household's sensitivity is identified by the livelihood systems and the nature of stressors. In this research, sensitivity is

determined by the household's capital in terms of food, water security, land, the status of housing, and health, as suggested in previous works [15], [17], [18]. Meanwhile, the adaptive capacity of households was calculated from the demographic profile, their knowledge of disaster risk reduction, livelihood strategies, and social networks.

Previous studies reported that livelihood vulnerability is significantly affected by both endogenous and exogenous factors. For example, Chuong et al. [22] revealed that the residing duration, family income, and household heads' CC perception influenced households' adaptive capacity. Vo et al. [23] found that farm households' flood adaptation decisions are positively influenced by gender, education level, number of employees, income level, local social connections, and perception of CC, while negatively affected by off-farm income and utterly unaffected by access to credit. Similarly, Dinh et al. [24], using multiple linear regression models to determine post-flood recovery rates, showed the underperformance of demographic and socioeconomic characteristics, including age, education level, and the number of employees. Meanwhile, social connections and local networks were stressed as crucial factors for households' recovery. Phuong et al. [20] indicated that the livelihood vulnerability to climate risks is significantly influenced by key factors of knowledge, housing type, training participation, number of mass media accessed, property loss, education level of household head, number of the local institutions involved, and marital status.

Of the several determinants of vulnerability to coastal flooding, it is critical to identify the most significant indicators and reveal their relationships to each other to develop effective CC adaptation policies and interventions. In this study, both socioeconomic (e.g., gender, education levels of the household heads, economic status, etc.) and psycho-exogenous factors (perception of floodings, knowledge and skills, feelings, etc.) were thus used to predict the probability of their effects on the livelihood vulnerability of coastal households as shown in Figure 1. Such efforts contribute evidence-based knowledge to decision-makers to enable coastal communities in Vietnam and other flood-prone regions worldwide to adapt effectively to the impacts of CC.

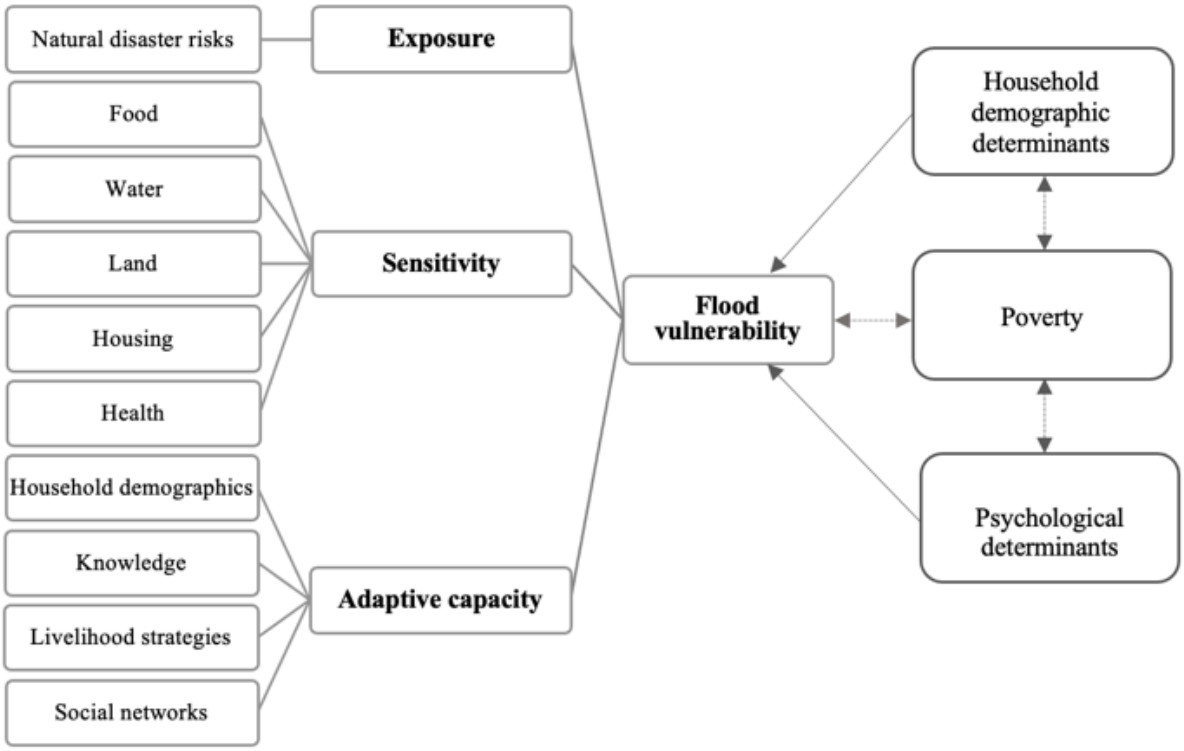

Figure 1. The conceptual framework of the study

3. Methodology

3.1. Study Sites

This study was conducted in two fishery communities of Hai Duong and Vinh Hien communes, respectively, located alongside the Thuan An and Tu Hien estuaries of the Tam Giang – Cau Hai (TG-CH) lagoon, Thua Thien Hue province, Central Vietnam (Figure 2). The geographical location of both areas has the common feature of being an oasis, bordering the sea on the east and the TG-CH lagoon on the west. Due to such disadvantages of geographical conditions, these regions are annually exposed to floods, causing significant losses in human lives and properties. Additionally, agriculture and TG-CH-based fishery activities are the main livelihoods in both communes, contributing to nearly 40% of the gross production value [7]. While Vinh Hien possesses 11,200 ha of a water surface area of TG-CH lagoon, making 70% of its 7,602 residents significantly reliant on agriculture, fishing, and aquaculture activities, Hai Duong commune had a population in 2020 of 6,963 people, of which 63.23% are identified as farmers and small-scale fisheries. Therefore, these are the two areas most prone to flooding in Thua Thien Hue province.

3.2. Data Collection

A cross-sectional survey of 360 fishery households in the Hai Duong and Vinh Hien communes was conducted face-to-face using a semi-structured questionnaire between September to December 2021 (flooding season) to obtain the primary data and specific evidence. Along with that, in-depth interviews with 12 key informants were carried out at three levels, including 2 officials of the Department of Agriculture and Rural Development (provincial level), 2 district agricultural extension staff, 2 officers in charge of agriculture at the commune level, and 6 village heads. Three focus group discussions (FGDs) were also organized, of which two FGDs were held at the community level (one at each commune) and one at the district level. These works are expected to provide more qualitative evidence on the specific impacts of floods on human life in the study areas.

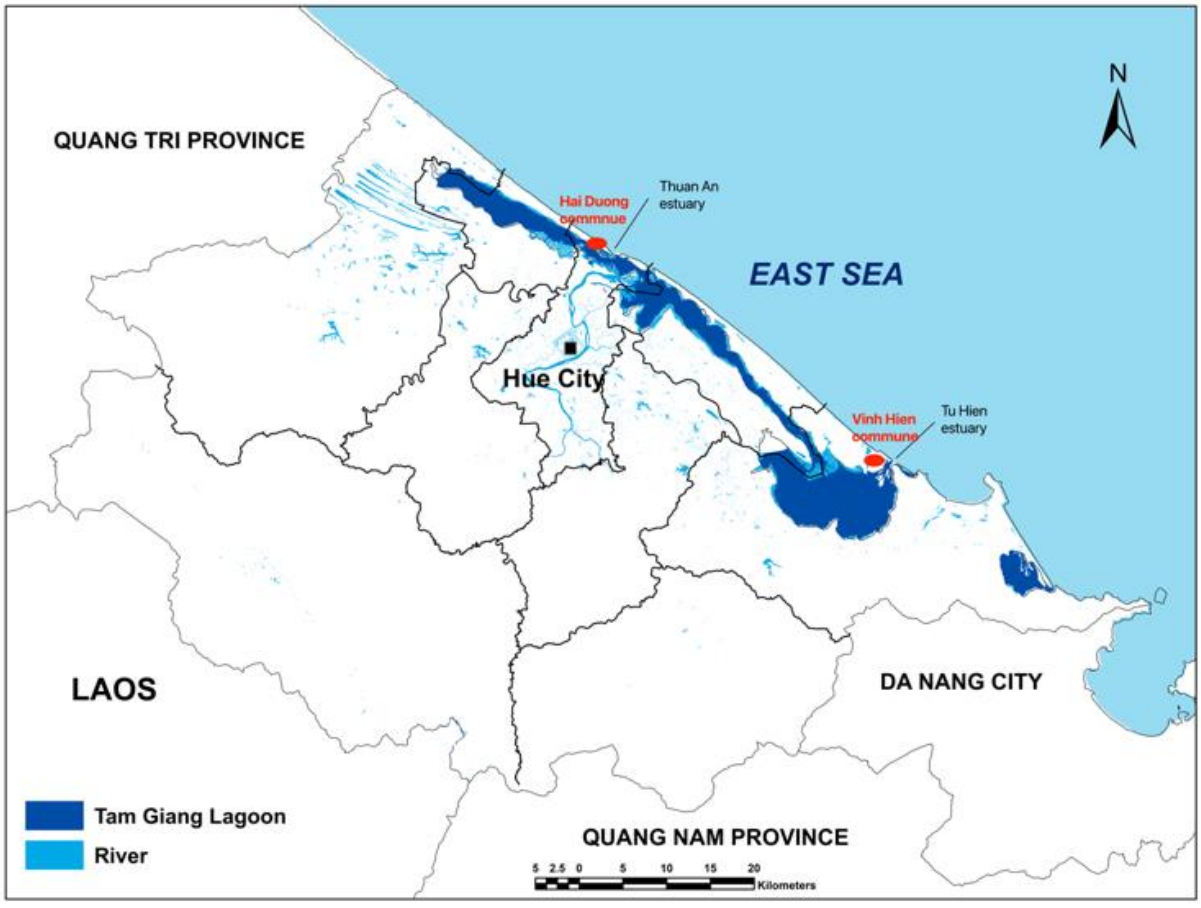

Figure 2. Map of study sites in Hai Duong and Vinh Hien communes, Thua Thien Hue province, Central Vietnam

3.3. Data Analysis

3.3.1. LVI-IPCC Calculation

Overall, the LVI-IPCC is measured from 10 major indicators which are made up of 34 sub-indices as shown in Table 1. The process of LVI-IPCC measurement generally included four main stages. First, all sub-components were normalized as the same unit from 0 to 1 as equation 1:

$$Index_{S_h} = \frac{S_h - S_{min}}{S_{max} - S_{min}} \quad (1)$$

Where Indexh is a normalized value of a sub-indicator for h household, Sh is the observed sub-component for h household, and Smax and Smin are the maximum and minimum values for total sampling data, respectively.

Second, each major component was calculated by averaging the related sub-indicators as equation 2:

$$M_h = \frac{\sum_{1}^{n} Index_{S_{hi}}}{n} \quad (2)$$

Where Mh is 1 of 10 major indicators for household h, IndexShi demonstrates the sub-indicator, indexed by i that made up each of the major indicators, and n is the number of sub-indicators in each major indicator.

Third, indices of three contributing factors (exposure, sensitivity, and adaptive capacity) at the household level were measured as equation 3:

$$CF_h = \frac{\sum_{i=1}^{n} W_{mi} M_{hi}}{\sum_{i=1}^{n} W_{mi}} \quad (3)$$

Where CFh is a major indicator for household h indexed by i; Wmi is the weight of each major indicator (the number of sub-indicators in a major indicator), and n is the number of major indicators in each contributing factor.

Finally, when there are all 3 values for exposure (Eh), sensitivity (Sh), and adaptive capacity (Ah), the LVI-IPCC vulnerability is calculated as follows:

$$LVI\text{-}IPCCh = (Eh - Ah)*Sh \quad (4)$$

Where LVI-IPCCh describes the livelihood vulnerability of household h. The LVI-IPCCh scales from –1 (least vulnerable) to 1 (most vulnerable).

3.3.2. Multivariate Regression Analysis

In this study, multiple linear regression analysis was used to identify factors that affect household LVI-IPCC vulnerability. This is often applied to estimate patterns, particularly when having many independent variables [25]. Especially, it can build an optimal multiple linear regression equation based on its ability to identify and select independent variables that have a significant linear effect on the dependent variable (Nguyen & Leisz, 2021). Basically, the equation of the multiple linear regression model is interpreted as follows:

$$y = \beta_0 + \beta_1 x_{1t} + \beta_2 x_{2t} + \beta_3 x_{3t} + \ldots + \beta_k x_{kt} + ut \quad (5)$$

where,

y is the dependent variable (LVI-IPCC index)

β_0 is the intercept

x_1, x_2,…, and x_k are the independent variables

β_1, β_2,…, and β_k are partial regression coefficients; and ut denotes the random error.

In the research, the dependent variable is the LVI-IPCC index of households. 14 independent variables include household demographics (age, gender, education level, and economic status); 10 remaining variables in terms of flood frequency, flood household damage, training participation, social networks, livelihood strategies, food, water, land, housing, and health. The SPSS 20 software was used for statistical analysis.

4. Results and Discussion

4.1. LVI-IPCC Index

The results for the major - and sub-indicators, along with the LVI-IPCC of two communities, are described in Table 1 and are visualized in Figure 3. This section presents and compares the values of exposure, sensitivity, and adaptive capacity between the two study areas. In general, the values of exposure and sensitivity have a positive relationship to LVI-IPCC vulnerability (higher exposure and sensitivity levels denote more vulnerability), while the adaptive capacity is inversely linked to LVI-IPCC vulnerability (higher adaptive capacity means less vulnerability to floods).

4.1.1. Exposure Index

The results show that the exposure value in the Hai Duong commune is 0.31 (Table 1), higher than in the Vinh Hien commune (0.14). This means that the Hai Duong villagers are more exposed to floods than the Vinh Hien people. This is because Hai Duong's surveyed households assessed the impact of flooding to be larger than that of the people of Vinh Hien. In fact, sub-indicators' values regarding the number of flooding events in the last 10 years, total assets loss, reduction of agricultural and aquacultural and fishing yield, and human injury or death caused by floods of the Hai Duong are all higher than those of the Vinh Hien. These findings complement the results of Hoang et al. (2020) that despite the sharing of flood-prone geographical locations, the flood-induced effects are different. Households evidenced that 10 floods in the last decade directly affected their livelihoods and well-being. They added that there was no specific trend in the frequency of floods in recent years. Previously, floods

often occurred every 2-3 years; however, in the recent 2 consecutive years in 2020 and 2021, there were massive floods.

4.1.2. Sensitivity Index

Similar results show that people living in the Hai Duong commune area are more sensitive to floods than those in the Vinh Hien commune, receiving an exposure index of 0.37 and 0.30, respectively. Among the five sub-indicators, while the land factor is fairly equal (0.01 and 0.02), the four subindices of food, water, housing, and health of Hai Duong populations are all higher than those of the people of Vinh Hien (Table 1). For example, the Hai Duong households reported lacking agricultural land and rarely storing food during the flood season. A higher estimated sensitivity index of 0.42 regarding food-related components in Hai Duong is not only because of flood hazards but also because of unsustainable agricultural and fishing practices. These findings concur with previous works [15], [26]. Similarly, survey results show that 15% of Hai Duong households live in semi-permanent or non-permanent houses, compared to only 2% in Vinh Hien commune. A woman in Hai Duong said: "…Last year's flood, the water rose about 1m above the floor, my family had to receive subsidies from the local government...".

4.1.3. Adaptive capacity Index

The household adaptability index is similar in both communities, at 0.56 (Hai Duong) and 0.55 (Vinh Hien). However, analysis of each sub-indices shows that, while Vinh Hien people are more actively participating in flood training courses (higher value of knowledge and skills) and have a high index value of the socio-demographic profile, Hai Duong villagers have a higher index of livelihood strategies. Household socio-demographics, such as the education levels of the household head, dependency ratio, and marital status, can influence an individual's or group's ability to cope with and recover from flood stress [27]. A higher dependency ratio would indicate that economically active individuals had many others to support; thus, family resources for responding to floods would be more limited [28]. Similarly, several studies argue that households whose heads have graduated from high school or higher are more resilient than those who have not [22], [29], [30]. There is little variation in the local institution indicators index values among communities. The social linkage between local villagers and organizations, including NGOs, cooperatives, employment networks, and other social institutions such as schools and hospitals, is an important factor of adaptive capacity in response to floods [7], [23], [29], [31]. As the access to social connection and community cohesion increases, households become less vulnerable to disasters as their ability to cope with the shocks increases [32], [33]. This study indicates that all surveyed households in both communes seek assistance from fishing associations or farmer unions rather than outside organizations (e.g., NGOs), as in the case of Manijanga village, India [28].

Table 1. Categorization of major components and sub-components to flood vulnerability in Hai Duong and Vinh Hien communes

Major components and sub-components	Units	Measurement (min-max)	Post-normalized Value	
			Hai Duong(N=180)	Vinh Hien(N=180)
1. Exposure			**0.31**	**0.14**
Natural disaster risks and damages			***0.31***	***0.14***
1.1 Number of flooding events in the last 10 years	Numeric	1 – 10	0.34	0.26
1.2 Total money loss caused by floods in the last 10 years	Million VnD*	0 – 500	0.03	0.01
1.3 Loss or reduction of agricultural yield	Dummy	0 – 1	0.60	0.27
1.4 Loss or reduction of aquacultural and fishing yield	Dummy	0 – 1	0.43	0.15
1.5 Livestock death due to floods	Dummy	0 – 1	0.39	0.04
1.6 Reduce income due to flooding events	Dummy	0 – 1	0.36	0.18
1.7 Human injury or death	Dummy	0 – 1	0.07	0.04
2. Sensitivity			**0.37**	**0.30**
Food			***0.42***	***0.36***
2.1 No storing food for flooding seasons	Dummy	0 – 1	0.30	0.43
2.2 Do not have the agricultural land area	Dummy	0 – 1	0.47	0.44
Water			***0.50***	***0.42***

Table 1 continued.

2.3 Not enough fresh water for the whole year	Dummy	0 – 1	0.15	0.01
2.4 Using natural water system	Dummy	0 – 1	0.98	0.96
2.5 Number of months without water annually	Months	0 – 1.5	0.55	0.48
2.6 Using a non-public water system	Dummy	0 – 1	0.31	0.21
Land			***0.01***	***0.02***
2.7 Total area of agricultural land vulnerable to flooding	m^2	0 – 13,333.33	0.01	0.02
2.8 Total area of aquaculture land vulnerable to flooding	m^2	0 – 75,000.00	0.01	0.02
Housing			***0.54***	***0.48***
2.9 Unstable house	Dummy	0 – 1	0.15	0.02
2.10 Flood-prone house	Dummy	0 – 1	0.93	0.94
Health			***0.29***	***0.18***
2.11 Do not have health insurance	Dummy	0 – 1	0.06	0.01
2.12 Distance from home to the nearest medical facility	Km	0 – 1.5	0.41	0.37
2.13 Households child misses school due to illness	Dummy	0 – 1	0.41	0.16
3. Adaptive capacity			**0.56**	**0.55**
Household demographics			***0.60***	***0.62***
3.1 Better-off household	Dummy	0 – 1	0.85	0.91
3.2 Independent-member ratio	Dummy	0 – 1	0.42	0.38
3.3 Household head graduated high school	Dummy	0 – 1	0.24	0.33
3.4 Not a single-parent household	Dummy	0 – 1	0.89	0.86
Knowledge and skills			***0.41***	***0.56***
3.5 Participating in flood training courses during the last 2 years	Dummy	0 – 1	0.26	0.34
3.6 Know the local early-warning system	Dummy	0 – 1	0.50	0.50
3.7 Always update the information related to flood risk reduction	Dummy	0 – 1	0.48	0.85
Livelihood strategies			***0.72***	***0.60***
3.8 Number of livelihood strategies	Numeric	1 – 5	0.22	0.09
3.9 Households dependent on agriculture and aquaculture/fishing as their primary income sources	Dummy	0 – 1	0.82	0.66
3.10 Bank savings	Dummy	0 – 1	0.10	0.06
3.11 Can fishing during flood season	Dummy	0 – 1	0.55	0.82
Social networks			***0.37***	***0.35***
3.12 Number of local grassroots organizations' participation	Numeric	0 – 4	0.23	0.17
3.13 Number of media	Numeric	0 – 4	0.53	0.54
3.14 Number of social-network platforms in use for updating the flooding information	Numeric	0 – 6	0.36	0.35
LVI-IPCC			**-0.084**	**-0.128**

**1 US$ ~ 23,000 VnD*

4.1.4. Overall LVI-IPCC Index

The overall IPCC - LVI was calculated by combining the three contributors of exposure, sensitivity, and adaptive capacity (Table 1). The IPCC - LVI scales from -1 (the least vulnerable) to 1 (the most vulnerable). Unsurprisingly, the analysis results suggested that Hai Duong is generally more vulnerable to floods than Vinh Hien, with the LVI-IPCC at -0.084 and -0.128, respectively, mainly due to higher values of exposure and sensitivity (Figure 4). However, in general, both communities should be identified as "moderate vulnerability" according to scales of many previous suggestions [18], [34]. This, as analyzed, may be due to the high adaptability index in both communities, especially in Hai Duong, with the highest value of livelihood strategies. These findings again support the existing results (e.g., [15], [35]) that adaptive capacity significantly contributes to the mitigation of adverse effects of floods in specific and natural stressors in general at household and community levels.

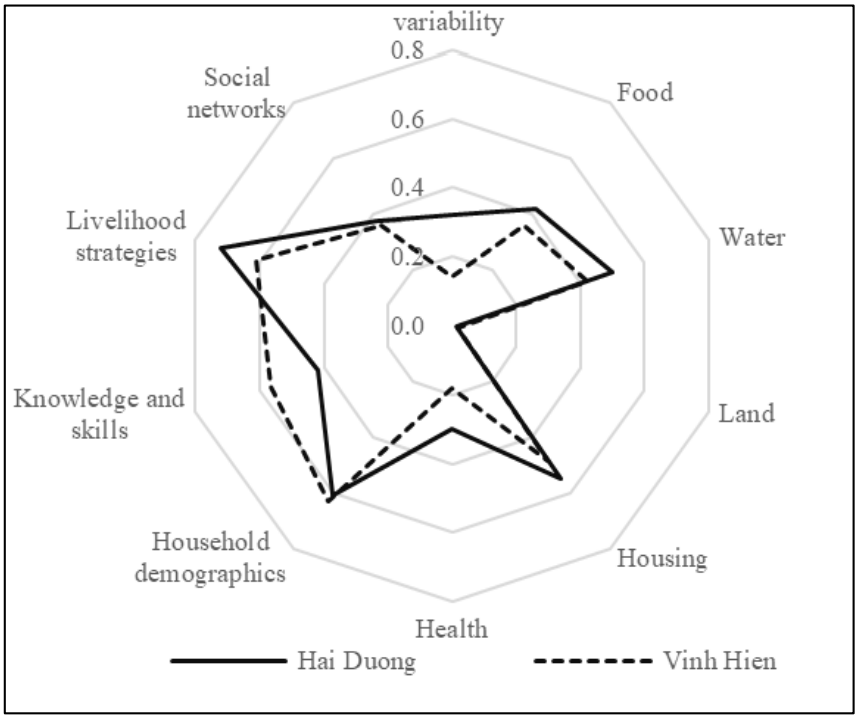

Figure 3. The major indicators of vulnerability among the Hai Duong and Vinh Hien commune

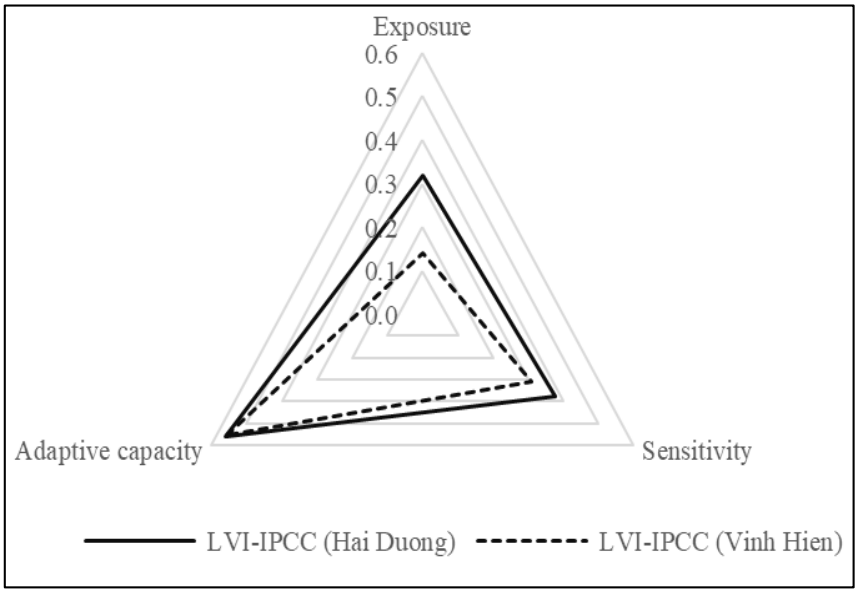

Figure 4. A comparison of three components of the LVI-IPCC index among the Hai Duong and Vinh Hien communes

4.2. The Determinants of Household Flood Vulnerability

The results of the multivariable regression analysis are shown in Table 2. Of the 14 independent variables (or explanatory variables), 8 variables have a significant relationship (sig <0.05) with the dependent variable (the household LVI-IPCC index), including the household economic status, the frequency of flood events, total damage due to floods, food, housing, health, livelihood strategies, and social networks variables. Among these eight variables, the larger beta value shows the more significant influence on the independent variable (e.g., factors of livelihood sources (beta = 0.23) and total damage due to floods (beta = 0.23). By contrast, a lower beta has less influence on the LVI-IPCC value of the household (e.g., better-off household (beta = -0.116) and health insurance (beta = 0.117)). The beta sign also illustrates the positive or negative relationship between the independent and dependent variables. Accordingly, a positive beta coefficient indicates a positive relationship between livelihood vulnerability and four variables regarding the number of flood events (beta = 0.178), total damages (beta = 0.230), housing (beta = 0. 106), and health (beta = 0. 117). In contrast, the variables have a negative coefficient, including better-off households (beta = -0.116), food (beta = -0.205), the number of livelihood sources (beta = -0.230), and social networks (beta = -0.218)) that show an inverse relationship to the household vulnerability.

The analysis obviously shows that low-income families are more vulnerable to floods than better-off households ($p=0.014<0.05$). This complements a range of previous findings. Moser & Satterthwaite (2008) [36] argue that the poor have narrow asset portfolios and limited resources, making them more vulnerable to external shocks. In contrast, the existing studies have demonstrated that wealthy households have diversified asset portfolios and close social links, and they also invest in learning, thus enhancing their resilience to natural disasters [23], [32], [35]. [37] argues that the wealthiest are more able to diversify their livelihoods, such as non-agriculture and small business, so when a disaster occurs, they switch from farming, which is susceptible to flooding, to other off-farm activities. Further, affluent households often spend their money on savings and have a close relationship with local financial institutions, so in the case of disaster recovery, they are always ready to use these advantages to recover quickly. This has been proven by [7], [11].

Our findings indicate that both frequency of occurrence and impact of floods negatively influence the vulnerability of fishing households (the greater the number of floods, the greater the vulnerability; the higher the damage, the more vulnerable). This is understandable because when there are more floods, people suffer more property loss and agricultural and fishing losses. Respondents also reported that when the flood returned, aquaculture was lost due to diseased fish and sudden pH changes. This coincides with many previous results on the relationship between flood effects and livelihood vulnerability [10], [15].

In this study, the factors of food, housing conditions, and health affect the vulnerability of households. Local people reported that floods and heavy rains happening between September and December annually in coastal regions affect crop productivity and reduce agricultural production areas. Insufficient food storage resulting from climatic stresses has contributed to harvest loss, thereby exacerbating food insecurity and ultimately leading to poverty [20], [38]–[40]. Furthermore, poor housing conditions and lack of access to health make households more vulnerable to natural disasters such as floods. Respondents expressed a high degree of risk tolerance mainly since they were poor and lacked the resources to build a home outside the flood-prone areas. This is similar to the case of residents of the state of Jalisco, Mexico [41]. In this sense, flooding risk becomes “consciously” acceptable without other economic options or possibilities. Due to poverty, among other socio-environmental factors, fishery households in both communes are forced to not only live in areas with high flood risk but also less able to recover from damage. As one elderly said, “if I have much money, I will build a big house, 2 or 3 floors, or even move to the higher land such as the center of districts”. These issues are consistent with current publications on the vulnerability of coastal and estuary communities worldwide [19], [41], [42].

Supporting early works [20], [23], [24], [38], [43], this study has shown a negative relationship between the number of livelihood strategies of households and their LVI-IPCC vulnerability. Accordingly, those households solely dependent on one income source (e.g., fishing) are more vulnerable to flood than those with multi-live livelihoods. Many studies have confirmed this argument. Ellis [38] emphasized that livelihood diversification and off-farm incomes help households ensure food security and reduce the threat of loss, especially in post-flood phases. Ahmad et al. [19], in turn, evidenced that livelihood diversification is a significant strategy measure in coping the flood hazards and CC. Attention to these issues will help policymakers take more effective interventions in flood risk reduction.

Table 2. The results of the multivariate regression analysis (N=360)

Variables	Category	Measurement	Beta	Sig.[a]	Collinearity Statistics	
					Tolerance	VIF
Dependent variable						
LVI-IPCC value	Numeric	Scaling from -1 (least vulnerable) to 1 (most vulnerable)				
Independent variables						
Age	Numeric	Years old	.084	.102	.755	1.324
Gender	Dummy	0=men, 1=women	.052	.262	.934	1.070
The household head graduated from high school	Dummy	0=no, 1=yes	.035	.486	.784	1.275
Better-off household	Dummy	0=no, 1=yes	-.116	.014*	.905	1.105
Number of flood events	Numeric		.178	.000**	.920	1.086
Total damage due to floods	Numeric	Million VnD	.230	.000**	.947	1.056
Do not store food for flood seasons	Dummy	0=no, 1=yes	-.205	.000**	.903	1.107
Do not have agricultural land	Dummy	0=no, 1=yes	.052	.267	.899	1.112
Not enough water for domestic use	Dummy	0=no, 1=yes	.042	.373	.889	1.125
Unstable housing	Dummy	0=no, 1=yes	.106	.027*	.874	1.144
Do not have health insurance	Dummy	0=no, 1=yes	.117	.011*	.956	1.046
Total number of training courses in the last 2 years	Numeric		-.079	.105	.833	1.200
Total number of livelihood sources	Numeric		-.230	.000**	.808	1.238
Total number of CSOs	Numeric		-.218	.000**	.905	1.104

[a]* and ** denote significant correlations at the 5% and 1% levels, respectively

Our findings reconfirm the previous works that social networks play an important role in improving households' adaptive capacity [32], [44], thus can reduce their vulnerability to flooding hazards. Several studies (e.g. [15], [20], [35]) agreed that being a member of a local association such as a fishery association or involving local programs hosted by NGOs or schools may enhance households' knowledge and awareness, thereby can improve adaptive capacity via good access to credit, technique and market supports, climate-related information exchange, extension visits, and training courses. Moreover, good social networks can help local people, especially those at the bottom of society, diversify their livelihoods, reduce risks and alleviate poverty, which are also found as the main factors of CC vulnerability in this study.

4.3. Flood Vulnerability-Poverty Nexus: Implications for Disaster Risk Reduction and Sustainable Rural Development

Studies on CC vulnerability in general and flood vulnerability in specific have massively grown in recent years with a series of interpretive frameworks and methodologies, both at micro and macro levels. In this study, we used a mixed-methods process (both quantity (LVI-IPCC) and qualitative (in-depth interviews and field observations)) to assess the flood vulnerability of two fishery communities in Central Vietnam. This has enabled us to provide a more overview of the prevalence of flood risk in a specific context of rural poverty. The calculation of the LVI-IPCC vulnerability index for low-lying communities in Thua Thien Hue province shows a trend towards greater vulnerability as the poor (socio-demographics), those living in flood-prone areas (spatial), those with limited resources (capitals), and those are lack of opportunity access (institutional aspects). Perhaps all these disadvantages revolve around the story of poverty. Poverty is a root cause that increases the propensity for individuals and households to be harmed by climatic stresses, including floods [45]. The poor inhabitants in low-lying regions claimed that there is damage to property and even fatalities due to floods annually; as a result, floods can further impoverish the poor

or force households to the edge of poverty [45], or rather this has invisibly pushed the poor into a vicious cycle between vulnerability and poverty (Figure 5). A number of previous works evidenced that natural disasters such as floods can not only immediately and directly affect income, assets, and other econometrics but also have longer-term psychological effects on poor households, contributing to the formation or exacerbation of "poverty traps" at both households and regional levels [46], [47]. This study concurs with these arguments and claims that floods are considered an extra burden to the poor fishermen who are already residing in poverty, are solely dependent on fishing, and are social exclusions.

The field-based evidence from this study reveals that due to poverty, local habitats are not able to build solid houses (concrete material) or buy land in the highlands for flood protection. Due to its unfavorable location and acceptance of poor housing conditions, these population groups are often exposed to flood risk, causing a higher vulnerability [35], [48]. The poor also do not have enough money to invest in their children's education, and the rate of purchasing health insurance is also lower than that of others. This has been shown to be one of the factors affecting household livelihood vulnerability [11], [22]. Some adopted coping or defense strategies to floods in order to reduce risks and try to escape poverty such as selling assets (lands), encouraging children to drop out of school, and cutting consumption. However, these practices proved ineffective, which not only did not lift them out of poverty but also led them to fall into a new poverty trap [46], [47]. Interviewees further provided that poor people often spend much time earning money outside the village or seasonal hired employment. They thus rarely participate in training courses or become a member of local organizations, or rather, they have limited access to flood information, undiversified livelihood sources, and weak social connections. These make the poor considered the ones who suffer the most during floods [11], [15], [29], [30].

Physical health and psychological aspects of the poor are also considered to affect the household's ability to resilience to and recover from floods. A poor woman shyly said, "...I don't want to go to the village meeting because I'm afraid of ...they (neighbors)...gossip". Recent studies (e.g., [45], [49]) show that the poor are often framed as having higher levels of illness, mental tension, stigmatization, shame, and social exclusions that increase financial disadvantage and barriers to their ability to respond to external stressors and poverty reduction efforts. Mani et al. [50] added that poverty also drains the cognitive abilities of the poor, causing worse financial decision-making, especially in developing countries.

Recognizing these issues within the framework of this study regarding rural poverty and flood mitigation, we propose three implications to help break out of this endless loop.

First, most households in both communes have less or a sole livelihood option that exacerbates the household's vulnerability to floods. Thus, diversifying livelihoods and increasing incomes seem to be the first step towards reducing poverty and improving the adaptive capacity of coastal fishery households. In agriculture practices, crop diversity, rotation, and intercropping between indigenous plants and the application of advanced technology have been proven to be effective as in the case of Chuong et al. [39]. Furthermore, applying off-farm activities such as community-based tourism should be encouraged [51]–[54]. Tran, et al. [56], in turn, argue that diversifying livelihoods via expanding value-added industries such as handicrafts, small businesses, and mobility schemes employment may be a possible proposal. Of course, for that, the support of third parties will be necessary, such as NGOs, local schools, and civil society organizations. Besides financial support, these institutions provide well-trained experts and good linkage with stakeholders.

Second, the villagers reported that most of them only join a fishery or farmer's association, so they are limited in connecting with other stakeholders such as businesses or higher-level social organizations. Thus, social networks should be expanded both inbound and outbound in the community. Expanding households' contact with their local institutions plays an important role in reducing flood risks as it can enhance the adaptive capacity of rural households by increasing the opportunity to access finance, infrastructure, and information [57], [58], as well as the opportunity to learn to each other [32]. Besides, job creation and income increase for members are the positive contributions of such organizations in agricultural development and new rural construction in Vietnam [58]. We note that the establishment of small credit groups or interest-sharing clubs (e.g., traditional crab farming clubs) will be a way to bring the community together. This also helps the bottom of society households to quickly integrate after natural disasters and reduce risks (disasters, markets), thereby reducing poverty sustainably.

Third, it is important to recognize the potential of local knowledge to enhance scientific and technical approaches to flood management and risk reduction. Local knowledge can provide a more comprehensive and context-specific response to flood hazards in the following four ways. Firstly, local communities often have valuable knowledge of their environment and weather patterns that can help predict floods. Incorporating this knowledge into early warning systems can alert communities in advance, enabling them to take necessary actions, such as evacuation [24]. Secondly, local knowledge can inform the development of adaptation strategies that are specific to the local context. These strategies may include traditional flood management practices, like building houses on stilts or planting flood-resistant crops, or community-led initiatives to manage flood risk [20], [22], [59]. Thirdly, involving local communities in flood management and risk reduction efforts can increase their engagement and effectiveness. Local knowledge can help

identify vulnerable groups and inform appropriate risk reduction measures [60]. Fourthly, traditional ecological knowledge can inform sustainable land and water resource management practices that can help reduce the impact of floods. Planting trees and restoring wetlands are examples of such practices that can absorb excess water and reduce flood risk [61], [62]. Therefore, it is essential for risk management and reduction programs to recognize and utilize the potential strength of local knowledge for sustainable development.

Finally, as noted previously, the potential flood-induced impacts on human well-being, health, and adaptive capacity are likely to be more severe for poorer populations and resource scarcity groups, and CC vulnerable regions, putting more pressure on public facilities and services in these areas. Improving public facilities and local media will be imperative in the case study. Many residents reported that "we are far from medical centers" or "have rarely heard early warnings from local authorities", especially in hard-to-reach areas. This makes them more vulnerable in the event of a quick flood and in the evening. Therefore, planners and authorities should pay attention to this issue to minimize the community's loss of life and property. Using funds (for poverty alleviation and CC reduction) and resources (such as land [63]) allocated by the central government should pay attention to the most vulnerable areas, such as flood-prone areas, the poor, people with limited access to information, and peripheral areas [41]. The study also recommends that public infrastructure and common social facilities should be used and incorporated multi-functionally into CC plans in general and flood recovery strategies.

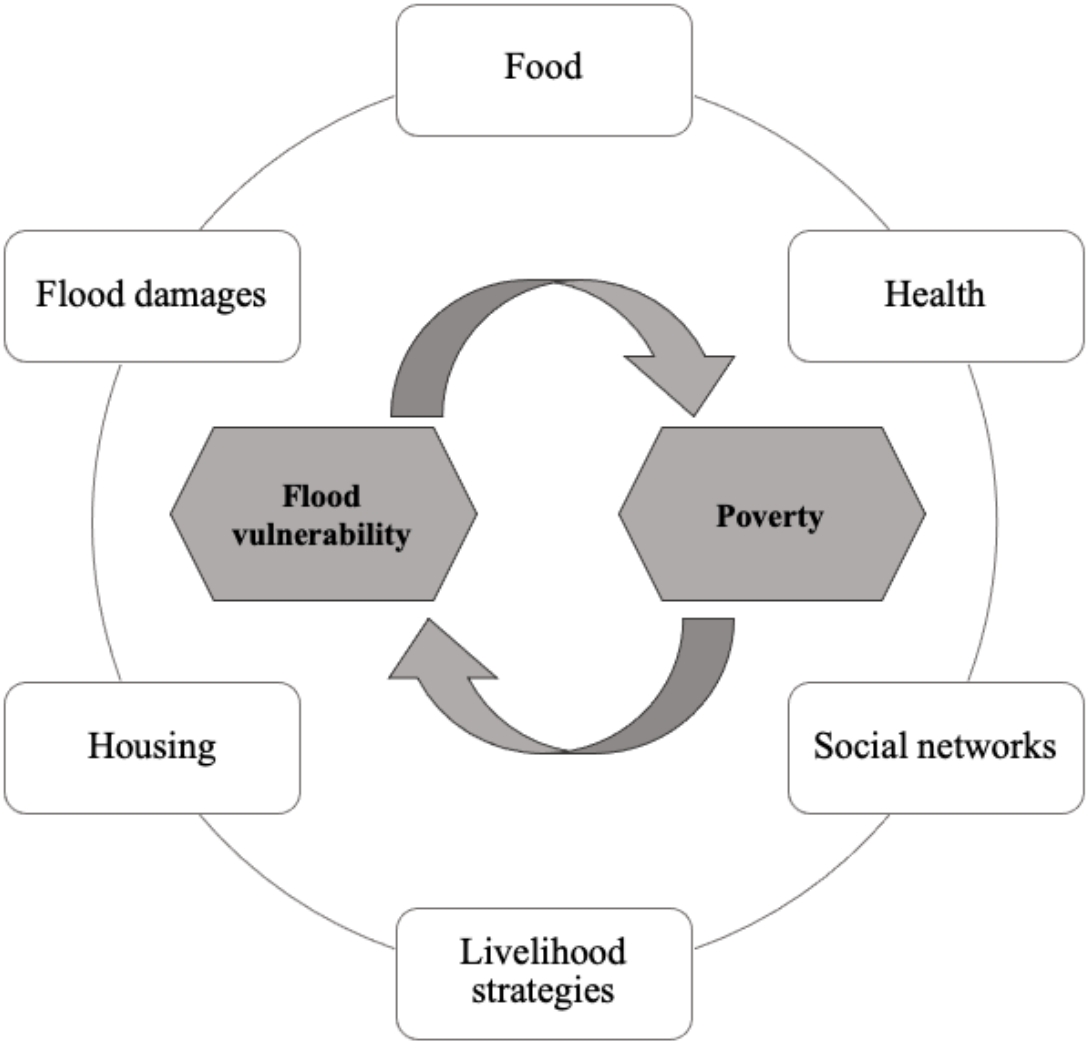

Figure 5. A vicious cycle of flood vulnerability and poverty

5. Conclusions

With specific reference to two coastal fishing communities in Thua Thien Hue province, Central Vietnam, this research contributes to the growing body of literature on climate change and disaster management by using the LVI-IPCC method to estimate and compare the vulnerability of the Hai Duong and Vinh Hien areas. Due to higher susceptibility and exposure, the livelihoods of communities in the Hai Duong area are more vulnerable to floods than those of Vinh Hien. Regression results show that variables related to housing, health, food security, livelihood strategies, economic conditions, and flood impact significantly influence the vulnerability of households in the study area. By combining these analyses and field observations, we argue that poverty is at the heart of all problems related to the vulnerability of coastal fishermen's livelihoods. However, this study is not intended to prove that flooding is the sole cause of poverty and vice versa. Instead, this study discusses the nexus of flood impacts, vulnerability, and poverty for fishery communities in low-lying regions via the formation of poverty traps, which is very lacking in current documents in Vietnam. It should be noted that poverty is widely recognized as a dynamic and multidimensional circumstance that is closely linked to historical factors and by the interplay of individual and community characteristics and larger socioeconomic political and cultural contexts [45], [49]. Poverty also intersects with other social elements of social exclusion such as gender and racial discrimination, [49], further reinforcing household vulnerabilities. Thus, the nexus of poverty and flood vulnerability is complex, multifaceted, and context-specific. For example, while a number of authors argue that floods and climate change are exacerbating household poverty [46], [47], others suggested that climate shocks can, under some circumstances, have positive social and economic impacts that may potentially benefit poor populations [64], [65].

Within the scope of this study, we argue that natural disasters like flooding may exacerbate poverty, and by contrast, poverty limits the capacity to adapt to floods of households, ultimately leading to high flooding vulnerability. Flooding hazards may ultimately create an endless poverty trap for the poor and thus can reverse future poverty reduction achievements. Thus, poverty alleviation is arguably the foremost blueprint to reduce the effects of natural disasters including floods. Poverty alleviation would make the poor and otherwise marginalized less vulnerable and more resilient to CC impacts including floods as identified earlier. Priority interventions for future efforts include greater attention to issues that assist the resilience of poor populations, allocating more resources to vulnerable groups, creating job opportunities and access to information for the hard-to-reach populations, and investigating the impacts of floods on relative poverty and inequality [45].

Lastly, it is important to acknowledge the limitations of this study. Firstly, the data collection was restricted to primary data gathered through household interviews and lacked crucial secondary socio-economic and environmental information such as population growth rate, regional GDP, and meteorological data. Secondly, the study emphasizes the need for hydrological tools or software to precisely measure the impact of floods and calculate vulnerability, which were not available for this study. Consequently, future research should prioritize addressing these limitations to enhance the effectiveness of flood management strategies.

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