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Decoding the livelihood vulnerability of flood-prone communities in Vietnam: Implications for disaster risk reduction and sustainable rural development

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Abstract: In the midst of increasing global uncertainties, understanding household vulnerability to disaster risks and identifying the most susceptible individuals and communities has become an urgent concern. This study assesses and compares the flood vulnerability of two communities, Quang Tho and Quang Phuoc, in Thua Thien Hue Province, Vietnam. The study utilizes primary data collected in 2022 from 280 rural households whose livelihood sources are agriculture and fishery. Flood vulnerability is determined by applying the Livelihood Vulnerability Index based on the Intergovernmental Panel on Climate Change's definition (LVI-IPCC) approach. Our analysis reveals that both communities exhibit moderate vulnerability to flood hazards across various dimensions. Notably, fishing-only communities are found to be more vulnerable to flooding compared to mixed agri-fishery farmers. Additionally, we have identified several factors that exacerbate vulnerability, including poverty, low education levels, single parenthood, limited resources, narrow livelihood strategies, and inadequate social connections. Therefore, development policies and disaster risk reduction programs should prioritize disadvantaged groups, focusing on promoting social inclusion and gender equality in accessing services and public resources. It is concluded that tailored disaster risk management and rural livelihood development initiatives are crucial to addressing each community's specific vulnerabilities and challenges, fostering resilience, and thus reducing future risks. Achieving greater sustainability and equilibrium for vulnerable groups necessitates continuous action and investment.

Keywords: *floods, livelihood vulnerability index, poverty alleviation, rural livelihood strategy, sustainable rural development*

Introduction

Global climate change is undeniably one of the most pressing developmental challenges facing humanity today. As climate change continues to escalate, it exposes millions of vulnerable people to unpredictable threats, jeopardizing their livelihoods and subjecting them to various risks (IPCC, 2022). This is vividly illustrated by the escalating frequency and severity of extreme weather events in numerous regions across the globe (Dinh et al.,

2021). Over the past two decades, more than 10,000 extreme weather events have unfolded on a global scale, resulting in nearly 500,000 fatalities and causing an astonishing 2.6 trillion US dollars in property (Eckstein et al., 2021). Alarming projections from the UNEP Adaptation Gap Report (UNEP, 2016) indicate that the impacts of climate change will lead to an annual global cost of adaptation, estimated to range between 140-300 billion dollars by 2030 and 280-500 billion dollars by 2050. It is important to acknowledge that developing countries bear a disproportionately heavy burden, with extreme weather events affecting nearly 190 million people annually since the early 1990s. Shockingly, this accounts for 79% of all fatalities and a staggering 97% of those impacted (Walsh & Ormond-Skeaping, 2022).

Vietnam, with its substantial coastal population and geographical configuration, faces severe flood impacts, with flooding alone contributing to about 97% of the country's annual natural disaster losses losses (Dinh et al., 2021; World Bank & ADB, 2020). Between 1989 and 2015, Vietnam grappled with the dire consequences of flooding, resulting in a heartbreaking toll of 14,927 deaths, 16,829 injuries, and a financial loss amounting to 3.7 billion USD (Luu et al., 2017). This crisis continues to plague nearly one million people, particularly those residing in delta regions, coastal areas, and low-lying areas (Kien et al., 2019). In a troubling forecast, climate change is expected to exacerbate this situation, potentially affecting an estimated 9 million people in low-lying and coastal areas by the year 2044, contingent upon emission levels (World Bank & ADB, 2020). The situation is further compounded by limited resources, inadequate infrastructure, and a lack of adaptive measures, factors that significantly amplify flood vulnerabilities (Ha et al., 2022; Nguyen et al., 2021). Notably, human activities, such as encroachment on rivers and unsustainable practices, have also been major contributors to the heightened flood risk (Abbas et al., 2017; Teo et al., 2018). While the academic community has dedicated significant effort to studying floods in Vietnam, the literature often overlooks the impact of flood hazards on specific populations, such as small-scale farmers and fishermen in rural areas, and their connection to poverty alleviation—a critical concern for low- and middle-income economies, in line with the United Nations Millennium Goals.

Vulnerability, a central concept in the context of climate change, examines the intricate interplay between human systems, the environment, and hazards. The Intergovernmental Panel on Climate Change (IPCC, 1996) defines vulnerability as the susceptibility of a system to climate change and its capacity to adapt. When it comes to flooding, it quantifies how predisposed an area or community is to the consequences of inundation. Factors contributing to flood vulnerability encompass a wide array of variables, including inadequate infrastructure, urban planning, emergency services, flood mitigation, population density, socio-economic conditions, and climate change impacts (Dinh et al., 2021; Hoang et al., 2020). Polsky et al. (2007) introduced a three-dimensional model, encompassing exposure, sensitivity, and adaptive capacity. Exposure refers to a system's vulnerability to disasters, sensitivity to the impacts, and adaptive capacity to cope with them. In the case of floods, livelihood vulnerability considers the damage to households and hinges on these three dimensions, with each aspect encompassing parameters like socioeconomic and cultural conditions, rendering vulnerability assessments context-specific.

Vulnerability assessment frameworks are fundamental tools in climate change studies, with primary household surveys being preferred over secondary socioeconomic statistics to minimize subjective biases in indicator selection (Jones & Tanner, 2015). The Livelihood Vulnerability Index (LVI), introduced by Hahn, Riederer, and Foster (2009), is a pioneering example of such an assessment. To further align with the IPCC's framework, Hahn et al. (2009) introduced the LVI-IPCC as an alternative method for assessing livelihood vulnerability. Like the LVI, the LVI-IPCC breaks down livelihood vulnerability into major and sub-components, categorizing them into three LVI-IPCC contributors: exposure, sensitivity, and adaptive capacity. This framework enables a more comprehensive understanding of livelihood vulnerability, specifically concerning flooding. This approach

has been adopted and adapted globally, with researchers employing it in disaster-prone developing countries like Mexico (Gran Castro & Ramos De Robles, 2019), India (Ahmad et al., 2023; Mitra & Mandal, 2022; Rehman et al., 2022), Nepal (Sujakhu et al., 2019), Pakistan (Ahmad & Afzal, 2022; Shahzad et al., 2021), Ghana (Etswire et al., 2013), and Vietnam (Hoang et al., 2020; Nguyen & Leisz, 2021; Tran et al., 2021).

In the Thua Thien Hue province, recent scholarly attention has been dedicated to the examination of livelihood vulnerability. Tan et al. (2023) undertook an investigation into the interconnection between vulnerability to climate change and poverty within coastal communities. Meanwhile, Phuong et al. (2022) directed their attention towards comprehending the susceptibility of livelihoods to climate change within ethnic minority communities in mountainous areas. Despite Thua Thien Hue being recognized as notably susceptible to flood risks, there remains a conspicuous gap in the exploration of livelihood vulnerability to such natural disasters among communities residing in low-lying areas. This research endeavor holds significance as it offers valuable insights for formulating recommendations that can foster resilience and mitigate future disaster risks. Furthermore, livelihood vulnerability itself is an inherently site-specific issue, influenced by an array of factors ranging from the geographical and climatic attributes of the locality to the cultural and socio-demographic characteristics. Thus, investigations of this nature, exemplified by the aforementioned studies, contribute to a nuanced and diversified comprehension of the subject matter.

This study seeks to bridge this gap by investigating the livelihood vulnerability to flood risks of two flood-prone communities in Central Vietnam, explicitly focusing on small-scale farmers and fishermen. Three interconnected objectives drive our research. Firstly, we aim to assess the comparative vulnerability of small-scale farming and fishing households to flooding by implementing the Livelihood Vulnerability Index based on the framework advanced by the Intergovernmental Panel on Climate Change (LVI-IPCC). Our second objective is to identify the key factors that contribute to household flood vulnerability. Lastly, we aspire to offer policy implications and recommendations aimed at alleviating flood risk and promoting sustainable rural development in the study area. Through these objectives, this study aims to provide invaluable insights into the complex landscape of flood risk in the context of rural poverty, offering practical guidance to policymakers, development practitioners, and scientists. Furthermore, it contributes to the expanding body of literature on climate change in Vietnam, while its findings can potentially serve as a valuable reference for other flood-prone communities worldwide grappling with similar geographical challenges and significant flood-related impacts.

Materials and Methods

Determinants of flood vulnerability

In this study, the LVI-IPCC approach was used to measure livelihood vulnerability to flood disasters by employing 35 sub- and 11 major- indicators (Figure 1). Exposure, one of the three LVI-IPCC contributors, was formed from two major components, namely climate variability (consisting of five indicators) and flood damage (consisting of six indicators), which is consistent with previous studies (Ahmad & Afzal, 2022; Hahn et al., 2009; Hoang et al., 2020; Phuong et al., 2022). The sensitivity index was calculated using five sub-components: food (two indicators), water (two indicators), land (two indicators), housing (two indicators), and health (three indicators), which have been widely used in earlier studies (Hahn et al., 2009; Hoang et al., 2020; Nguyen et al., 2021; Nguyen & Leisz, 2021). The adaptive capacity component included four sub-components, including socioeconomic demographics, livelihood strategies, household perception of flooding, and social networks.

In addition, flood knowledge and awareness, recommended by Phuong et al. (2023), were added as subcomponents by comparing Ahmad and Afzal (2022) and Hahn et al. (2009). Furthermore, knowledge and awareness of flood risks through participation in training or disaster preparedness drills have been found to enhance household adaptivity (Ha et al., 2022; Nguyen et al., 2021; Phuong et al., 2022; Vo et al., 2021), which in turn reduces vulnerability.

In addition to conducting livelihood vulnerability assessments, several recent studies (e.g., Sujakhu et al., 2019; Mogomotsi et al., 2021; Nguyen & Leisz, 2021; Phuong et al., 2023; Tran et al., 2022; and Zhang et al., 2019) have investigated the factors that contribute to household vulnerability. Livelihood vulnerability can be influenced by a range of endogenous and exogenous factors. Building on the theoretical behavioral background and existing vulnerability studies, this study identified five key factors that can drive household flood vulnerability: (1) household head profiles, such as age, gender, marital status, and education level; (2) household demographics, including household classification, agricultural land condition, health and housing status, and access to health services; (3) flood risks, such as asset loss and income reduction due to flooding events; (4) farmers' livelihood strategies for adapting to floods; and (5) social networks. Figure 1 presents the research framework for these elements.

Several empirical studies have suggested that the profiles of household heads, such as gender, age, marital status, and educational qualification, are strongly related to household livelihood vulnerability and adaptive capacity. Many studies have confirmed that male-headed household heads tend to adopt more adaptation strategies than their counterparts; therefore, they are more likely to adapt than are women (Getahun et al., 2021; Hilemelekot et al., 2021; Phuong Thi Tran et al., 2023; Vo et al., 2021). The age of the household head is closely linked to agricultural farming experience; therefore, there is a positive relationship with the adaptability of the household (Getahun et al., 2021; Mogomotsi et al., 2020). Household vulnerability is significantly influenced by marital status (Muthelo et al., 2019; Phuong et al., 2022). Typically, single-parent or divorced/widowed households may be more vulnerable than others, predominantly ethnic minority groups (Phuong et al., 2022). Likewise, household vulnerability is strongly influenced by the household head’s educational level. The majority of previous results have demonstrated that the more educated the household head, the better the adaptive capacity, thereby reducing susceptibility to changes in weather and climate (Alemayehu & Bewket, 2017; Belay & Fekadu, 2021; Getahun et al., 2021; Phuong T. Tran et al., 2022; Vo et al., 2021).

Socioeconomic characteristics and household asset background, including the wealth of the household (Tamesgen Tadesse Deressa et al., 2009; Phuong et al., 2022), housing conditions (Ghosh & Ghosal, 2020; Nguyen & Leisz, 2021; Phuong et al., 2022), food and water status (Hilemelekot et al., 2021; Nguyen & Leisz, 2021), land-related factors (Alemayehu & Bewket, 2017; Asrat & Simane, 2018; Nguyen & Leisz, 2021), and access to health services (Ghosh & Ghosal, 2020) are determinant factors for household adaptation, thereby affecting the vulnerability of households' livelihoods.

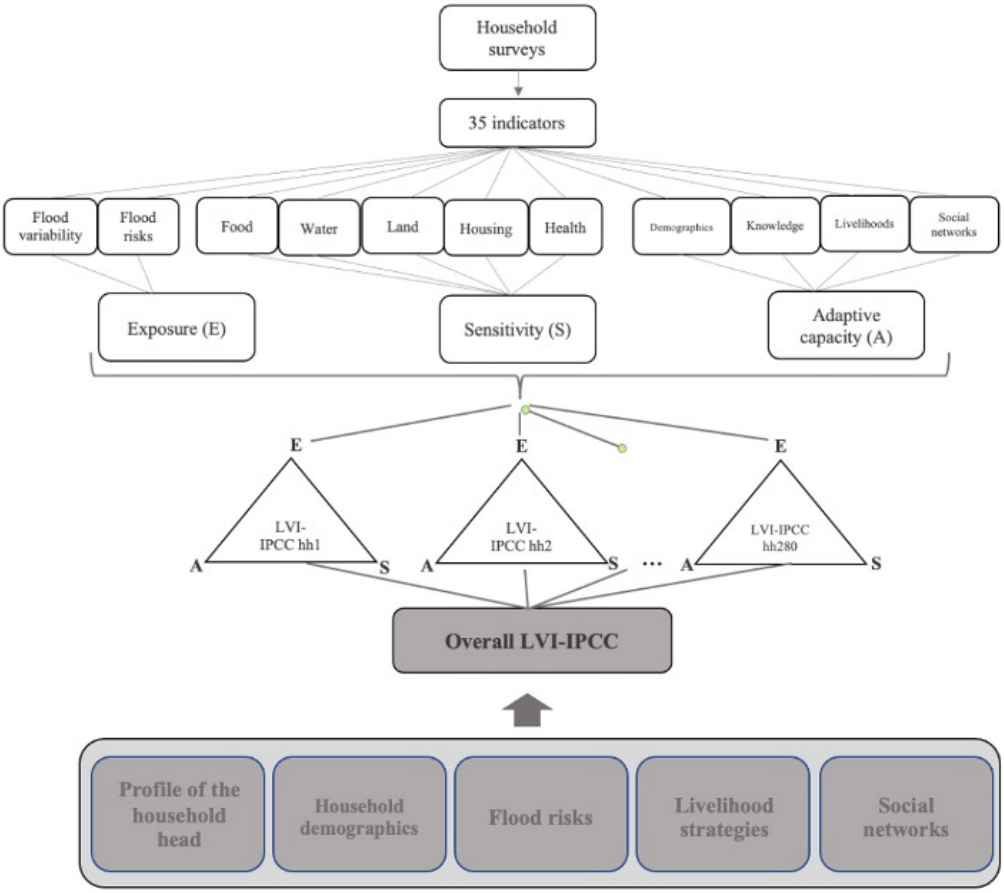

Figure 1 - Conceptual framework of the study

The degree of damage to property and income due to floods is identified as the main factor affecting households' flood vulnerability. Tran et al. (2022) showed that flood damage variables significantly impact rice households' vulnerability in Nghe An Province, Vietnam. Similarly, Phuong et al. (2023) found that household vulnerability was positively correlated with extreme weather events and disaster damage. Hilemelekot et al. (2021), in turn, claimed that Ethiopian farmers, who are frequently exposed to floods, are forced to implement a range of adaptation strategies. Thus, they are less vulnerable than others.

Similarly, many authors have argued that households' livelihood vulnerability to climate-related shocks, including flooding, has a negative relationship with livelihood diversification. For example, Deressa et al. (2009) concluded that the higher the percentage of diverse income, the higher the flood adaptation probability is (Tamesgen Tadesse Deressa et al., 2009). Similarly, Asrat and Simane (2018) found that one unit of additional income from off-farm sources increases the probability of adaptation by 2.1% (Asrat & Simane, 2018). A wide range of studies agreed that income diversification and multiple livelihood strategies could help farmers reduce losses and income because they can shift to off-farm works and less weather-depend activities such as tourism and crafts during the disaster season (Deressa et al., 2011; Phuong et al., 2022; Tran et al., 2022; Tran et al., 2021).

Finally, we hypothesized that linking communities through local organizations would play an important role in improving the resilience of households to floods, thereby reducing their vulnerability. Getahun et al. (2021) and Hilemelekot et al. (2021) indicate that farmers with good access to extension advisory services are less vulnerable than those without access. Similarly, many studies argue that households with diverse social connections, such as joining local organizations and having multiple devices for access to weather information, tend to have a higher adaptive capacity and thus may be less vulnerable (Nguyen & Leisz, 2021; Phuong et al., 2022; Vo et al., 2021).

Calculation of the LVI-IPCC

In this study, 35 indicators were used to calculate the 11 sub- and three major components (exposure, sensitivity, and adaptive capacity) that constitute household livelihood vulnerability to floods. These 35 indicators were finely selected from emerging archives focusing on vulnerability assessment around the world (Ahmad et al., 2022; Ahmad & Afzal, 2022; Hahn et al., 2009; Hoang et al., 2020; Nguyen et al., 2021; Nguyen & Leisz, 2021; Panthi et al., 2016; Phuong et al., 2022; Shahbaz et al., 2021; Tran et al., 2021). However, compared with the work of Hahn et al. (2009) and many earlier studies (e.g. Nguyen and Leisz, 2021; Hoang et al., 2020), we supplemented the variable of knowledge of floods through three indicators: participation in flood training courses, attending flood prevention drills, and knowledge of local flood warning systems. This was supported by a range of previous studies (Phuong et al., 2022; Sen et al., 2020), which suggested that households' knowledge and awareness contribute to improving their adaptive capacity. This also helps farmers better prepare for floods, thereby minimizing damage (Dinh et al., 2021; Ha et al., 2022; Nguyen et al., 2021).

The procedure of the LVI-IPCC calculation took four main phases, including the normalization of indicators, balancing the weights for the sub-components, calculating the three major components, and calculating the overall LVI-IPCC index.

First, because the indicators have different units (for example, a unit of m2 was used for land area, while the distance to the nearest health station is measured in km), there is a standardized procedure for the same unit (from 0 to 1) has been carried out. as in equation 1all sub-components were rescaled from 0 to 1 (or normalization) given different measurement units. The indicators were normalized using Equation 1:

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

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

Second, each sub-component was calculated by averaging the related indicators using Equation 2:

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

Where Mh is one of the 11 sub-components for household h, IndexShi demonstrates the indicator, indexed by i that made up each of the major indicators, and n is the number of indicators in each major indicator.

Third, the three major components of exposure, sensitivity, and adaptive capacity of household h were calculated using Equation 3:

$$CF_h = \frac{\sum_{i=1}^n WmiMhi}{\sum_{i=1}^n Wmi} \qquad (3)$$

Where CFh is a major component of household h indexed by i, Wmi is the weight of each subcomponent, and n is the number of subcomponents in each major component.

Finally, as suggested by Hahn et al. (2009), the overall LVI-IPCC was calculated using Equation 4:

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

Where LVI-IPCCh represents the flood vulnerability of the household h. The LVI-IPCCh scales from − 1 (least vulnerable) to 1 (most vulnerable). where Eh, Ah, and Sh indicate the exposure, sensitivity, and adaptive capacity of household h, respectively.

Multivariate regression model

Multiple linear regression analysis was applied to identify the determinants of household flood vulnerability. This model is often employed to predict the relationship between a dependent variable and two or more independent variables (Zhang et al., 2019). The outstanding advantage of this method is that it can create an optimal multiple linear regression equation based on its ability to identify and select independent variables (or explanatory variables) that have a significant linear effect on the dependent variable (in this case, the LVI-IPCC scores) (Nguyen & Leisz, 2021). Therefore, it has been extensively used in recent vulnerability assessment studies (Y. T. B. Nguyen & Leisz, 2021; T. T. Phuong et al., 2022). This model is shown in Equation 5 below:

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

where y is the dependent variable; β_0 is the intercept; x_1, x_2,…, and x_k are independent variables; β_1, β_2,…, and β_k are partial regression coefficients; and ut denotes the random error.

In this study, the household flood vulnerability, as quantified by the LVI-IPCC index, served as the dependent variable. Sixteen independent variables were considered for their potential significant correlations with the dependent variable, including age, gender, education level, household classification, marital status, flood-induced loss of assets, income reduction due to floods, food, water, flood-prone-agricultural, prone-aquaculture areas, housing conditions, health status, knowledge of flood reduction, livelihood strategies, and social networks. To conduct the statistical analysis, the study employed SPSS 20 software.

Data and Case Study

Description of study areas

The study was conducted in the Thua Thien Hue Province, located in the North Central Coast region of Vietnam. The province is particularly vulnerable to flooding due to its low-lying terrain and lengthy coastline, which is connected to several fluvial systems. The area is prone to various natural disasters, particularly floods and storms, as documented by previous studies (Vo et al., 2021; Dinh et al., 2021). According to the General Report on Climate in Thua Thien Hue Province (GRCTP) in 2021, approximately two-thirds of the province's population is at risk of flooding during intense rainfall episodes. Given these factors, Thua Thien Hue Province was chosen as a suitable case study area for investigating household vulnerability to flooding.

In 1999, a severe flood devastated Thua Thien Hue Province, and it remains a vivid memory for many of the residents. During this event, water levels rapidly rose, with the station on the Huong River measuring 5.81 meters, equivalent to the height of a double-decker house. The flood resulted in 550 deaths, dozens of people missing, and over 630,000 damaged houses, with a financial toll estimated to be as high as 4,536 billion VND (VDMA, 2019). The construction of large dams by the government was believed to have reduced the fear of flooding in the province, but the 2017 catastrophe renewed concerns. It was one of the strongest hurricanes to strike Southeast Asia in the last two decades, with wind speeds reaching nearly 150 km/h (UNDP, 2018). The overall cost of damage incurred by the event was estimated to be 921.379 billion VND, the highest amount recorded in the past decade.

In 2020, the central region of Vietnam, including Thua Thien Hue Province, experienced a series of devastating floods. Four major floods occurred in just a month (October to November), and some hydrological stations recorded flood peaks higher than those in 1979, 1999, and 2017, setting a new record. The flood of 1979 stands out as a significant event in Vietnam's history due to its substantial loss of life and extensive economic devastation. Unofficial data suggests that this flood resulted in floodwaters rising from 1.5 meters to 3 meters above ground level (Huan & Van, 1979). The rapid surge of water led to the destruction of thousands of homes and critical infrastructure. The 2020 floods in the central region are considered a new historical flood event, reaching alarming level IV, an extremely dangerous natural disaster level, and causing far-reaching impacts and damage across the entire area (Dinh et al., 2021; Ha et al., 2022).

The survey was conducted in Quang Tho and Quang Phuoc Communes in Quang Dien District (Figure 2), which is located in the low-lying terrain of Thua Thien Hue Province, Vietnam. The district has a population of around 86,000, and agriculture and aquaculture are the main sources of livelihood, contributing 38.6% to the district's overall production value. Agriculture is viewed as a vital part of livelihood by the residents of Quang Tho, while fishing and aquaculture are the primary sources of income for the residents of Quang Phuoc. The area's geography, characterized by low-lying terrain, dense river systems, and proximity to the Tam Giang Lagoon, offers significant advantages for the local economy. However, it also makes the area particularly susceptible to flooding. Therefore, it is crucial to assess the comparative vulnerability of smallholder farmers and fishermen to flooding and identify the critical factors contributing to household vulnerability. Such assessments are necessary to make recommendations to reduce flood risk and promote sustainable rural development in the study area.

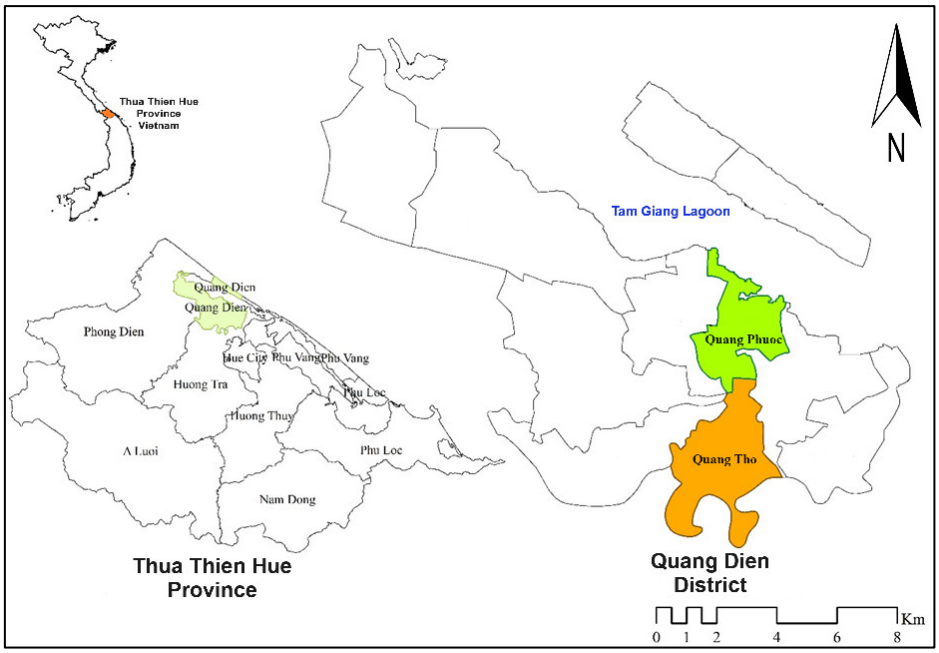

Figure 2 - Map of study sites in Quang Tho and Quang Phuoc communes, Thua Thien Hue province, Vietnam

Data Collection and Analysis

Data were collected in the Quang Tho and Quang Phuoc communes, Quang Dien District, from early September to late December 2022. In-depth interviews were conducted with key informants in Quang Dien District, including the Vice Head of the Agriculture and Rural Development Department, Vice-Chairpersons in Quang Tho and Quang Phuoc communes, and village heads from six selected villages, to provide an overview of the study area's local

socioeconomic and flood-related secondary data. Five focus group discussions (FGDs) were conducted, with four at the community level in the Quang Tho and Quang Phuoc communes and one at the district level, to gather qualitative evidence on the specific impacts of floods on human life in the study area. Primary data for analysis were collected through a cross-sectional survey of 280 households evenly divided between Quang Tho and Quang Phuoc communes, utilizing face-to-face interviews. The household head (either the husband or wife) was the target respondent, given their decision-making power, strong understanding of floods, and their impact on household livelihoods. A comprehensive questionnaire was created by reviewing relevant documents and incorporating the insights of specialists who deeply understand floods and villager lifestyles.

The questionnaire is structured into five primary sections. It commences with the collection of demographic information encompassing age, gender, and educational attainment. Parts two, three, and four, constituting the core areas of investigation, are dedicated to inquiries pertaining to household exposure, sensitivity, and adaptive capacity. This tripartite section employs a combination of closed and open-ended questions to augment the depth of information gathered. Finally, the concluding section comprises open-ended inquiries designed to elicit insights into the challenges experienced by households in the context of flooding, along with their recommendations for enhancing future mitigation strategies. In this study, we employed a T-test to assess differences between the two study areas across various parameters, including 35 sub-indices, 11 main indices, 3 LVI-IPCC components, and the overall LVI-IPCC total score (as depicted in Table 1). Specifically, a p-value below 0.1 (or less than a 10% significance level) signifies a statistically significant difference. Furthermore, in the context of our regression model, a p-value less than 0.1 indicates that the independent variable has a statistically significant impact on the dependent variable (LVI-IPCC value). Conversely, if the p-value exceeds 0.1, it leads us to reject the hypothesis that the independent variable influences the dependent variable.

Results

Assessing flood vulnerability

In this section, we shall deconstruct the LVI-IPCC into its constituent elements, namely Explore, Sensitivity, and Adaptive capacity. Within each of these components, we will undertake a comprehensive analysis and comparative assessment of the sub-indices across the two study areas. The results of the estimation of the overall LVI-IPCC, major and sub-components, and 35 indicators for the two communities are shown in Table 1. To conclude, the study will visually represent the overall LVI-IPCC index for both communes using a chart.

- *Exposure to floods*

The analysis results indicated that the average livelihood exposure index to floods of Quang Phuoc households (0.354) was likely to be higher than that of Quang Tho (0.288), at the 1% significance level ($p<0.01$) (see detail in Table 1). However, both communities were moderately exposed to flooding. The higher exposure index of the Quang Phuoc communities may be due to a higher level of flood risk damage. The results suggest that with regard to human impact ($p<0.01$), Quang Phuoc falls below Quang Tho. In contrast, in all five facets of exposure, which encompass property damage, income reduction, agricultural and fishery production depreciation, as well as human casualties, Quang Phuoc communes consistently manifest higher values compared to their counterparts in Quang Tho communes (refer to Table 1). For example, the exposure value associated with asset loss due to flooding events for Quang Phuoc farmers was 0.286, compared with only 0.157 for Quang Tho households ($p<0.001$). Analyzing the value related to deducing income due to flooding

events also returned a similar result (0.457 for Quang Phuoc versus 0.321 for Quang Tho, p = 0.02). Three consecutive floods in 3 years, 2019, 2020, and 2021 severely damaged household livelihoods, especially in the fishery sector. Farmers have added that the frequency and extent of floods today are different from those in the past. They illustrated "unpredictable" when floods happen faster and often occur at night, so "we can't keep up" ("*trở tay không kịp"* in Vietnamese) (source: in-depth interviews, 2022). In addition, because of nature-induced floods, such as heavy rain, existing dams in the highlands discharge a large volume of water, causing local flooding downstream. These notes are covered in detail in the discussion section.

- *Sensitivity to floods*

The results showed that The sensitivity level of the Quang Phuoc commune was higher than that of the Quang Tho commune, but this was not statistically significant (p=0.533) (Table 1). The results also indicated that while there were no differences in water, land, and housing factors between the two regions, there were significant differences in issues related to food storage during the flood season, agricultural land area, and family member health problems. Specifically, the households of Quang Phuoc reported that they have little agricultural land, and households' livelihoods are mainly dependent on fishery, so they do not have enough food to store. This stark disparity underscores the heightened food sensitivity in Quang Tho, where the index stands at 0.775, in contrast to Quang Phuoc's 0.557, a distinction that carries statistical significance at the 1% level. Furthermore, they mainly grow one rice crop, so in the rainy season, they often have to buy more food. In contrast, households in the Quang Tho commune rely largely on agricultural and vegetable production. They can also cultivate two rice crops and have vegetables to eat all year round, even to sell; therefore, they have a surplus of food for the flood season. The health index, too, underscores noteworthy variations between the two communes. Quang Phuoc boasts a more substantial index, registering at 0.197, in contrast to Quang Tho's more modest 0.099 ($p<0.001$). This divergence can be attributed, in part, to the fact that residents of Quang Phuoc commune reported less frequent health insurance coverage and a greater distance to medical facilities compared to their counterparts in Quang Tho commune.

- *Households' adaptive capacity to floods*

The adaptive capacity index was built from 13 indicators that were grouped into four sub-components: household demographics, knowledge of flood reduction, livelihood strategies, and farmers' local contact. A T-test showed a statistically significant difference between the two communities at the 1% level (Table 1). In particular, the lower sensitivity of the Quang Phuoc households is mainly due to the significant difference in the sub-components of knowledge of floods ($p<0.01$), livelihood options (0.01), and social networks ($p < 0.05$). In fact, while 62.9% of households in the Quang Tho commune reported having attended at least one training course related to disaster risk reduction in the past two years, this figure for the Quang Phuoc commune community was only 33.6%. Similarly, the proportion of households in Quang Tho with members participating in local flood prevention drills was higher than that of households in Quang Tho (27.1% vs. 14.3 %, respectively). All these indicators made the flood awareness of the Quang Phuoc commune community lower than that of the Quang Tho households. Further attention to this issue is provided in the Discussion section. We added that livelihood strategies and social networks play an important role in the adaptability of households. Specifically, the livelihood strategies of households in the Quang Tho commune are more diverse, so the post-standardized score is higher than that of households far from Quang Phuoc (statistically significant at the 1% level). However, both communities tended to connect less with local organizations. This led to a low index of social cohesion in both communities (approximately 0.35). 56.67 Of the respondents, 56.67% joined the three organizations, mainly fishery associations, farmers' unions, and women's unions.

Table 1 - Categorization of major components and sub-components to flood vulnerability in Quang Tho and Quang Phuoc communes

Major components and sub-components	Units	Measurement (min-max)	Post-normalized Value		p-value[a]
			Quang Tho (N=140)	Quang Phuoc (N=140)	
Exposure (2)			***0.288***	***0.354***	0.000***
Flood-related variability (5)			*0.421*	*0.399*	0.000***
Number of flooding events in the last 10 years	Numeric	1 – 12	0.397	0.286	0.000***
Annual avg. number of heavy rainy days (>50mm)	Days	3 – 30	0.545	0.545	–
Mean and SD of monthly avg. precipitation	mm	5.33 – 35.29	0.342	0.342	–
Mean and SD of monthly avg. maximum daily temperature	^oC	3.47 – 5.52	0.390	0.390	–
Mean and SD of monthly avg. minimum daily temperature	^oC	2.21 – 3.22	0.431	0.431	–
Flood risks and damages (6)			*0.155*	*0.308*	0.000***
Asset loss due to flooding events	Dummy	0 – 1	0.157	0.286	0.009***
Reduce income due to flooding events	Dummy	0 – 1	0.321	0.457	0.020**
Reduce or loss of agricultural yield	Dummy	0 – 1	0.200	0.314	0.029**
Reduce or loss aquacultural and fishing yield	Dummy	0 – 1	0.179	0.214	0.454
Livestock death due to floods	Dummy	0 – 1	0.064	0.450	0.000***
Human injury or death	Dummy	0 – 1	0.007	0.129	0.000***
Sensitivity (5)			***0.196***	***0.189***	0.533
Food (2)			*0.775*	*0.557*	0.000***
Did not store food during flooding seasons	Dummy	0 – 1	0.871	0.636	0.000***
Did not have the agricultural land	Dummy	0 – 1	0.679	0.479	0.001***
Water (2)			*0.114*	*0.132*	0.498
Not enough fresh water for domestic uses	Dummy	0 – 1	0.186	0.229	0.378
Using a non-public water suppliers	Dummy	0 – 1	0.043	0.036	0.759
Land (2)			*0.009*	*0.003*	0.256
Total area of agricultural land vulnerable to flooding	m^2	0 – 1,500,000	0.011	0.002	0.244
Total area of aquaculture land vulnerable to flooding	m^2	0 – 2,000,000	0.007	0.004	0.638
Housing (2)			*0.029*	*0.054*	0.196
Unstable house	Dummy	0 – 1	0.021	0.050	0.199
Flood-prone house	Dummy	0 – 1	0.036	0.059	0.396
Health (3)			*0.099*	*0.197*	0.000***
Did not have health insurance	Dummy	0 – 1	0.029	0.050	0.358
Distance from home to the nearest hospitals	Km	0 – 7	0.212	0.499	0.000***
Having child misses school due to flooding	Dummy	0 – 1	0.057	0.43	0.585
Adaptive capacity (4)			***0.483***	***0.435***	0.006***
Household demographics (4)			*0.646*	*0.649*	0.335
Non-poor household	Dummy	0 – 1	0.950	0.914	0.236
Independent-member ratio	Dummy	0 – 1	0.350	0.363	0.699
Head of household graduated from high school or higher	Dummy	0 – 1	0.429	0.507	0.195
Not a single-parent family	Dummy	0 – 1	0.89	0.86	0.565
Knowledge (3)			*0.633*	*0.493*	0.000***

Major components and sub-components	Units	Measurement (min-max)	Post-normalized Value		p-value[a]
			Quang Tho (N=140)	Quang Phuoc (N=140)	
Participating in flood training courses during the last 2 years	Dummy	0 – 1	0.629	0.336	0.000***
Know the local early-warning system	Dummy	0 – 1	1.000	1.000	0.987
Have participated in at least one drill on flood prevention	Dummy	0 – 1	0.271	0.143	0.008***
Livelihood strategies (3)			*0.246*	*0.167*	0.005***
Number of livelihood strategies	Numeric	1 – 4	0.252	0.150	0.000***
Can fishing during flood season	Dummy	0 – 1	0.193	0.071	0.003***
Salary jobs	Dummy	0 – 1	0.293	0.279	0.792
Social networks (3)			*0.351*	*0.353*	0.385
Number of CSOs	Numeric	0 – 5	0.274	0.324	0.075*
Number of devices used for updating flood information	Numeric	0 – 7	0.538	0.415	0.498
Number of social-network platforms in use for updating the information during the floods	Numeric	0 – 7	0.242	0.260	0.000***
Overall LVI-IPCC			***-0.039***	***-0.016***	0.000***

[a]*note: *,**, and *** denote statistically significant difference (T test) at the 10%, 5%, and 1% levels, respectively*

- Overall LVI-IPCC

Overall, when comparing with the scale from -1 to 1 of the LVI-IPCC, we found that both communities have a value lower than 0. Thus, both communes were defined as moderately vulnerable to flooding. However, the LVI-IPCC index of the Quang Phuoc commune (-0.016) is higher than that of the Quang Tho commune (-0.039), with significance at the 1% level. This implies that households in the Quang Phuoc commune are more vulnerable to flooding in their livelihoods than those in the Quang Tho commune. This can be due to a higher index of exposure ($p<0.001$), a lower value of adaptive capacity, and a similar value of sensitivity ($p<0.001$). The variation in the three contributing factors to the LVI-IPCC between the two communes is shown in Figure 3. The differences in the sub-components and indices between the two communities will be analyzed in detail in the next section.

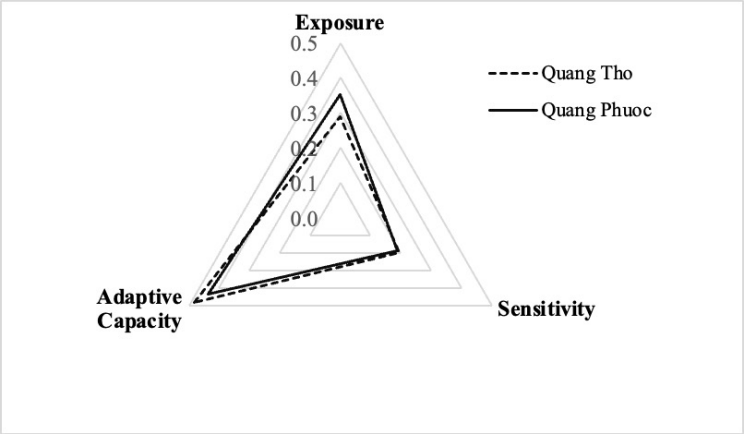

Figure 3 - The variation in three contributing factors to LVI-IPCC between two communes

Determinants of the flood vulnerability

This section highlights and compares the determinants of the LVI-IPCC vulnerability index between Quang Phuoc and Quang Tho households using multivariate logistic regression. Sixteen explanatory variables representative of the five main groups were used to identify the contribution of household LVI-IPCC vulnerability. The detailed results are presented in Table 2.

In general, three main points in the multivariate regression model should be highlighted. First, the sig value ($p<0.1$) represents a statistically significant correlation between the independent variable and dependent variables (LVI-IPCC value). Accordingly, the results showed that there were 10 factors affecting the vulnerability of Quang Tho communes: the age of the household head (p=0.038), marital status (p=0.029), education level (p=0.003), income reduction due to floods (p=0.000), economic status (p=0.001), water (p=0.000), flood-prone aquaculture areas (p=0.01), housing condition (p=0.002), livelihood strategies (p=0.002), and social networks (p=0.000). Meanwhile, the LVI-IPCC value of Quang Phuoc households was influenced by eight factors: marital status (p=0.035), asset loss due to floods (p=0.045), income reduction (p=0.009), food (p=0.001), water (p=0.001), flood-prone aquaculture areas (0.047), housing conditions (p=0.028), and social networks (p=0.000).

The beta value denotes the degree of influence of the independent variable on the vulnerability value. The larger the beta value, the more important it is; conversely, the smaller the beta value, the weaker the interaction among them. Accordingly, independent variables that had a strong relationship with Quang Tho household vulnerability included social linkage (B=-0.278), water (B=-0.268), and income reduction by floods (B=0.265). Similarly, for Quang Phuoc households, the variables that had the most potent effect on vulnerability to flooding, in descending order, were social networks (B=-0.285), water (B=-0.257), food (B=-0.235), and income loss (B=0.198).

Finally, the sign of the beta coefficient represents a positive or negative relationship between the independent and dependent variables. The vulnerability of households in both communities was positively affected by the variables of marriage status, flood-induced asset loss, and income reduction. Meanwhile, determinants related to household heads' age, education level, economic status, food, water, flood-prone aquaculture areas, livelihood diversification, and social networking contacts have negative relationships with household vulnerability. Notably, there is only one case: the variable related to the housing condition of the household. While this variable had a positive relationship with the vulnerability of Quang Phuc households, it had a negative effect on the LVI-IPCC index of farmers living in Quang Tho communes. Thus, these differing results were in place or site-specific outcomes.

Table 2 - Results of multivariate regression analysis on factors affecting the degree of the LVI-IPCC vulnerabilitya between the two communities

Independent variables		Category (measurement)	Quang Tho (N=140)		Quang Phuoc (N=140)	
			Beta	p-value[b]	Beta	p-value[b]
The profiles of the household head	Age	Numerics (years)	-0.155	0.038**	0.094	0.276
	Gender	Dummy (0=men; 1=women)	0.090	0.197	-0.076	0.293
	Marriage status	Dummy (0=not single-parent; 1=single parent)	0.155	0.029**	0.168	0.035**
	Education levels	Numerics (0=no educated; 1=primary; 2=secondary; 3=high school; 4=higher)	-0.237	0.003***	-0.125	0.139
Flood risks	Asset loss	Dummy (0=not asset loss in last flooding; 1= having asset loss)	0.107	0.118	0.166	0.045**
	Income reduction	Dummy (0= Having not income reduction in last flooding; 1= having income reduction)	0.265	0.000***	0.198	0.009***
Socioeconomic characteristics	Economic status	Dummy (0=poor; 1=non-poor)	-0.229	0.001***	-0.084	0.275
	Storing food	Dummy (0=did often not store food for flood seasons, 1=often storing food)	-0.135	0.056*	-0.235	0.001***
	Enough water	Dummy (0=not enough fresh water for domestics, 1=enough)	-0.268	0.000***	-0.257	0.001***
	Flood-prone aquaculture areas	Numerics (m^2)	-0.171	0.010***	-0.133	0.047**
	Flood-prone agriculture areas	Numerics (m^2)	-0.062	0.354	-0.031	0.636
	House condition	Dummy (0=unstable; 1=stable)	-0.197	0.002***	0.153	0.028**
	Health insurances	Dummy (0=no, 1=yes)	-0.027	0.664	-0.065	0.332
	Participation in training courses	Dummy (0=no, 1=yes)	-0.123	0.059*	-0.017	0.817
Livelihood strategies	Livelihood options	Numerics (livelihood sources)	-0.211	0.002***	-0.017	0.816
Social networks	Number of medias	Numerics (number of medias)	-0.278	0.000***	-0.285	0.000***
Model summary[b]						
Adjusted R Square			0.536		0.426	
Std. Error of the Estimate			0.01901		0.02166	
F			10.247		7.459	
Sig.			0.000		0.000	

Discussion and implications

As global uncertainty increases, encompassing factors such as climate change and the ongoing global pandemic, interest in questions like "How to measure households' livelihood vulnerability?" and "who are the most vulnerable?" continues to grow. While many previous conventional attempts have attempted to answer the first concern (Ahmad & Afzal, 2022; Hoang et al., 2020; Huong et al., 2019; Panthi et al., 2016; Sam et al., 2017; Shahzad et al., 2021; Tran et al., 2021), this study seeks to achieve both goals, specifically in the context of two flood-prone small-scale farming communities in Quang Tho and Quang Phuoc. These areas are heavily reliant on agriculture and fishery-based livelihoods. This section presents extended discussions drawn from earlier findings, which have implications for flood-resilience capacity-building programs and disaster reduction policies at the community and meso levels in Vietnam and other developing countries.

First, our study used the LVI-IPCC scaling from -1 to 1 to measure household livelihood vulnerability. Our results showed that the mean index values for Quang Tho and Quang Phuoc communes were -0.039 and -0.019, respectively, indicating a moderate level of vulnerability to flooding disasters in both regions. However, households in Quang Phuoc commune were found to be more vulnerable than those in Quang Tho commune ($p<0.001$), mainly due to a higher exposure index and lower adaptive value. Specifically, Quang Phuoc had a higher exposure value (0.354) due to the significant loss and damage to property, income, and livestock caused by floods. This was confirmed by our regression results, which showed that households reporting loss of assets and reduced income due to floods were more vulnerable than those that did not. These findings are consistent with previous studies that have demonstrated the risks that water shortages or excess water pose to households' livelihoods, as they can reduce crop yields and cause food insecurity (Tran et al., 2022). Severe flooding also degrades soil quality and damages crops on a large scale (Nguyen et al., 2021; Reynaud & Nguyen, 2016). Increased frequency of natural disasters weakens farmers' ability to adapt and erodes their confidence in adopting advanced technologies (Hilemelekot et al., 2021). As climate change becomes more complex, floods occur more erratically and with greater intensity, putting households at greater risk of food insecurity at the community level and ultimately leading to negative impacts on the national economy (Dilley & Boudreau, 2001; Hilemelekot et al., 2021; Reynaud & Nguyen, 2016). Furthermore, while the construction of hydroelectric dams in the highlands may have some benefits, it also carries risks for lowland areas, as in our case study. Our in-depth interviews with local people revealed that "water discharge from dams in uplands on heavy rainy days caused the flood level to increase rapidly, leading to serious damage to agriculture and fisheries" (Source: in-depth interviews, 2022).

In the context of this study, our results suggest that in addition to planning for hydropower projects, it is crucial to prioritize quick recovery for communities, particularly those with significant losses of life and property, as part of flood risk mitigation strategies. This aligns with the findings of Dinh et al. (2021), who emphasized the importance of prompt recovery and resilience of households following floods to minimize social costs and reduce economic and social hardship. Several studies have highlighted the significance of internal community factors, including social learning configurations and community cohesion, in helping flood-prone communities recover and stabilize their lives (Ha et al., 2022; Phuong et al., 2018). To this end, expanding local relationships by joining agricultural cooperatives or participating in local organizations can enhance rural communities' flood resilience and adaptive capacity (Chuong et al., 2020; Dinh et al., 2021; Phuong et al., 2022). Our research findings support this view. The regression results indicate that households that participate more in social organizations are less vulnerable to floods. However, our study showed that farmers in both areas were less likely to engage in

such activities. Therefore, we recommend that local governments should establish mechanisms to encourage and support people to join local organizations, such as small credit groups, or participate in NGO projects. Additionally, access to extension advisory services and training courses that provide adaptation skills and technology have been demonstrated to improve households' adaptive capacity, thereby reducing their vulnerability (Hilemelekot et al., 2021; Sen et al., 2021; Tran et al., 2023).

Second, our study findings suggested that household vulnerability to floods is not solely determined by the flood event itself but also by individual characteristics of the household head, such as age, education, and marital status. Our results are consistent with previous studies (Chuong et al., 2020; Getahun et al., 2021; Mogomotsi et al., 2020; Phuong et al., 2022) indicating that older households are less vulnerable due to their experience and indigenous knowledge in weather observation and agricultural production. To some extent, household heads' experience and indigenous knowledge are related to this (Mogomotsi et al., 2020). According to Chuong et al. (2020), the elderly, who have many years of experience in weather observation, apply their accumulated expertise in agricultural production to mitigate the damage caused by natural disasters when they occur. Another finding is that higher levels of education of household heads have been shown to decrease vulnerability to flooding, as a one-level increase in education reduces vulnerability by 23.7% for Quang Tho households, in line with other studies (Alemayehu & Bewket, 2017; Belay & Fekadu, 2021; Getahun et al., 2021; Tran et al., 2022; Vo et al., 2021). In terms of marital status, our study confirms that single-parent households (including widows and divorcees) are more vulnerable to floods, partly due to the lack of a labor force, psychological factors, and social exclusions (Muthelo et al., 2019; Phuong et al., 2022). To address these vulnerabilities, community development programs should prioritize increasing the level of education among households through free literacy classes, while development policies and disaster risk reduction programs should target disadvantaged groups in society, with a focus on promoting social inclusion and gender equality in access to services and public resources (Phuong Thi Tran et al., 2023; Tran et al., 2022). Allocating resources for local natural disaster prevention should also prioritize these vulnerable groups (Sen et al., 2020; Ha et al., 2023; Tran et al., 2023). As an illustration, in the case of the annual subsidy allocated for natural disaster prevention, our proposed modification suggests a departure from the erstwhile practice of uniform distribution among all households. Instead, we advocate a more equitable approach, wherein a greater allocation is apportioned to households exhibiting higher vulnerability, and such disbursements are expedited.

Third, our study highlighted the significant impact of household demographic characteristics and resources on livelihood vulnerability to floods. Specifically, we found that household access to food, water, and less flood-prone land is negatively associated with flood vulnerability. This result resonates with the findings of prior studies conducted worldwide despite variations in research contexts (Alemayehu & Bewket, 2017; Asrat & Simane, 2018; Tamesgen Tadesse Deressa et al., 2009; Ghosh & Ghosal, 2020; Hilemelekot et al., 2021; Nguyen & Leisz, 2021; Phuong et al., 2022; Tan et al., 2023). For instance, households that report having sufficient food stocks during the rainy season, adequate water supply for their families, and access to land that is less prone to flooding are less vulnerable to floods. Therefore, policies aimed at reducing flood vulnerability should prioritize efforts to enhance household access to these basic resources. Additionally, promoting sustainable agriculture practices that increase food production and improve land management can help improve household resilience to floods and other environmental hazards. Further, our study found a strong association between flood vulnerability and the economic status of households. Regression results indicate that households living in poverty are more vulnerable to floods, especially in the Quang Tho commune, as reflected by their higher LVI-IPCC index. These results are consistent with previous studies (Ha et

al., 2022; Huynh et al., 2020; Mogomotsi et al., 2020; Ngu et al., 2023; Phuong et al., 2022; Sen et al., 2020; Vo et al., 2021; Zhang et al., 2019). Poverty is a significant factor that limits the ability of communities to mitigate risks, cope with natural events, and recover from damages caused by them (Dinh et al., 2021). Moser and Satterthwaite (2008) also argue that poverty is often linked to smallholder farmers having a narrow asset portfolio, which increases their vulnerability to climate risks. In addition, limited livelihood diversification and heavy reliance on agriculture and fishery are common characteristics of poor households that contribute to their vulnerability to natural disasters. Our analysis also shows that increasing the number of income sources can reduce vulnerability by 21.1% (Table 2), highlighting the importance of livelihood diversity, which can include a range of on-farm, off-farm, and non-farm activities.

In our study, we found that households living in different geographical environments have varying incomes, levels of off-farm livelihoods, and livelihood diversification, which can lead to differences in the scope of livelihood strategies and social connections, affecting their ability to adapt to floods. For example, the Quang Phuoc commune, located in low-lying areas along the Tam Giang-Cau Hai lagoon (Figure 2), primarily relies on fishing and aquaculture, and has limited non-farm income sources. As a result, households in this area are more vulnerable to flood impacts. Conversely, households in the Quang Tho commune, situated near the city center and in a higher area with more agricultural land, have more diversified livelihoods, which increases their adaptive capacity to floods. Finally, we emphasize the pivotal role of support and intervention measures by local authorities, local social organizations, and NGOs in bolstering the resilience of rural households' livelihoods, recognizing the inherent connection between precarious livelihoods and heightened vulnerability to natural disasters. The consideration of increasing income from specific local livelihood activities becomes imperative. Encouraging and facilitating deeper participation of farmers in the agricultural and aquatic product value chain emerges as a potential solution. For daily-harvested products in relatively modest quantities, communities should contemplate direct collection and supply to consumers, transcending mere production. It is evident that minimizing intermediaries in the supply chain will significantly augment farmers' benefits. Local authorities and social organizations must assume a proactive role in identifying and establishing connections with potential consumers, including restaurants, schools, businesses, and mini supermarkets, among others, to foster a stable consumer market. As for seasonally mass-harvested products, contemplating their transformation into local specialties is viable. However, this endeavor demands a more comprehensive investment in human resources, processing and preservation technology, and market operations. Consequently, strategic planning and support necessitate the active involvement of higher levels of government, as well as non-profit community development organizations.

Conclusion

This study investigated the vulnerability of smallholder farmers in low-lying areas of Thua Thien Hue Province, Vietnam to floods, using cross-sectional data collected from 280 farming respondents. The LVI-IPCC method was used to estimate and compare the flood livelihood vulnerability of Quang Tho and Quang Phuoc villages. The results showed that fishing and lowland communities are highly vulnerable to flooding, and that household poverty, livelihood strategies, social connections, and the profile of the head of household all exacerbate vulnerability. These findings support current efforts in disaster risk reduction and rural development in developing countries. Based on our results, we propose recommendations and implications, including the need to prioritize poverty alleviation and reduce social exclusion. We emphasize that more evidence should be integrated into development and risk-reduction programs. Additionally, we highlight the importance of

support from local governments and sociopolitical organizations in reducing household vulnerability. Achieving greater sustainability and balance for vulnerable groups requires continued action and investment.

This study's significance extends both to academic research and practical application in the domains of disaster risk management and rural development. Academically, it stands out through its comparative analysis of flood vulnerability in the specific communities of Quang Tho and Quang Phuoc in Thua Thien Hue Province, Vietnam. The utilization of the Livelihood Vulnerability Index based on the Intergovernmental Panel on Climate Change's definition (LVI-IPCC) as an assessment approach is a noteworthy methodological contribution, offering a unique perspective on flood vulnerability. The study's identification of factors exacerbating vulnerability, including poverty, low education levels, single parenthood, limited resources, livelihood strategies, and social connections, enriches the academic understanding of the multidimensional nature of vulnerability. On a practical level, this research extends its relevance through its policy recommendations. It underscores the importance of prioritizing disadvantaged groups and promoting social inclusion and gender equality in the distribution of services and public resources, providing actionable guidance for policymakers and disaster risk reduction programs. Moreover, the emphasis on tailored disaster risk management and sustainable rural development initiatives serves as a blueprint for practitioners, allowing for the design of interventions that are responsive to the unique vulnerabilities and challenges of each community. Finally, the study's call for continuous action and investment serves as a reminder of the enduring commitment required to address vulnerability and enhance resilience in these vulnerable groups.

However, this study has some limitations that should be taken into consideration. First, the results were based on a small sample size of selected communities at the commune level, and therefore, caution should be exercised when generalizing the findings to other areas. Including larger samples from multiple districts or provinces in Vietnam could improve the generalizability of the study's findings. Second, this research did not include indicators related to culture, identity, and social norms, which could be valuable in understanding vulnerability to flooding. Furthermore, the study did not explore macroeconomic and socioeconomic factors, such as population density, infrastructure, and planning, which could be included in future studies to provide a more comprehensive understanding of flood vulnerability in the region. Ultimately, unweighted methods assign equal importance to all data points or factors, irrespective of their actual significance or relevance. This propensity for uniform treatment can result in the oversimplification of intricate systems and a potential misrepresentation of the genuine interconnections within the data. Furthermore, because unweighted methods treat all data points on an even footing, they exhibit sensitivity to outliers. Notably, an outlier with an extreme value can disproportionately impact the outcomes, potentially introducing distortions. Hence, it is imperative for future research endeavors to be mindful of these limitations and make efforts to mitigate them.

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Conflict of interest

The authors declare that they have no conflicts of interest.

Ethics declaration

All procedures in human participatory studies adhered to ethical research standards and were conducted with the informed consent of the participants.

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