

Assessing agricultural household vulnerability to climate change: A case study in Chau Thanh district, Ben Tre province, Vietnam

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ABSTRACT

Climate change significantly impacts the livelihoods of agricultural households, increasing their vulnerability. This study developed 49 indicators grouped into 12 main components to assess the livelihood vulnerability index (LVI) of agricultural households in Chau Thanh district, Ben Tre province. Using data from a survey of 300 farm households, complemented by secondary data on climate factors, a composite index was calculated to compare variations in vulnerability across the region. The overall LVI for Chau Thanh district was 0.32, indicating moderate vulnerability. Among the 12 main components, livelihood strategies, land, water, natural disasters and climate variability, and finance and income were identified as the most vulnerable dimensions, whereas housing was the least vulnerable. Using the LVI developed based on the intergovernmental panel on climate change (IPCC) framework, Giao Long commune was found to be more vulnerable than the other communes. To address these challenges, solutions based on the human, natural, and financial capitals of the livelihood efficiency index (LEI) were proposed. These solutions aim to enhance the adaptive capacity of agricultural households while mitigating the impacts of climate change, thereby fostering sustainable livelihoods in the district.

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1. Introduction

Vietnam is recognized as one of the countries in Southeast Asia most vulnerable to the impacts of climate change (Yusuf & Francisco,

2009), particularly in recent years (VMONRE, 2021). The two largest deltas in Vietnam, the Red River Delta and the Mekong River Delta, are experiencing significant disruption to the lives and livelihoods of their inhabitants, especially

farmers (VNASTI, 2006; Entzinger & Scholten, 2016). Although numerous climate change adaptation strategies have been implemented, the situation continues to evolve in complexity, particularly in the Mekong River Delta, the nation's largest agricultural region (VNASTI, 2006). Key climate-related challenges in this area include prolonged droughts and increasingly severe saltwater intrusion.

Ben Tre is a province situated in the lower Mekong River basin, bordering the East Sea, and is formed by four major rivers: the Tien, Ba Lai, Ham Luong, and Co Chien rivers. The province has 179,885 ha of agricultural land, representing 75.59% of the total area, with 19,101 ha (8.03%) designated for paddy fields and 33,692 ha (14.16%) for aquaculture (BTSO, 2023). In 2022, the province's gross regional domestic product (GRDP) at current prices was 63,585 billion VND, with the agriculture, forestry, and fishery sector contributing 35.37% (BTSO, 2023). Agriculture serves as a key driver of economic development in Ben Tre. Chau Thanh, the gateway district of Ben Tre province, boasts fertile alluvial soils deposited by the Mekong River branches, making it highly suitable for agricultural production, including fruit orchards and vegetable cultivation. However, agricultural activities in Chau Thanh are increasingly impacted by climate change, particularly saltwater intrusion (Thien et al., 2023). Climate change is a gradual yet persistent disaster that impacts agriculture through increased pest and disease outbreaks, more frequent and severe landslides, droughts, floods, reduced crop yields, crop failures, and higher livestock mortality rates (Harvey et al., 2014). Farmers' livelihoods are especially vulnerable, as they rely heavily on climate-sensitive sectors like agriculture, particularly in developing countries (Sujakhu et

al., 2018). Poor and agrarian communities in these regions are disproportionately affected by climate change due to their limited adaptive capacity and restricted access to alternative production methods (IPCC, 2007; Skoufias et al., 2012). Livelihood vulnerability assessments are crucial for developing strategies, evaluating policies, and guiding programs at various levels (Sujakhu et al., 2018). The concept of vulnerability remains ambiguous, with its definition varying across different disciplines (Gallopín, 2006). This study aimed to assess the climate change vulnerability of farming households in Chau Thanh district, Ben Tre province, Vietnam, using the livelihood vulnerability index (LVI) developed by Hahn et al. (2009), which can help mitigate adverse impacts.

2. Materials and Methods

2.1. Study site

Chau Thanh district in Ben Tre province consists of 20 communes and one town (Figure 1). The district has a population of 177,159, with 171,511 people (96.81%) residing in rural areas (BTSO, 2023). Chau Thanh covers an area of 22,489 ha, of which 16,060 ha (71.41%) are agricultural land (BTSO, 2023). The district is known for its specialization in fruit cultivation, with key crops including coconut, rambutan, durian, grapefruit, cocoa, and mangosteen (PCCT, 2023). However, agricultural practices are largely spontaneous and small-scale, with uneven product quality that lacks competitiveness in comparison to agricultural products from neighboring regions (Nguyen et al., 2022).

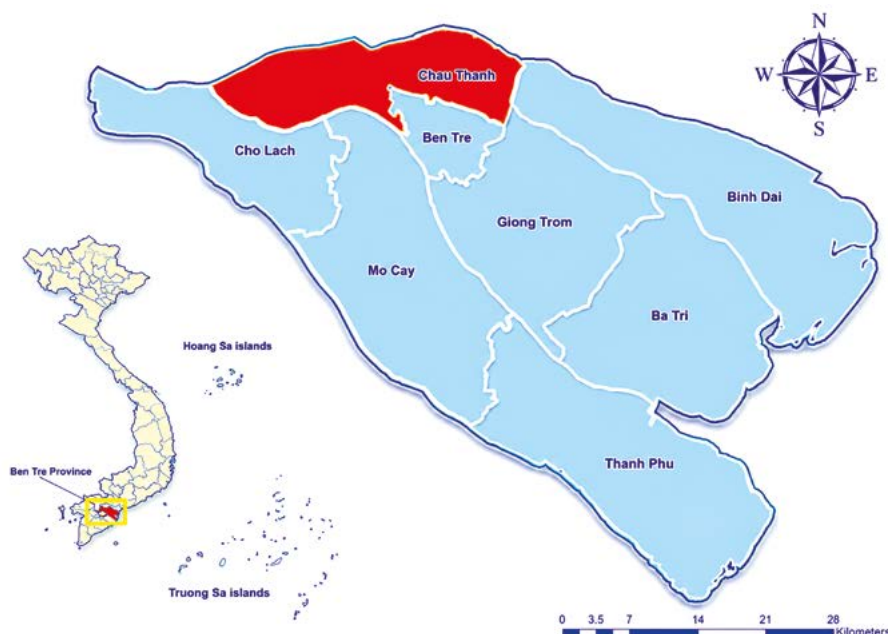


Figure 1. The map of the study site.

2.2. Data collection

This study employed a combination of methods, including secondary data analysis and structured interviews. Secondary data collection focused on gathering reports, documents, policies, and resolutions related to agricultural development, natural disasters and climate variability in Chau Thanh district. Simultaneously, primary data was obtained through structured interviews conducted during fieldwork.

Three communes, Phu Tuc, Tan Phu, and Giao Long, were purposefully selected within Chau Thanh district. For the household survey, 100 households were interviewed in each commune. The communes were selected based on the varying impacts of saline intrusion on agricultural cultivation (Thien et al., 2023). Additionally, in terms of geographical location,

Tan Phu, Phu Tuc, and Giao Long communes are situated along the Tien river from west to east, following the river's flow toward its mouth. Respondents were household heads or their spouses, predominantly farmers who had been engaged in agriculture and aquaculture for at least five years. The interviews were conducted in August 2024 using a structured questionnaire designed to gather information on topics such as health, knowledge and skills, food security, natural resources, disasters, social issues, finance, infrastructure, and livelihoods. Throughout the research, detailed field notes were meticulously recorded, capturing key information, conversations, interactions, and significant events (Stake, 2010). Structured interviews were chosen because they reduce the cognitive demands of information processing (Pettersen & Durivage, 2008). Additionally, the time allocated for each household interview was determined by the scope of the information being sought, making it

easier to control the interview duration. However, it is important to note that structured interviews resemble oral examinations, which may remind respondents they are being evaluated. As a result, respondents might attempt to present themselves in a more favorable light, potentially filtering the information they provide (Pettersen & Durivage, 2008).

2.3. Data analysis

This study employed three types of analysis: (1) developing the LVI main components and indicators, (2) calculating the LVI based on the IPCC framework (IPCC, 2007), and (3) calculating a livelihood effect index (LEI). Additionally, a t-test was used to compare the mean scores of the main components and indicators across the three communes.

2.3.1. Developing the LVI

The methodology applied for calculating vulnerability to climate variability was based on previous studies by Hahn et al. (2009), Shah et al. (2013), and a case study in Vietnam by Huong et al. (2018). However, modifications were made to tailor the method to this specific case study. The set of main components from Huong et al. (2018) was adopted, but three new indicators were introduced: one under knowledge and skills and two under natural disasters and climate variability (Table 1). The LVI framework in this study includes 12 components and 49 indicators of livelihood vulnerability. Each main component is composed of multiple indicators, and each indicator and main component contributes equally to the overall LVI score (Sullivan et al., 2002).

Table 1. The developed livelihood vulnerability index framework.

Capitals	Main components	Indicators	Units	Data sources	References
Human	Health	(1) Households with at least one member suffering from chronic diseases	%	Survey	Hahn et al. (2009)
		(2) Households with at least one member suffering from communicable diseases	%	Survey	
		(3) Households with at least one member missing work or school due to illness in the past month	%	Survey	
		(4) Average time to the nearest health care centre	minutes	Survey	

Knowledge and skills	(5) Unlettered household head	%	Survey	Hahn et al. (2009)
	(6) Households that have not yet received any training to cope with climate change	%	Survey	Mendoza et al. (2014)
	(7) Household members have not received any vocational or higher training	%	Survey	
	(8) Households with less than 10 years of farming experience	%	Survey	Can et al. (2013)
	(9) Households that do not know how to apply measures to mitigate or avoid the consequences of saltwater intrusion	%	Survey	New
Food	(10) Households that depend on their own family farm for food	%	Survey	Hahn et al. (2009)
	(11) Average Crop Diversity Index	index	Survey	
	(12) Households that do not sell their agricultural products	%	Survey	Shah et al. (2013)
Livelihood	(13) Household members working outside the community	%	Survey	Hahn et al. (2009)
	(14) Average Agricultural Livelihood Diversification Index	index	Survey	
	(15) Households that depend solely on agriculture as a source of income	%	Survey	
	(16) Households' nonfarm activities affected by climate change	%	Survey	Huong et al. (2018)
	(17) Households with no jobs during extreme weather events	%	Survey	
	(18) Households that depend on (exploiting) natural resources	%	Survey	Shah et al. (2013)
	(19) Landless households	%	Survey	Shah et al. (2013)

	(20) Households with small farmland (less than 1 ha)	%	Survey	Can et al. (2013)
	(21) Households with land degradation due to climate-related extremes over the past 10 years	%	Survey	Lamichhane (2010)
Water	(22) Households that have heard about any water-related conflicts in the community	%	Survey	Hahn et al. (2009)
	(23) Households that collect water directly from rivers, streams, or canals	%	Survey	
	(24) Households that do not have a reliable water supply	%	Survey	
Natural disasters and climate variability	(25) Number of floods, erosions, and droughts in the past 5 years	events	Secondary data	
	(26) Number of months affected by saltwater intrusion in the past 5 years	months	Secondary data	New
	(27) Households affected by saltwater intrusion in the past 5 years	%	Survey	New
	(28) Households with an injury or death resulting from the most severe natural disaster in the past 5 years	%	Secondary data	Hahn et al. (2009)
	(29) Households that did not receive any warning about impending natural disasters	%	Survey	
	(30) Households that suffered property damage due to natural disasters or extreme climate events in the past 5 years	%	Secondary data	Shah et al. (2013)
	(31) Mean standard deviation of the daily average maximum temperature by month over the past 5 years	°C	Secondary data	Hahn et al. (2009)

		(32) Mean standard deviation of the daily average minimum temperature by month over the past 5 years	°C	Secondary data	
		(33) Mean standard deviation of average precipitation by month over the past 5 years	mm	Secondary data	
Social	Socio-demographic profile	(34) Dependency ratio	ratio	Survey	
		(35) Female-headed households	%	Survey	
		(36) Number of household members	persons	Survey	Huong et al. (2018)
		(37) Poor households	%	Secondary data	
	Social networks	(38) Receive:Give ratio	ratio	Survey	Hahn et al. (2009)
		(39) Borrow:Lend money ratio	ratio	Survey	
		(40) Households that have not received any assistance from local government	%	Survey	
		(41) Households that do not participate in any organizations	%	Survey	Huong et al. (2018)
		(42) Households without TVs	%	Survey	Panthi et al. (2016)
		(43) Households without internet	%	Survey	
Financial	Finance and income	(44) Households with debt	%	Survey	Huong et al. (2018)
		(45) Households with a net income lower than VND 10M	%	Survey	Can et al. (2013)
		(46) Households that cannot access any financial services	%	Survey	Huong et al. (2018)
Physical	Infrastructure	(47) Average time to reach the nearest bus station	min	Survey	
		(48) Average time to reach the nearest post office	min	Survey	
	Housing	(49) Households with non-solid houses	%	Observation	Shah et al. (2013)

2.3.2. LVI calculation

Since the indicators are measured on different scales, they were first standardized into indices using the following equation:

$$\text{Index}_{s_i} = \frac{s_i - s_{\min}}{s_{\max} - s_{\min}}$$

Where s_i is the original value of the indicator, and $s_{\min}$ and $s_{\max}$ are the minimum and maximum values, respectively, determined from the data across the three communes. After standardization, the indicators were averaged using the formula:

$$M_i = \frac{\sum_{i=1}^n \text{index}_{s_i}}{n}$$

Where M_i represents one of the 12 main components, and n is the number of indicators within that component. The overall LVI score was calculated as a weighted average of the main components:

$$\text{LVI} = \frac{\sum_{i=1}^{12} w_{M_i} M_i}{\sum_{i=1}^{12} w_{M_i}}$$

Here, the weights w_{M_i} are determined by the number of indicators in each main component to ensure equal contribution to the final LVI score (Sullivan et al., 2002). The LVI is scaled from 0 (least vulnerable) to 0.5 (most vulnerable) (Hahn et al., 2009).

2.3.3. LVI-IPCC calculation

An alternative approach to calculating the LVI was developed using the IPCC framework (Hahn et al., 2009; Shah et al., 2013; Huong et al., 2018). The 12 main components were reorganized according to the IPCC framework, which categorizes vulnerability into exposure,

sensitivity, and adaptive capacity. Exposure is measured by the number of natural disasters and the average variability in maximum and minimum monthly temperatures and precipitation over the past five years. Adaptive capacity includes demographic factors, livelihood strategies, knowledge and skills, infrastructure, housing, and social networks, while sensitivity is determined by food and water security, land use conditions, financial status, and health. The same indicators and equations from 2.3.2 were used, but the main components were combined into contributing factors:

$$CF = \frac{\sum_{i=1}^n w_{M_i} M_i}{\sum_{i=1}^n w_{M_i}}$$

Where CF is one of the IPCC-defined contributing factors (exposure, sensitivity, or adaptive capacity). Finally, the LVI-IPCC was calculated as:

$$\text{LVI-IPCC} = (e - a) * s$$

Where e is exposure, a is adaptive capacity, and s is sensitivity. The LVI-IPCC is scaled from -1 (least vulnerable) to 1 (most vulnerable) (Hahn et al., 2009).

2.3.4. LEI calculation

The LEI was calculated based on five capital groups: human, natural, social, physical, and financial capital. The 12 main components were grouped into these livelihood assets, and the main components for each asset were averaged using the following equation:

$$\text{LEI} = \frac{\sum_{i=1}^5 w_{M_i} M_i}{\sum_{i=1}^5 w_{M_i}}$$

Where LEI represents the vulnerability index for one of the five livelihood assets. The LEI

is scaled from 0 (least vulnerable) to 1 (most vulnerable) (Huong et al., 2018).

3. Results and Discussion

3.1. Livelihoods of farming households

Rice cultivation in Chau Thanh district, Ben Tre province has ceased since 2019, as farmers

have transitioned from rice paddies to more valuable fruit crops like pomelo and coconut, or repurposed the land for residential or production use. By 2022, the district's fruit farming area totaled 7,554 ha (Table 2).

Table 2. Agricultural statistics for Chau Thanh district, Ben Tre province in 2022

	2018	2019	2020	2021	2022
Planted area of rice (ha)	22	0	0	0	0
Planted area of maize (ha)	51	24	4	6	2
Planted area of cassava (ha)	5	0	0	0	0
Planted area of vegetables and beans (ha)	218	93	16	26	20
Planted area of coconut (ha)	7,989	7,987	7,990	8,038	7,989
Planted area of cocoa (ha)	210	107	79	74	74
Planted area of orange and mandarin (ha)	185	184	185	186	163
Planted area of lemon (ha)	52	58	67	76	84
Planted area of pomelo (ha)	3,331	3,440	3,594	3,742	3,683
Planted area of banana (ha)	490	477	479	452	434
Planted area of mango (ha)	11	11	14	18	16
Planted area of longan (ha)	254	211	190	150	137
Planted area of rambutan (ha)	2,074	1,857	1,789	1,397	1,307
Planted area of durian (ha)	951	1,105	1,093	1,212	1,314
Planted area of mangosteen (ha)	127	120	109	106	98
Number of cows (head)	4,114	3,915	3,927	3,836	3,070
Number of pigs (head)	26,796	12,085	10,764	12,147	8,831
Number of poultry (head)	698	673	716	722	748
Number of goat and sheeps	22,696	20,685	21,547	19,454	19,848
Area of aquaculture (ha)	611	465	457	390	280

Source: BTSO (2023).

Although the fruit-growing area has shown a declining trend from 2018 to 2022, Chau Thanh remains the district with the largest fruit acreage in the province. The coconut plantation area spans 7,989 ha, with an estimated annual yield of 70,196 tons, of which approximately 70% is used for oil production and 30% for fresh consumption. Through various project programs, seminars, and technical training provided by local authorities, farmers' practices have gradually improved, leading to better productivity, quality, and efficiency in coconut farming. While the district boasts the largest area for key fruit crops like grapefruit and bananas in the province, these crops are dispersed across the district and have not yet been developed into specialized, concentrated farming zones based on land and water conditions. To maximize land-use efficiency, increase economic returns, and improve the livelihoods of farmers, it is crucial to devise development strategies and appropriately restructure agricultural production based on the district's land and water potential. In addition to fruit farming, the district has emphasized livestock development, with 3,070 cows, 8,831 pigs, and 748 poultry, mostly raised on small household farms (Table 2). In recent years, there has been a gradual shift toward larger farm-based operations. Aquaculture also plays a significant role in the district, covering 280 ha in 2022. This includes intensive farming, mainly *Siluriformes* (catfish) for export, as well as extensive and cage farming, with total aquaculture production reaching 39,252 tons.

3.2. LVI

The LVI values for the 12 main components, calculated using 49 indicators for the communes of Phu Tuc, Tan Phu, and Giao Long, are presented in a spider diagram (Figure 2) and

Table 3. The diagram employs a scale with 0.1-unit increments, ranging from 0 (least vulnerable) at the center to 0.5 (most vulnerable) at the outer edge. Overall, Phu Tuc and Giao Long recorded higher LVI scores (0.33) compared to Tan Phu (0.31). Among the 12 main components, all communes displayed the least vulnerability in housing (0.01 - 0.03), as most agricultural households possess solid structures that are less susceptible to climate change. However, agricultural households in Chau Thanh district were found to be more vulnerable in the areas of livelihoods, land, water, natural disasters and climate variabilities, and finance and income. When compared to northwest Vietnam (Huong et al., 2018), agricultural households in Chau Thanh district were less vulnerable. LVI in northwest Vietnam showed higher vulnerability in housing and social networks, explaining the higher overall vulnerability compared to Chau Thanh district. The LVI of Chau Thanh district also closely aligns with Thanh Phu district (Ben Tre province) in 2018 - 2019, which recorded a score of 0.355 (Can et al., 2020).

While the overall differences in vulnerability among the three communes were relatively minor, more detailed analysis reveals important variations. In the knowledge and skills sector, the LVI for Chau Thanh District ranged from 0.18 to 0.27, lower than northwest Vietnam (0.41 - 0.62) due to a lower percentage of unlettered household heads and farmers' extensive experience in agriculture. However, the lack of effective training on climate change adaptation, particularly regarding saltwater intrusion, remains a significant issue (Thien et al., 2023). Specifically, in Giao Thuy Commune, 31% of farming households lacked knowledge on implementing measures to mitigate or avoid the consequences of saltwater intrusion, which

coincided with the highest percentage (64%) of households that had not received any training on climate change adaptation. In contrast, the proportion of farming households lacking this knowledge was significantly lower in Tan Phu (6%) and Phu Tuc (2%), contributing to the reduced vulnerability of these communes in the knowledge and skills component. In the food dimension, low crop diversity due to climatic conditions and saltwater intrusion has pushed farmers to cultivate high-value crops like pomelo and durian, leading to decreased production of traditional crops such as rice, cassava, maize, vegetables, and cocoa (Table 2). Phu Tuc had the lowest average crop diversity index, which significantly increased its vulnerability in the

food sector, resulting in the highest LVI score for food (0.33). Additionally, 24% of households in Phu Tuc relied solely on their own family farms for food, and 31% did not sell their agricultural products, further contributing to its high vulnerability in this sector. Livelihood vulnerability was notably higher in Phu Tuc (0.51), where more households had members working outside the community than in Tan Phu (0.34) or Giao Long (0.37). This aligns with the rural-to-urban migration trend seen in northwest Vietnam (Huong et al., 2018) and central Vietnam (Nguyen et al., 2015). Over the past decade, agricultural households have shifted toward specializing in singular livelihoods, often with income solely dependent on agriculture.

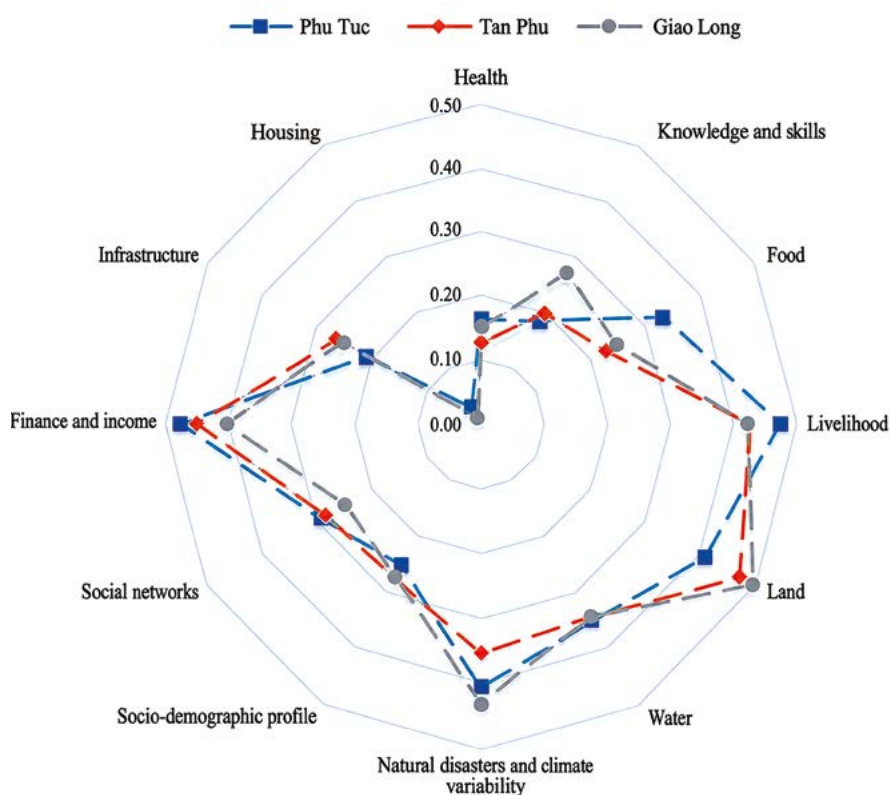


Figure 2. Vulnerability spider diagram depicting the 12 main components of the livelihood vulnerability index for three communes in Chau Thanh district, Ben Tre province.

Table 3. Results of the capitals, main components, and indicators for three communes in Chau Thanh district, Ben Tre province

Capitals	PT	TP	GL	Main components	PT	TP	GL	Indicators	PT	TP	GL
Human	0.30	0.26	0.29	Health	0.16	0.13	0.15	(1)	0.12	0.08	0.18
								(2)	0.06	0.03	0.18
								(3)	0.30	0.21	0.09
								(4)	0.17	0.18	0.15
				Knowledge and skills	0.18	0.20	0.27	(5)	0.09	0.06	0.03
								(6)	0.61	0.59	0.64
								(7)	0.09	0.15	0.12
								(8)	0.11	0.14	0.26
								(9)	0.02	0.06	0.31
				Food	0.33	0.23	0.25	(10)	0.24	0.21	0.12
								(11)	0.45	0.38	0.38
								(12)	0.31	0.09	0.24
				Livelihood	0.47	0.43	0.43	(13)	0.51	0.34	0.37
								(14)	0.48	0.48	0.50
								(15)	0.59	0.77	0.68
								(16)	0.89	0.80	0.90
								(17)	0.24	0.15	0.06
								(18)	0.13	0.03	0.04
Natural	0.40	0.38	0.43	Land	0.41	0.47	0.50	(19)	0.05	0.02	0.01
								(20)	0.40	0.53	0.58
								(21)	0.78	0.87	0.90
				Water	0.35	0.34	0.34	(22)	0.03	0.03	0.01
								(23)	0.97	0.97	0.94
								(24)	0.05	0.03	0.08
				Natural disasters and climate variability	0.41	0.35	0.43	(25)	0.44	0.44	0.56
								(26)	0.37	0.37	0.38
								(27)	0.98	0.91	1.00
								(28)	0.01	0.00	0.02
								(29)	0.05	0.02	0.01
								(30)	0.77	0.41	0.88
								(31)	0.39	0.39	0.39
								(32)	0.33	0.33	0.33
								(33)	0.32	0.32	0.32
Social	0.28	0.28	0.26	Socio-demographic profile	0.25	0.28	0.27	(34)	0.33	0.53	0.49
								(35)	0.29	0.18	0.21
								(36)	0.34	0.34	0.36
								(37)	0.05	0.05	0.03

				Social networks	0.29	0.28	0.25	(38)	0.34	0.22	0.19
								(39)	0.26	0.15	0.15
								(40)	0.21	0.27	0.25
								(41)	0.62	0.88	0.76
								(42)	0.08	0.03	0.00
								(43)	0.24	0.15	0.14
Financial	0.48	0.45	0.40	Finance and income	0.48	0.45	0.40	(44)	0.11	0.09	0.12
								(45)	0.94	0.91	0.94
								(46)	0.38	0.35	0.15
Physical	0.15	0.18	0.17	Infrastructure	0.21	0.26	0.25	(47)	0.27	0.36	0.34
								(48)	0.15	0.17	0.17
				Housing	0.03	0.01	0.01	(49)	0.03	0.01	0.01

PT: Phu Tuc; TP: Tan Phu; GL: Giao Long. The order of the indicators corresponds to Table 1.

Land emerged as the most vulnerable component, with scores of 0.50 in Giao Long, 0.47 in Tan Phu, and 0.41 in Phu Tuc. Between 78 and 90% of farmers experienced land degradation due to climate-related extremes, particularly saltwater intrusion (Thien et al., 2023). In addition, most farmers owned agricultural land, but its small size and degradation from saltwater intrusion and erosion, particularly in Giao Long (90%), exacerbated vulnerability. Water vulnerability was moderate (0.34 - 0.35), as many farmers directly relied on river water for irrigation, making them highly susceptible to drought and saltwater intrusion. Natural disasters and climate variability vulnerability scores were consistent with Thanh Phu District (Can et al., 2020), primarily driven by extreme weather events such as erosion, drought, and saltwater intrusion. Among the communes, Giao Long (0.43) was the most vulnerable to these

impacts, followed by Phu Tuc (0.41) and Tan Phu (0.35) which aligns with Thien et al. (2023). The financial and income sector also showed high vulnerability (0.40 - 0.48) due to low agricultural household incomes.

The LVI-IPCC contributing factors and overall vulnerability scores for the three communes are summarized in Table 4. The LVI-IPCC values for Phu Tuc, Tan Phu, and Giao Long were 0.039, 0.021, and 0.044, respectively. Based on LVI-IPCC, Giao Long was the most vulnerable to climate change, with the highest exposure (0.432) and low adaptive capacity (0.292). Conversely, Tan Phu was the least vulnerable (0.021), aligning with findings by Thien et al. (2023), as its geographic location in the western part of the district and well-developed irrigation infrastructure mitigate the impacts of saltwater intrusion.

Table 4. Calculation of livelihood vulnerability index-intergovernmental panel on climate change (LVI-IPCC) contributing factors for the three communes in Chau Thanh district, Ben Tre province

IPCC contributing factors to vulnerability	Phu Tuc	Tan Phu	Giao Long
Exposure	0.407	0.354	0.432
Adaptive capacity	0.290	0.288	0.292
Sensitivity	0.335	0.311	0.317
LVI-IPCC	0.039	0.021	0.044

3.3. LEI and solutions

The LEI results for the five capitals - human, natural, social, financial, and physical are presented in Figure 3. According to the results, agricultural households in Chau Thanh district were most vulnerable in the human (0.29), natural (0.40), and financial (0.44) capitals. To address these vulnerabilities and help agricultural households adapt to climate change while mitigating its impacts, the following solutions are proposed in order of priority:

3.3.1. Financial capital

Low-interest loans and credit access: Establish low-interest loan programs and credit facilities to enable farmers to invest in adaptive measures, such as salt-tolerant crop varieties, efficient irrigation systems, and post-harvest storage technologies. This is particularly crucial in Phu Tuc (38%) and Tan Phu (35%), where a significant proportion of farmers lack access to financial services.

Crop insurance: Develop and promote affordable crop insurance schemes to protect farmers from financial losses caused by extreme climate events, including droughts, floods, and saltwater intrusion.

Savings programs: Organize community-based savings groups or cooperatives to help farmers build financial reserves for emergencies and enhance resilience.

3.3.2. Natural capital

Soil improvement measures: Implement strategies to improve soil quality, particularly in Giao Long (90%) and Tan Phu (87%) communes degraded by saline intrusion, through organic amendments, soil testing, and the introduction of salt-tolerant crops.

Crop diversification: Promote the planting of diverse crops to enhance soil health, reduce pest outbreaks, and increase resilience to climate variability, especially in Phu Tuc commune (because of the lowest average crop diversity index).

Freshwater storage systems: Encourage the construction of freshwater storage systems, such as ditches and ponds, to support irrigation and agricultural activities during dry seasons.

Rainwater harvesting: Develop systems for rainwater collection and storage to provide water for irrigation and household use during drought periods.

Efficient irrigation systems: Introduce modern water-saving irrigation techniques, such as drip irrigation and sprinkler systems, to minimize water wastage.

Desalination technology: Establish small-scale desalination units in areas affected by saltwater intrusion to supply fresh water for agricultural use.

3.3.3. Human capital

Training programs: Conduct training sessions on sustainable natural resource management and climate adaptation strategies, tailored to local conditions, particularly in Giao Long commune, where 31% of households lacked knowledge on mitigating the impacts of saltwater intrusion.

Workshops on climate risk management: Provide practical workshops to help farmers manage climate risks, diversify their agricultural practices, and adopt climate-resilient crops and technologies.

Financial literacy education: Train farmers in financial management, focusing on creating budgets, managing debts, and planning long-term investments for climate adaptation.

By addressing these key vulnerabilities in the financial, human, and natural capitals, agricultural households in Chau Thanh can build resilience to climate change impacts, improve their livelihoods, and ensure sustainable agricultural practices.

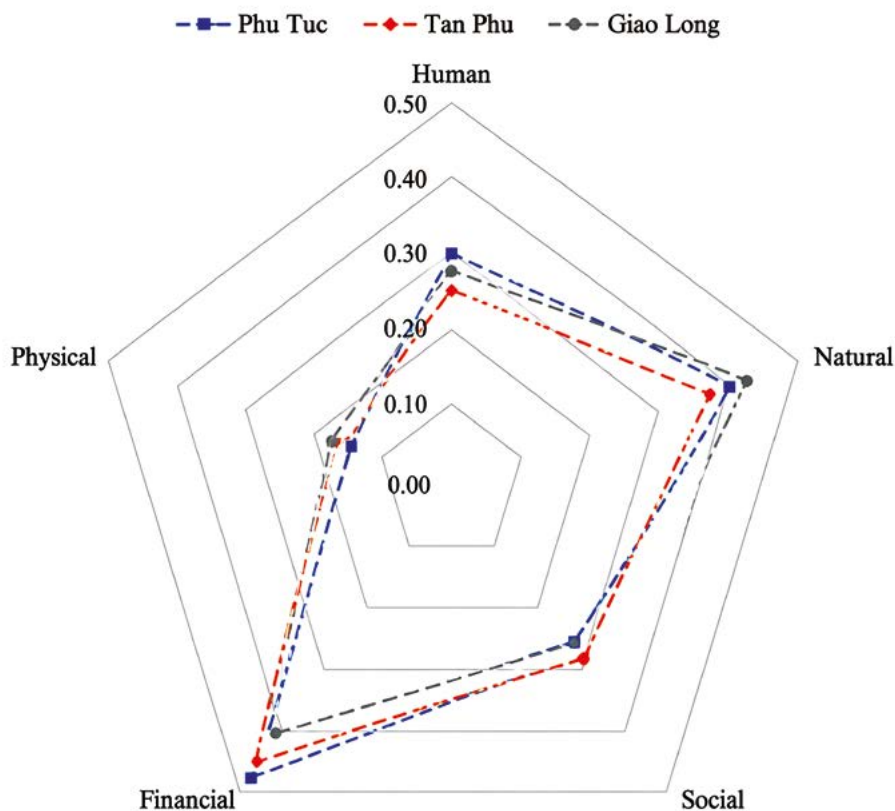


Figure 3. Vulnerability spider diagram depicting the 5 capitals of the livelihood efficiency index for three communes in Chau Thanh district, Ben Tre province.

4. Conclusions

This study assessed the vulnerability of agricultural households in Chau Thanh district, Ben Tre province, to climate change using the livelihood vulnerability index framework. With data collected from 300 households and complemented by secondary climate data, the overall livelihood vulnerability index of Chau Thanh district was calculated to be 0.32, indicating moderate vulnerability. Among the 12 main components, livelihoods, land, water, natural disasters, and financial resources were identified as the most vulnerable sectors, whereas housing exhibited the least vulnerability.

The livelihood vulnerability index and intergovernmental panel on climate change results highlighted that Giao Long commune had the highest vulnerability due to greater exposure and lower adaptive capacity compared to Tan Phu and Phu Tuc communes. Key drivers of vulnerability included land degradation caused by saltwater intrusion, limited crop diversity, reliance on river water for irrigation, and insufficient adaptive capacity to cope with extreme climate events.

Solutions to mitigate these vulnerabilities were proposed based on the livelihood effect index, focusing on strengthening financial, human, and natural capitals. These included improving access to financial services, providing low-interest loans, and introducing crop insurance; organizing training programs on climate risk management and sustainable farming practices; and adopting sustainable land and water management strategies, such as rainwater harvesting and soil improvement techniques.

Addressing these key vulnerabilities will not only enhance the resilience of farming households in Chau Thanh district but also provide a framework for similar communities in Vietnam and beyond to adapt to climate change impacts. Future studies should explore the long-term effectiveness of proposed solutions and their scalability to other regions.

Conflict on interest

The authors declare no conflict of interest.

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