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Climate change vulnerability and poverty nexus: evidence from coastal communities in central Vietnam

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Abstract: The vulnerability assessment of small-scale households on the central coast of Vietnam has been inadequate despite the apparent impacts of climate change. This knowledge gap presents challenges for identifying at-risk individuals and communities and could impede effective public policy and resource allocation for adaptation efforts. To address this issue, this study employed the Livelihood Vulnerability Index referencing IPCC definitions (LVI-IPCC) framework to examine livelihood vulnerability and its determinants among 455 small-scale households in the coastal areas of Phu Vang district, Thua Thien Hue province, Vietnam. The LVI-IPCC calculation utilized a database of 11 major and 33 sub-indicators collected through a household survey conducted in 2021. The findings revealed that these households exhibit moderate vulnerability to natural disasters and climate shocks, as reflected by their high sensitivity index scores. Additionally, the study identified a persistent cycle of poverty and livelihood vulnerability among coastal communities, wherein poverty and reliance on nature-based income serve as the root cause of the exposure and a gateway to this loop. This study strongly advocates for a pro-poor approach that places poverty alleviation at the forefront of community development planning and climate change agendas. Under this approach, developing value chain models in agriculture and aquaculture and diversifying livelihoods through activities such as community-based tourism is highly recommended.

Keywords: *Climate change, coastal areas, livelihood vulnerability, poverty, Vietnam*

Introduction

Global warming and climate change (CC) are among humanity's most disturbing realities in the 21st century (IPCC, 2022). The growing volatility of extreme weather events in different parts of the world is probably the most visible manifestation of climate change. In the previous two decades, almost 11,000 extreme weather events have directly resulted in the deaths of more than 475,000 individuals and the direct cost of 2.56 trillion dollars (Eckstein et al., 2021). In the first half of 2022, around 4,300 people perished in natural catastrophes worldwide, regrettably more than in previous years (Munich, 2022). Approximately 180 million people annually fall into emergencies due to natural disasters (CRED, 2020). Damage caused by natural catastrophes amounts to 0.29% of the global gross domestic product. More than 80% of these were caused by weather and climate-related catastrophes (Pielke, 2019).

Vietnam, located in Southeast Asia, has been severely affected by natural disasters in recent decades. Vietnam was recognized as one of the twenty countries most affected by extreme weather events over the past two decades (Eckstein et al., 2021). According to the Poverty and Shared Prosperity 2020 research, Vietnam ranked sixth, with 45.8% of its population (45.5 million people) at risk of catastrophic floods (Rentschler & Salhab, 2020). Its tropical monsoon climate, extensive coastline, dense river system, and dense population along rivers and coastlines all contribute to Vietnam's high climate-related risks (Chau et al., 2014; Razafindrabe et al., 2012). Additionally, excessive human interventions, such as deforestation or ineffective land-use management, have enhanced the likelihood of these threats (Chau et al., 2013; McElwee, 2004). This type of climate-related calamity has disrupted the livelihoods of the majority of the population that rely primarily on agricultural operations for subsistence. An increase in the intensity and anomaly in the frequency of occurrence of several natural disasters caused food insecurity, poverty, and health-related issues (ADB, 2013; Dinh et al., 2021; Ha et al., 2022). Natural catastrophes cost Vietnam 1 to 1.5 percent of its gross domestic product annually (Hieu & Dung, 2021; WB, 2010).

Since "climate risk" is a function of the severity and frequency of a hazard and its vulnerability (risk = hazard * vulnerability), risk reduction can be achieved by reducing the communities' vulnerability (Dar & Alam, 2020; Rouabhi et al., 2019; UNDRR, 2017). Regarding the vulnerability concept, Polsky's (2007) framework is widely acknowledged as one of the most comprehensive and well-regarded models, notable for its inclusion of multiple dimensions, components, and measurement approaches. The first ring of three essential dimensions explains vulnerability: exposure, sensitivity, and adaptive capability. Exposure is a human-environment interaction system that encounters specific hazards. Sensitivity describes the consequences of specific hazards, whereas adaptive capacity describes reactions rather than stressors and dangers. Each vulnerability dimension comprises a collection of components that rely on specific hazards, effects, and responses. Even though the concept of vulnerability explains its fundamental characteristics, its evaluations vary between systems and institutions. Man and his environment are particularly vulnerable to climate parameters and socioeconomic and extrinsic factors. Vulnerability assessment can differ based on the exposure and sensitivity of individuals and their systems; hence, a context-specific approach is required to investigate underlying risks and mitigate their effects (Howe et al., 2013). Climate-induced vulnerability is a growing concept used to assess people facing specific hazards. The social and biophysical systems in which people live directly affect vulnerability characteristics. Thus, understanding climate projections about human societies, political systems, and health profiles are required to comprehend issues arising in communities (Alam, 2017).

Prior scholarly investigations have established that distinct factors dynamically interact within a given context to ascertain the vulnerability of a system. In other words, livelihood vulnerability assessment should be closely linked to specific socioeconomic contexts and climatic conditions. Based on this, a variety of approaches have been designed to measure livelihood vulnerability at multiple levels. At household and community scales, the Livelihood Vulnerability Index (LVI) and LVI referring to the framework of the Intergovernmental Panel on Climate Change (called LVI-IPCC), are the most popularly applied worldwide to gauge the CC effects (Hoang et al., 2020; Nguyen et al., 2021a), because both employ primary data from household surveys and existing hydrometeorological reports. The LVI-IPCC is calculated by three components: exposure, sensitivity, and adaptive capacity (Adu e, 2018; IPCC, 2014; Shahzad et al., 2021). This method provides a tried-and-true technique for identifying vulnerabilities at different times and scales. It offers options to contextualize the index for a local scenario by adding or removing subcomponents considering the needs of a study area (Adu et al., 2018). This approach is very flexible in collecting data from local contexts and mixing it with meteorological parameters to confirm respondents' perceptions.

In this study, we applied the LVI-IPCC framework developed by Hahn, Riederer, and Foster (2009) to (1) measure the livelihood vulnerability of households in Phu Vang coastal plain district, Thua Thien Hue province, central Vietnam, and (2) determine factors contributing to households' vulnerability. Such efforts should be encouraged as they enrich field-based evidence in the context of increasing and unpredictable climate risks in the central coastal region of Vietnam and provide critical references for local governments to design effective policies and interventions.

Conceptual framework

Vulnerability to CC (hereafter referred to as vulnerability) is commonly defined as the "propensity" to be adversely affected by climate-related extreme events (IPCC, 2022). The third 2007 IPCC report conceived the term as "the degree to which a system is susceptible to and unable to cope with adverse CC effects, including climate variability and extremes" (IPCC, 2007). The vulnerability has since been considered a component of climate risk and has become a central concept in academic CC research (Füssel & Klein, 2006). A series of reports have agreed that vulnerability varies across communities, regions, and countries and can change over time (IPCC, 2022). Unsurprisingly, in the literature, several frameworks were applied to examine vulnerability and discuss coping strategies across the world; the most used measures included three components: (i) exposed populations, (ii) their adaptive capacity, and (iii) their sensitivity (Hoang et al., 2020; Huong et al., 2018).

Within the scholarly community, Hahn et al. (2009) are recognized as trailblazers in the field, given their seminal contribution in 2009, which involved the utilization of LVI and LVI-IPCC methods. This indicator-based approach has since been widely applied to assess household vulnerability to climate shocks and disasters of various scales. This study builds on this publication's framework due to its universality and error-less. The LVI-IPCC framework is based on a divergent combination of integrated indicators, ranging from the socioeconomic characteristics of households to their adaptive capacity, as well as their livelihood strategies (Huong et al., 2018). Also, this framework is used to assess the vulnerability at both household and community levels via primary data in countries where reliable secondary data are absent (Hoang et al., 2020). More importantly, the LVI-IPCC data offer an unbiased evaluation of climatic shocks and cross-checking of data on the adaptation of small-scale coastal households.

In general, the LVI-IPCC encompasses three main components: exposure, sensitivity, and capacity of CC adaptation (Figure 1). Exposure includes climate variability (e.g., hydrometeorological data from the closest station) and natural disasters, such as the number of extreme weather events in the last ten years. Sensitivity comprises five subcomponents: food, water, land, housing, and electricity. Meanwhile, households' adaptive capacity is measured based on their socioeconomic demographics, knowledge of CC, livelihood strategies, and social networks. Notably, in this study, we modified some of the sub-components and questions to fit the local socioeconomic and cultural context.

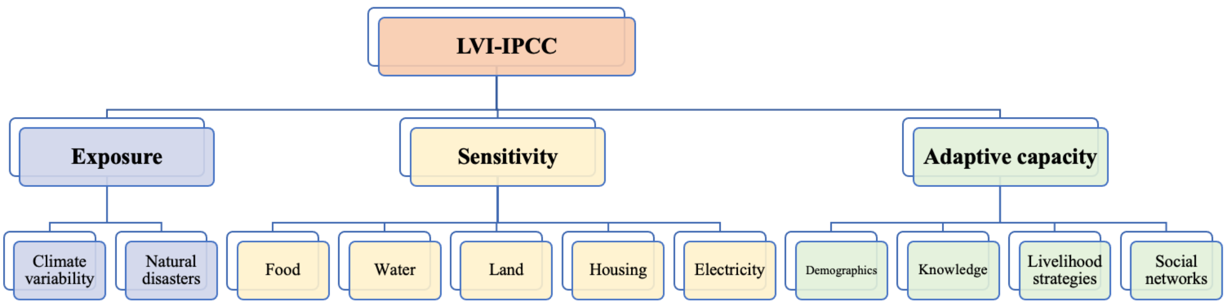

Figure 1 – Conceptual framework of the study. Source: Authors adapted from (Hahn et al., 2009)

Methods

Study sites and data collection procedure

This study was conducted in Phu Vang district, Thua Thien Hue province, Central Vietnam (Figure 2). With a long coastline combined with geographical disadvantages, this province is recognized as one of the most affected regions by CC in Vietnam. According to the People's Committee of Thua Thien Hue Province's report, 47 storms directly affected the province from 1952 to 2020, generating torrential rain and severe flooding (PCTTH, 2021). This region was most recently hit by two storms (storms No. 5 and No. 6, according to the Vietnamese government's naming system) within only one week (from October 13 to 20, 2022). Two people died, four others were hurt, and over 60,000 homes were flooded by 1-3 meters due to this incident. More than 21.7 km of riverbanks, coasts, and 38 km of agricultural dikes have been destroyed by landslides, heavy rain, and increasing sea levels. In this area, there are often four to five floods every year. Additionally, more than 70% of people in Thua Thien Hue live in rural regions and work in sectors connected to agriculture, which strongly rely on the environment and water supplies (PCTTH, 2021). The rising severity of natural catastrophes (storms, floods) negatively influences locals' daily lives and agricultural and aquacultural livelihoods.

Phu Vang is identified as the most vulnerable area to CC in Thua Thien Hue, especially in storms and floods. Regarding the disadvantage of its geographical location, most of its area is considered an oasis because of its long coastline to the east; to the west, it is exposed to the Tam Giang-Cau Hai lagoon, the largest one in Southeast Asia. More so, this is an estuary and downstream area. Therefore, the water flow is enormous in the annual rainy season, causing flooding and landslides. For example, storms No. 5 and No. 6 caused 3.2 km of coastline to be eroded from 5 to 7 meters and, in some places, more than 15 meters in Phu Vang. Finally, the livelihood of the majority of residents depends heavily on agriculture and aquaculture. Therefore, a detailed assessment of the vulnerability of farmers and fishery households in this area is urgently needed to provide a baseline for policymakers to mitigate the impacts of natural disasters.

This study applied three main tools for data collection: household surveys, in-depth interviews with key informants, and focus group discussions (FGDs). Between September and November 2021, a random sample of 455 households that relied primarily on agriculture and fishing livelihoods were interviewed using the pre-tested semi-structured questionnaire. It began with the household's demographic data before listing 33 questions to determine its vulnerability. In order to develop in-depth debates concerning the effects of CC on agricultural productivity and aquaculture/fisheries, there were open-ended questions at the conclusion. Seven in-depth interviews were conducted with the participation of two policymakers, a head of fishery associations, two heads of villages, and two local agricultural extension officials to get an overview of the political and economic context, as well as to increase the trust between the researcher and the locality (Tan et al., 2022). Three FGDs were organized simultaneously, with four to six participants in each group. These discussions provide a history of previous disasters and their effects on local communities. Furthermore, the focus group discussions (FGDs) revealed socioeconomic and cultural insights into the area.

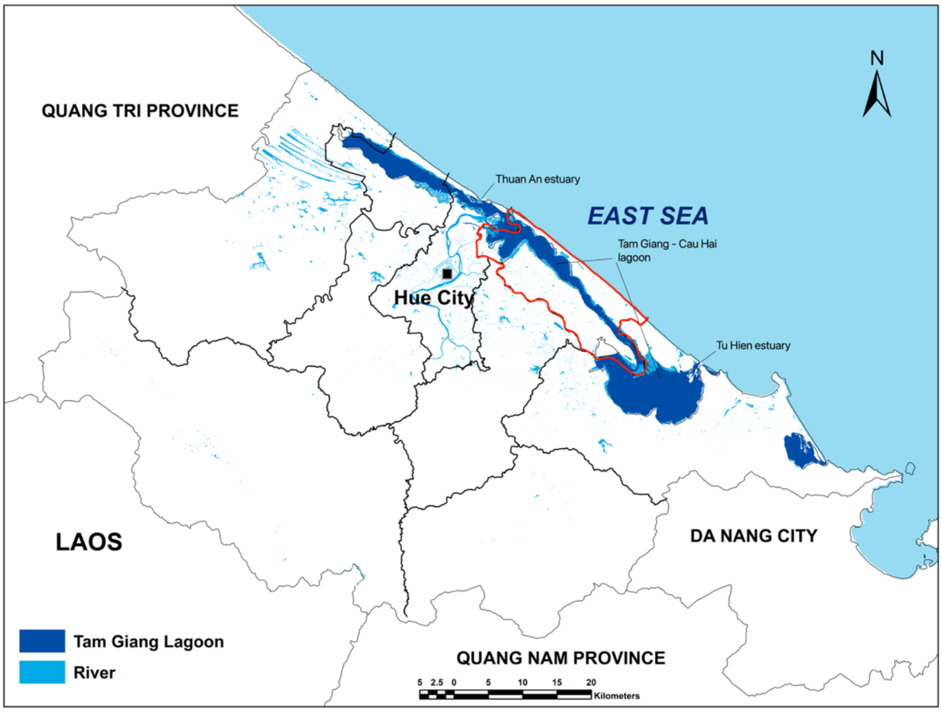

Figure 2. Map of case study in Phu Vang district, Thua Thien Hue province, Vietnam

Data analysis

LVI-IPCC calculation

In the beginning, 38 sub-components were found by doing a desk review of numerous prior works in the field (Ahmad & Afzal, 2022; Ahmad et al., 2022; Hahn et al., 2009; Hoang et al., 2020; Nguyen & Leisz, 2021; Panthi et al., 2016; Shahbaz et al., 2021). For two fundamental causes, the database added three new variables while removing seven existing ones; as such, some indicators were previously calculated at the community level or applied in upland regions and, therefore, would not be suitable for coastal households (Nguyen & Leisz, 2021; Hahn et al., 2009). This also follows the consultation of two local agricultural extension staff and residents of the Phu Vang district, who are well aware of events in their villages. Finally, a dataset of 33 sub-indicators was used for the LVI-IPCC calculation. The LVI-IPCC measurement process experienced four main stages.

In the first stage, all sub-components were rescaled from 0 to 1 (or normalized) and given different measurement units as presented in equation 1:

$$\text{Index}_{sh} = \frac{S_h - S_{min}}{S_{max} - S_{min}} \qquad (1)$$

Where Index_{Sh} is a normalized value of a sub-indicator for h household, S_h is the observed sub-component for h household, and S_{max} and S_{min} are the maximum and minimum values for total sampling data, respectively.

In the second step, the average of the related sub-indicators was used to figure out each major component, as shown in Equation 2:

$$M_h = \frac{\sum_1^n Index_{Shi}}{n} \qquad (2)$$

Where M_h is 1 of 10 major indicators for household h, $Index_{Shi}$ 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.

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

$$CF_h = \frac{\sum_1^n W_{mi} M_{hi}}{\sum_1^n W_{mi}} \qquad (3)$$

Where CF_h is a major indicator for household h indexed by i; W_{mi} 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, the LVI-IPCC was measured using equation 4 as developed by Hahn et al. (2009):

$$\text{LVI-IPCC}_h = (E_h - A_h)*S_h \qquad (4)$$

Where LVI-IPCC_h shows the livelihood vulnerability of household h. The LVI-IPCC_h scales from –1 (least vulnerable) to 1 (most vulnerable). E_h, A_h, and S_h denote the exposure, sensitivity, and adaptive capacity of household h, respectively. If the value of A_h is greater than the values of E_h and S_h, then household h is considered to have less vulnerability, as shown in Table 1. Similarly, we can determine the vulnerability of each household, thereby assessing the vulnerability of the whole sample.

Table 1 – Assessment of livelihood household vulnerability to climate variability by LVI-IPCC index. Source: adapted from (Ahmad et al., 2022; Shahzad et al., 2021)

LVI-IPCC contributors	Categories for LVI-IPCC determination	Considered as
Exposure	If adaptive capacity > (exposure + sensitivity)	Less vulnerability
Sensitivity	If adaptive capacity ~ (exposure + sensitivity)	Moderate vulnerability
Adaptive capacity	If adaptive capacity < (exposure + sensitivity)	High vulnerability

Multiple linear regression method

In this study, multiple linear regression analysis was carried out to determine which latent variables are most important for household vulnerability. This is often used to predict models involving more than one independent variable (Zhang et al., 2019). Primarily, it can construct 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). Generally, this model is shaped as follows:

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

where,

y is the dependent variable

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 u_t denotes the random error.

In our case, the value of household vulnerability (LVI-IPCC index) is identified as the dependent variable. Meanwhile, for the LVI-IPCC of households, 15 independent variables were used, including 6 variables of household demographics (age, gender, residing duration, education level, economic status, and marital status); the remaining 9 independent variables include natural disaster damage, training participation, social network, livelihood strategies, food, water, land, housing, and electricity. The SPSS 20 software was used for statistical analysis.

Results and Discussions

Assessment of livelihood household vulnerability

Each sub-component of livelihood vulnerability indices for surveyed households in Phu Vang district, including minimum, maximum, and post-normalized values, is shown in Table 2. These indexes are visually represented by a spider histogram, as depicted in Figure 3. Accordingly, the 11 major components of the vulnerability indices ranged from 0.014 to 0.634. Regarding the indexes of exposure and sensitivity, a higher sub-component value means more vulnerability. In contrast, for adaptive capacity, a higher value indicates a high degree of adaptation and, hence, less vulnerability.

Exposure

Exposure consists of two components: climate variability and natural disaster risks. The overall exposure index to climate risks is 0.266. The high value of exposure to climate variability (at 0.404) indicates that coastal households' livelihoods are highly vulnerable to climate variabilities, such as the number of heavy rainy days, high temperatures (heat), and the number of climate-related extreme events. This finding is similar to previous studies (Hoang et al., 2020; Nguyen & Leisz, 2021; Sen et al., 2021). Surveyed households reported that, on average, 1-2 types of natural disasters with negative impacts on agriculture and fisheries happen annually, of which floods and tropical storms are the two most frequent and impactful events. These events usually take place in the rainy season, which runs from September to December every year. The results revealed that the average household loss from natural disasters is estimated at 11.66 million VND in the past ten years. The respondents added that storms caused significant property damage, such as destroying fish cages, while floods led to mass fish deaths and the loss of rice crops, especially during the summer-autumn season. Hydrometeorological data showed that the Phu Vang area had unusual trends over the past decade. Rain tends to be less, especially in summer, causing drought and saltwater intrusion, but heavy rain (>50 mm/day) often concentrates in the last three months of the year, causing long-term flooding. Moreover, local people reported that the temperature difference between day and night is high, making the fish in the cages susceptible to disease or death.

Sensitivity

This indicator is composed of 5 main indices. As suggested in earlier works, we kept the four components, land, housing, and water (Hahn et al., 2009; Nguyen & Leisz, 2021; Panthi et al., 2016; Zhang et al., 2019). Instead of the health item, we substituted the electricity index, which is a crucial measure in the national disaster prevention and reduction strategy. Each component is composed of two sub-components. Overall, the sensitivity index is high (0.371), indicating higher vulnerability of livelihoods and households in the Phu Vang area, as indicated by the vulnerability for water (0.505), electricity (0.493), housing (0.473), and food (0.369). This result corroborates the findings of Ahmad et al., 2022; Hoang et al., 2020; and Shahzad et al., 2021, who reported similar outcomes.

The results showed that 15 of 455 households (3.3%) reported lacking access to adequate clean water for domestic use, and 445 households claimed they had to utilize water from sources other than the public supply (tap water), such as dug wells and rainfall. However, these sources are erratic, especially with annual water shortages in the May-July (summer) months. Similarly, while most people passively depend on the national electricity supply system, very few use renewable electricity at home, such as solar panels or generators. This causes many difficulties, mainly if a disaster occurs suddenly at night. Notably, 23 respondents reported living in unstable houses such as bamboo or non-cement materials, and 418 households (91.8%) complained that they reside in flood-prone areas; 100% of respondents complained that "… the latest flood in October 2020 made the entire house flood from 50 to 150 centimeter, and even some houses suffered heavy damage" (source: in-depth interviews, 2021). A total of 178 households relied solely on fishing and had no land for agricultural production, while 158 households did not store food for the disaster season. These factors contribute to the higher sub-indices and ultimately increase the vulnerability of Phu Vang residents to the effects of CC.

Adaptive capacity

The households in the study demonstrated a relatively high capacity to adapt to climate change, as indicated by the adaptive capacity index's average value, which is close to 0.5. The adaptive capacity index comprises various factors, including household demographics, disaster risk reduction-related knowledge and skills, livelihood strategies, and social networks. Among these factors, household demographics and disaster risk reduction-related knowledge and skills had the highest indexes, at 0.634 and 0.595, respectively. A significant proportion of the households surveyed were better off, with 91.8% falling into this category; 38.2% had attended at least one disaster risk prevention training course; 89.4% regularly received information on natural disasters and weather; and 50.09% knew the early warning system for disasters. During in-depth interviews in 2021, respondents noted that they were accustomed to living with floods and, as such, had gained experience and knowledge that allowed them to prepare for floods.

Table 2. Categorization[a] of major components and sub-components to vulnerability in Phu Vang district (N=455)

Components[b]	*Phu Vang district*
Exposure	**0.266 ± 0.092**
Climate variability	**0.404 ± 0.039**
Number of climate-related extreme events in last 10 years (1-12)	0.314 ± 0.198
Annual avg. number of heavy rainy days (>50mm) (3-30 days)	0.545
Mean standard deviation of monthly avg. precipitation (5.33-35.29 mm)	0.342
Mean standard deviation of monthly avg. maximum daily temperature (3.47-5.52 ^oC)	0.390
Mean standard deviation of monthly avg. minimum daily temperature (2.21-3.22 ^oC)	0.431
Natural disaster risks	**0.128 ± 0.173**
Total amount of asset loss caused by natural disasters in the last 10 years (0 – 500 million VnD[c])	0.023 ± 0.077
Loss or reduce of agricultural and aquaculture yield (dummy: 0, 1)	0.290 ± 0.454
Livestock death due to natural disasters (dummy: 0, 1)	0.041 ± 0.200
Reduce income due to climate-related extreme events (dummy: 0, 1)	0.226 ± 0.418
Injury or death due to weather events or natural disasters (dummy: 0,1)	0.059 ± 0.236
Sensitivity	**0.371 ± 0.082**
Food	0.369 ± 0.338
No storing food (dummy: 0,1)	0.347 ± 0.476
Do not have agricultural land area (dummy: 0,1)	0.391 ± 0.488
Water	**0.505** ± **0.112**
Not enough fresh water for the whole year (dummy: 0,1)	0.032 ± 0.178
Not using public water system (dummy: 0,1)	0.978 ± 0.146
Land	**0.014** ± **0.043**

Total area of agricultural land vulnerable to natural disasters (0-100,000 m^2)	0.014 ± 0.053
Total area of aquaculture land vulnerable to natural disasters (0-75,000 m^2)	0.014 ± 0.069
Housing	**0.473** ± **0.163**
Unstable house (dummy: 0,1)	0.028 ± 0.166
Flood-prone house (dummy: 0,1)	0.918 ± 0.273
Electricity	**0.493** ± **0.057**
No access to public electricity (dummy: 0,1)	0.002 ± 0.046
No use of renewable energy (dummy: 0,1)	0.984 ± 0.123
Adaptive capacity	**0.479** ± **0.109**
Household demographics	**0.634** ± **0.176**
Better-off household (dummy: 0,1)	0.918 ± 0.273
Independent-member ratio (0-1)	0.408 ± 0.279
Household head graduated high school (dummy: 0,1)	0.327 ± 0.469
Not a single-parent (dummy: 0,1)	0.881 ± 0.323
Knowledge and skills	**0.595** ± **0.298**
Participating in training courses on CC mitigation programs (dummy: 0,1)	0.382 ± 0.486
Know the local early-warning system (dummy: 0,1)	0.509 ± 0.500
Always update the information related to natural disasters and risk reduction (dummy: 0,1)	0.894 ± 0.307
Livelihood strategies	**0.270** ± **0.197**
Number of livelihood strategies (1-5)	0.107 ± 0.165
Households dependent on agriculture and aquaculture/fishing as their main income sources (dummy: 0,1)	0.619 ± 0.485
Bank savings (dummy: 0,1)	0.083 ± 0.276
Social networks	**0.367** ± **0.165**
Number of local grassroots organizations' participation (0-4)	0.220 ± 0.243

Number of media (0-4)	0.526 ± 0.216
Number of social-network platforms in use for updating the information related to natural disasters (0-6)	0.354 ± 0.256
LVI-IPCC	**-0.032 ± 0.041**

[a]Values are average ± standard deviation; [b]Numbers in parentheses indicate the range of observed values; [c]1 US$ ~ 23,000 VnD

LVI-IPCC

The value of LVI-IPCC ranges from -1, illustrating the least vulnerable scenario, to +1, indicating extreme vulnerability. The overall value of the estimated LVI-IPCC in Phu Vang is 0.032, which denotes moderate CC vulnerability, as shown in Figure 4. Calculated contributors of the LVI-IPCC include exposure (0.266), sensitivity (0.371), and adaptive capacity (0.480), as indicated in the study area, with more considerable severity aggregated (exposure + sensitivity = 0.637) than adaptive capacity. The low adaptive capacity of 0.480, rather than sensitivity and exposure (0.637), resulted in higher vulnerability in the study area, primarily due to poor social networks and livelihood strategies. The results show that the social network of households in Phu Vang district is limited when the average index is 0.367. Respondents reported participating in almost one local grassroots organization, usually an agricultural cooperative or a fishery association. Similarly, 61.9% of households depend on agriculture and fisheries as their primary sources of income. Only 33.4% of households have more than three sources of income, mainly from small businesses and government employment. The percentage of households with money to deposit in the bank is low (only 8.3%). The index of sensitivity (0.371) is attributable to current issues of water (0.505), electricity status (0.493), and food situation (0.369), as reported previously.

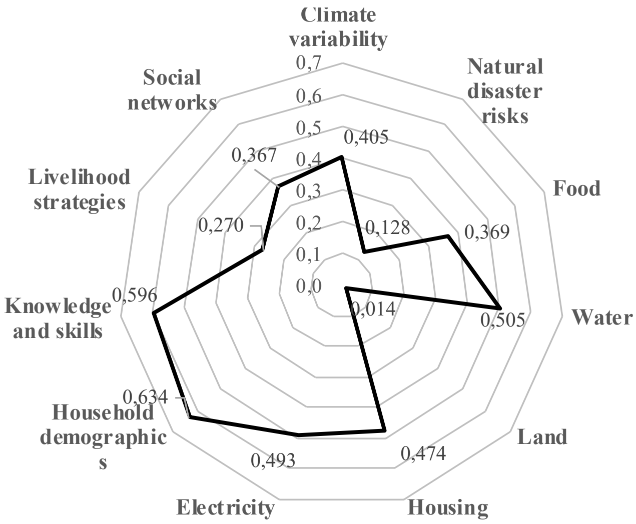

Figure 3. Spider diagram of 11 sub-component values in Phu Vang district

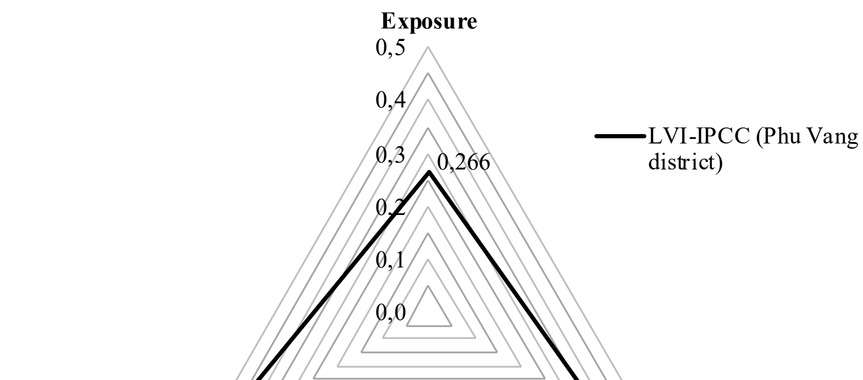

Figure 4. The value of LVI-IPCC and three contributors in Phu Vang district

Determinants of LVI-IPCC

Table 3 shows the findings of the multiple regression analysis identifying the variables influencing the livelihood vulnerability of households in Phu Vang. In general, household demographics, food, land, water, housing, knowledge, livelihood strategy, and social networks significantly influenced the household's LVI-IPCC vulnerability. The beta index shows how much influence each factor has on LVI-IPCC. The larger the beta value, the greater the effect on LVI-IPCC, such as knowledge and skills (B = -0.366) and food (B = 0.360). Conversely, lower values denote less impact, including for age (B = 0.092), non-poor household (B = 0.089), and residence period (B = 0.088) variables. The negative value of beta represents the inverse relationship between the independent variable and LVI-IPCC, while the positive beta sign represents a positive influence. Accordingly, the LVI-IPCC vulnerability positively relates to five explanatory variables: food, land, residence period, water, and housing.

Natural disasters and climate variability likely increase vulnerability, leading to rural households' food security issues (Dilley & Boudreau, 2001). The study confirms this statement; the analysis results show that households that do not stockpile food for disaster season tend to be more vulnerable to climate risks than those that do. Food security is also related to land-holding areas. The farmers reported that agricultural produce (mainly rice and vegetables) had been affected by erratic rainfall, floods, and drought, causing low productivity. Furthermore, while 39.12% of households have no agricultural land, the remaining households have marginal farms (0.5-1 hectares) or smallholdings (0.5 hectares) with agricultural activities at sustainable levels. The results show that households without agricultural land are more vulnerable than others, and a vicious circle of poverty persists. Due to a lack of agricultural land, they face food shortages and do not stockpile food for periods of natural disasters. As a result, they are more vulnerable than other members of society. These results corroborate the findings of Kolawole et al. (2016); Muthelo et al. (2019).

Unlike expectations, a long residing period increased households' vulnerability to climate risks; a rise in the residing period by one year would increase LVI-IPCC vulnerability by 8.8%. Previous publications show that older residents are more experienced in disaster response but are also more vulnerable (Huynh & Stringer, 2018; Kolawole et al., 2016; Rigg e al., 2020). People with long-term experience are more subjective when a disaster occurs. An elderly person said, "... floods happen yearly, ... don't worry, everything is ready." (Source: in-depth interviews, 2021). In the Phu Vang district, besides using the public water supply, most local people depend on groundwater for drinking and surface water for aquacultural practices (Gentle et al., 2014; Ha et al., 2022; Hoang et al., 2020). The deterioration and changes of the surface water due to heat have inevitably led to an overdependence on groundwater, leading to a scarcity of safe and good-quality water (Sam et al., 2017). We added that most houses are not permanent and have only one floor, so they are prone to flooding in the rainy season. López-Marrero & Yarnal (2010) stated that weakly-structured houses are highly susceptible to natural disasters. Again, this is related to poverty; hence, poor households have narrow asset portfolios and cannot invest in improving their housing status, leading to greater vulnerability to climate shocks (Moser & Satterthwaite, 2008).

Table 3. Determinants of livelihood vulnerability for households in Phu Vang district (N=455)

Independent variables		Category (measurement)	Beta	Sig.[a]	Collinearity Statistics Tolerance	VIF
Household demographics	Age	Continuous (years old)	-0.092	0.026**	0.581	1.723
	Gender	Dummy (0=men, 1=women)	0.043	0.207	0.851	1.175
	Residing period	Continuous (years)	0.088	0.023**	0.660	1.515
	Non-poor household	Dummy (0=no,1=yes)	-0.089	0.007*	0.922	1.084
	Household head graduated high school	Dummy (0=no,1=yes)	-0.227	0.000*	0.793	1.261
	Not a single-parent	Dummy (0=no,1=yes)	-0.226	0.000*	0.871	1.148
Climate variability and disaster risks	Asset loss due to natural disasters	Continuous (million VnD)	-0.054	0.093	0.962	1.040
Food	No storing food	Dummy (0=no,1=yes)	0.360	0.000*	0.946	1.057
Land	Do not have the agricultural land area	Dummy (0=no,1=yes)	0.179	0.000*	0.841	1.189
Water	Not enough fresh water for the whole year	Dummy (0=no,1=yes)	0.111	0.001*	0.938	1.067
Housing	Unstable house	Dummy (0=no,1=yes)	0.107	0.001*	0.962	1.040
Electricity	No access to the public electricity	Dummy (0=no,1=yes)	0.038	0.229	0.978	1.022
Knowledge and skills	Participating in training courses	Dummy (0=no, 1=yes)	-0.366	0.000*	0.907	1.103
Livelihood strategies	Number livelihood strategies	Continuous (numeric)	-0.182	0.000*	0.862	1.160
Social networks	Number of local organizations' participation	Continuous (numeric)	-0.188	0.000*	0.880	1.137
R Square			0.570			
Adjusted R Square			0.555			
Std. Error of the Estimate			0.026			
F Change			38.747			
Sig. F Change			0.000			

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

Meanwhile, the LVI-IPCC index has been negatively affected by the variables of age, education levels of the household head, marriage status, knowledge of risk reduction, economic situation, livelihood strategy, and social networks. The results revealed that older farmers were more vulnerable than young ones. Two main reasons could explain this. First, older respondents were less likely to engage in income and livelihood activities due to physical disadvantages such as health. This is similar to the discovery made by Tran et al. (2022) in the case study in Nghe An province. Second, older individuals may face limitations in accessing and adopting new scientific advancements and technologies. In fact, more than 70% of the surveyed older respondents (> 50-year-olds) do not use smartphones. By contrast, young farmers are more enthusiastic about learning advanced farming techniques, such as smart aquaculture for CC adaptation solutions. This is consistent with the findings of Nguyen et al. (2021b), Rigg et al. (2020), Son & Kingsbury (2020), and Huynh & Stringer (2018).

The results revealed that people with less education, lack of knowledge related to risk reduction, and single-parent families tended to be more vulnerable than other groups. This corroborates with Kelly and Adger (2000), who argued that sociodemographic characteristics might impact individuals' preparedness to deal with, recover from, and adapt to external risks and stress. In Phu Vang, household heads who have graduated from high school or attained higher education tend to be less vulnerable ($p<0.05$). Household heads with higher education had a higher probability of adopting advanced techniques in agricultural production and engaging in livelihood diversification (Ha et al., 2022; Dinh et al., 2021; Sen et al., 2020; Sujakhu et al., 2018). Participation in training courses and improving understanding of risk reduction also play essential roles in households' vulnerability and adaptation in the Phu Vang district. Sen et al. (2020) argued that local extension programs and short training courses could positively influence adaptation to agricultural-specific climate shock coping strategies. Similarly, there's evidence that the provision of tailor-made courses and locally mediated communications can leverage social learning and enhance adaptive capacity and resilience (Huynh et al., 2022a; Phuong et al., 2018a). Therefore, we argue that improving education and training knowledge for local members is crucial to diversifying livelihoods and increasing incomes while mitigating CC-related risks.

Notably, we found that the poor are more vulnerable than other groups. Obviously, poverty is closely related to limited livelihood options and disconnected social networks. Indeed, livelihood strategies are one of the most influential variables in a household's adaptive capacity (Paavola, 2008). While the poor solely depend on 1-2 primary sources of income, mainly agriculture and fisheries (Chuong et al., 2020; Vo et al., 2021), the wealthier households seek to diversify their incomes, assets, and livelihood activities via investment, leading to reduced risks in the event of the failure of any one of them (Leartlam et al., 2021). The findings of our case study revealed that 39.42% of households rely heavily on agriculture or fishing, with 68.93% classified as poor. Additionally, our results suggest that poor households often have poor social networks and are less likely to participate in local institutions and agricultural extension programs, causing low levels of adaptation.

These findings confirm the statements of previous studies that households' linkage with local organizations and participation in joint social activities in rural areas play a vital role in supporting adaptive capacity during disasters (Dinh et al., 2021; Huynh et al., 2020; Sen et al., 2020; Son et al., 2020). Phuong et al. (2018b) explained that participation in social activities, social networks in the community, and access to agricultural services contribute to enhancing the social learning of farmers, especially in rural, agriculturally dependent areas. Similarly, Hidayat et al.(2021)argued that Indonesian households that collaborate well with local companies and NGOs seem more resilient than those that do not. Tran et al. (2022) also stated that being a cooperative member may improve households' adaptive capacity as it increases accessibility to broader sources of information. Others claimed that the farmers' contact with various institutions increased their opportunities for accessing credit, agricultural extension visits, and improved infrastructure (Leartlam et al., 2021; Sen et al., 2020; Sujakhu et al., 2019). Such social linkages are also significant for strengthening communities' awareness of climate-related risks and their livelihood diversification strategies (Belay & Fekadu, 2021; Vo et al., 2021). Attention to such issues will be crucial in providing interventions to enhance adaptation to climate risks, especially for the poor and marginalized groups.

Conclusion and implications

Although Vietnam is considered one of the world's most vulnerable regions to CC, assessments of the vulnerability of estuarine and coastal populations are thoroughly underreported. This study aimed to bridge that knowledge gap by applying the LVI-IPCC framework as adapted from Hahn et al. (2009). With the advantage of integrating divergent socioeconomic aspects, the LVI-IPCC framework has become a set of indicators widely applied in many parts of the world. This study expanded on the work of Hahn et al. (2009) but with some minor changes to accommodate the local socioeconomic and political context. This study estimated the vulnerability of fishermen living in Phu Vang district, one of the most vulnerable areas in Thua Thien Hue province, central Vietnam. The LVI-IPCC value is -0.032, which implies that the vulnerability is moderate. This can be explained by their high sensitivity and low adaptability. This study has also identified factors that affect household vulnerability, including household demographics, food, land, water, housing, knowledge, livelihood strategy, and social networks.

More importantly, the study has shown a relationship between vulnerability and poverty. We consider poverty as the starting point of livelihood vulnerability in the study area (Figure 5). Poverty leads to limited asset portfolios, such as a lack of productive land and decreasing access to agricultural production machinery and technological advances. Poverty is also the cause of the lack of investment in agricultural production and the limited connection with local grassroots organizations. These lead to low awareness and knowledge of household natural disaster risks. These constraints ultimately lead to high vulnerability to climate and weather change. Thus, poverty reduction should be the foremost priority and must be placed at the outset of all policies and programs related to community development and disaster risk reduction. As such, within the scope of this study, three policy implications are proposed as follows:

Firstly, most households in the Phu Vang district heavily rely on agriculture, aquaculture, and fishing, which are highly susceptible to extreme climate phenomena. These phenomena often result in reduced productivity, lower yields, or even failed harvest (IPCC, 2007). Unfortunately, households usually bear these losses themselves as the government's budget is insufficient to provide extensive support. Conversely, agricultural products and seafood experience a significant drop in demand and price during favorable seasons. Therefore, besides enhancing adaptability to extreme weather events, local authorities require solutions and interventions to guarantee stable output for agricultural and fishery products. The adoption of a value chain model for the production and consumption of these products should be considered. By implementing agricultural and aquacultural production along the value chain, all participants can share the benefits and responsibilities, regulate market supply and demand, and trace the products' origins to meet sustainable agriculture's development requirements. This approach improves production efficiency and enhances income for farmers and businesses. Additionally, relying solely on a single livelihood option poses considerable risks (Sam et al., 2017). Thus, diversifying livelihoods and increasing incomes appear to be the initial steps toward reducing poverty and enhancing the adaptive capacity of coastal households. The combination of traditional farming techniques with the application of advanced technology in agricultural production has proven to be effective. Furthermore, prioritizing alternative livelihoods, such as community-based tourism, to mitigate risks is also crucial. Therefore, the support of third parties, including NGOs, local authorities, and civil society organizations, becomes necessary (Tan et al., 2019; Tran, Nguyen, Huynh, Pham, & Schinkel, 2023). Apart from financial support, these institutions provide access to well-trained experts and product market connections.

Secondly, it is crucial to raise awareness and knowledge of climate change among local villagers through disaster risk reduction training and tailor-made agricultural extension courses. In this regard, the local government plays a vital mediator in mobilizing resources from social organizations and local businesses to support disadvantaged groups. Simultaneously, they can effectively allocate resources from the central government to address factors contributing to community vulnerability, such as electricity, roads, and water infrastructure. However, it is essential to note that not all forms of learning can effectively enhance adaptation strategies or increase adaptive capacity, as cautioned by Berkes (2009). Poorly designed learning initiatives may even have adverse effects. Therefore, organizers must carefully consider the most vulnerable individuals and areas and the underlying reasons before implementing any training programs. The study will provide valuable data for community planners and developers, emphasizing the importance of incorporating local communities' social norms and cultural aspects to foster enthusiastic and active participation among learners. A participatory approach would be particularly advantageous in this scenario.

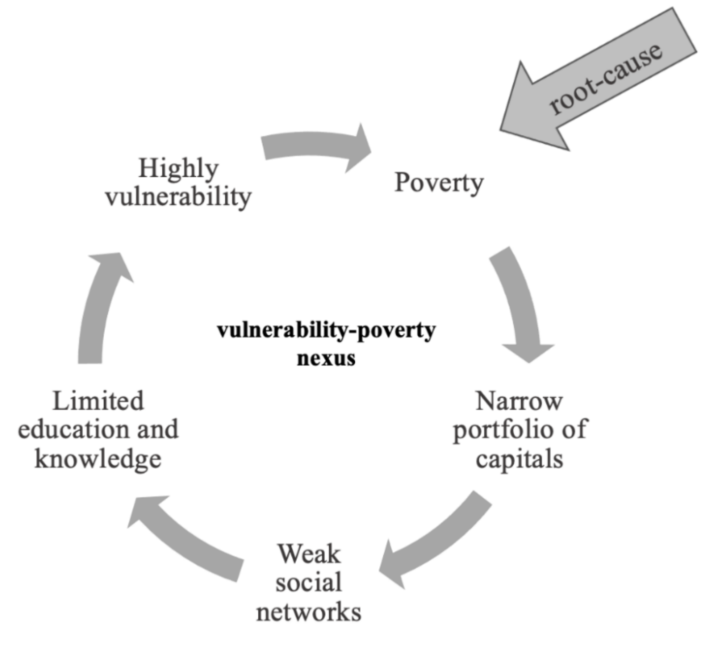

Figure 5. The endless loop of poverty and livelihood vulnerability

Finally, expanding households' engagement with their social networks and local organizations plays a crucial role in reducing disaster risks and simultaneously enhancing adaptive capabilities, as discussed earlier. In the Phu Vang district context, fostering improved social connections between community members within and outside the region through agricultural cooperatives and community-level fishery associations becomes imperative to mitigate livelihood vulnerability. Several studies have demonstrated that being a member of a farming cooperative can enhance households' adaptive capacity by providing access to finance, infrastructure, information, and opportunities to establish social networks (Leartlam et al., 2021; Phuong et al., 2018a). Furthermore, these organizations contribute positively to agricultural development and the construction of new rural areas in Vietnam through job creation and increased income for their members (Phuong et al., 2023; Tran et al., 2022).

In brief, with specific reference to the context of a coastal community in Vietnam, this study evidenced the vicious cycle of livelihood vulnerability and poverty. It was argued that poverty could serve as both the root cause of livelihood vulnerability problems and the most crucial point to get out of the vicious trap discussed. However, poverty alleviation requires long-term efforts, particularly regarding the country's political economy. Thus, the most important task is identifying a consistent goal, appropriate approaches, and a specific strategy. The implications of this study could be lessons for the Vietnamese government and other regions that share similar socioeconomic, cultural, and vulnerability contexts as an initial step in mitigating this trend.

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Compliance with ethical standards

All procedures performed in participatory human studies were obtained with the informed consent of the participants and were by ethical research standards. This article does not contain any studies involving animals performed by authors.

Conflict of interests

The authors declare no conflict of interest.

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