ENVIRONMENTAL RESEARCH
COMMUNICATIONS

PAPER • OPEN ACCESS

Assessing coastal community resilience to climate change in Central Vietnam through the Climate Disaster Resilience Index (CDRI)

To cite this article: Nguyen Thi Huong Giang *et al* 2024 *Environ. Res. Commun.* **6** 105033

Environmental Research Communications

OPEN ACCESS

RECEIVED
2 July 2024

REVISED
28 September 2024

ACCEPTED FOR PUBLICATION
11 October 2024

PUBLISHED
24 October 2024

PAPER

Assessing coastal community resilience to climate change in Central Vietnam through the Climate Disaster Resilience Index (CDRI)

Nguyen Thi Huong Giang[1], Tran Xuan Minh[1], Hoang Dung Ha[2] and Nguyen Thi Kim Chung[3]

[1] Institute of Agriculture and Natural Resources, Vinh University, 182 Le Duan Str., Vinh City, Nghe An, Vietnam
[2] University of Agriculture and Forestry, Hue University, 102 Phung Hung Str., Hue City, Vietnam
[3] Centre for Practice and Experiment, Vinh University, 182 Le Duan Str., Vinh City, Nghe An, Vietnam

E-mail: minhtx@vinhuni.edu.vn

Keywords: coastal communities, Climate Disaster Resilience Index (CDRI), climate change, Vietnam

Supplementary material for this article is available online

Abstract

This study investigates the climate resilience of coastal communities in Vietnam's Nghe An province, a region highly exposed due to its extensive coastline and dense population. Employing the Climate Disaster Resilience Index (CDRI), the research assesses the resilience of three districts — Quynh Luu, Dien Chau, and Nghi Loc — to climate-induced disasters. The analysis reveals good to high overall resilience across five dimensions (physical, social, economic, institutional, and natural). Dien Chau boasts the highest score (4.06), followed by Quynh Luu (4.04), and Nghi Loc (4.01). While strong infrastructure and essential services contribute to high physical resilience, social capital development requires further attention. Economic resilience is bolstered by employment rates, but income and asset accumulation need improvement. Effective policies and disaster risk management strategies highlight strong institutional resilience. Natural resource management demonstrates adaptability, but land-use planning warrants enhancement. This study underscores the districts' good preparedness for climate challenges while pinpointing areas for improvement across all CDRI dimensions. By addressing these vulnerabilities, Nghe An's coastal communities can further strengthen their resilience.

1. Introduction

Coastal communities globally are at the forefront of climate change impacts, facing challenges such as rising sea levels, extreme weather events, and saltwater intrusion (Parry *et al* 2007). Vietnam, with a coastline extending over 3,260 km, is among the most affected nations. The high population density in coastal areas, comprising approximately 70% of the national total, heightens the vulnerability to climate-related disasters, threatening lives, livelihoods, and infrastructure, and causing significant economic and social disruption (Hoang *et al* 2022, Nguyen Trung 2023).

Current trends and projections for climate change in Vietnam, especially in coastal regions, indicate significant warming and precipitation changes. Studies show that temperatures are projected to rise across Vietnam under all representative concentration pathway scenarios, with a more intense increase in the northern regions and during summer (Tran-Anh *et al* 2022, Phan and Nguyen 2023). Additionally, Vietnam's extensive coastline faces a serious threat from rising sea levels, with mean sea level increases recorded through tide gauge and satellite data. Furthermore, the vulnerability assessment of small-scale households in coastal areas reveals moderate vulnerability to natural disasters and climate shocks, emphasizing the need for poverty alleviation strategies and diversified livelihoods to enhance resilience (Tan *et al* 2023). These findings underscore the importance of proactive adaptation measures to mitigate the impacts of climate change on Vietnam's coastal regions.

In Nghe An, a coastal province of Vietnam, studies have documented climate change's detrimental effects on agricultural productivity and livelihoods (Bien *et al* 2022). Vulnerability assessments underscore the importance of natural disasters, crop areas, and adaptation capacity in determining vulnerability levels across different districts. Climate change impacts in Nghe An province, have been studied extensively. Research indicates that adverse weather conditions, as part of climate variability, have led to a decline in sugarcane yields and income for cane growers in Tan Ky district (Nguyen *et al* 2023). Additionally, rice producers in Nghe An have experienced changes in rainfall patterns and temperature, affecting rice productivity, with some adopting adaptive strategies like changing planting schedules and improving irrigation practices (Bien *et al* 2022). Livelihood vulnerability assessments show that rice households in Nghe An are slightly vulnerable to climate change, with floods, droughts, and institutional factors significantly affecting vulnerability levels (Tran *et al* 2022). Moreover, the socio-economic vulnerability assessment in the province highlights the importance of natural disasters, crop areas, and adaptation capacity in determining vulnerability levels across different districts (Hoang 2019). Understanding these climate change impacts is crucial for implementing effective adaptation strategies and policies to enhance resilience and sustainable development in Nghe An province.

While mitigating climate change impacts and ensuring sustainable development in Nghe An province is crucial, research on enhancing coastal community resilience remains limited. This study addresses this gap by employing a modified Climate Disaster Resilience Index (CDRI) approach. Resilience, defined as the ability to absorb, adapt to, and recover from disruptions while maintaining essential functions, is crucial for mitigating climate change effects (Shackleton *et al* 2024). The CDRI, originally developed for disaster resilience evaluation, offers a framework to analyze various resources within a system. Here, we introduce a modified 5 × 5 matrix CDRI method specifically tailored to Nghe An's coastal communities.

Our research aims to develop and apply the modified CDRI method to assess the development resources and resilience of coastal communities in Nghe An to climate change. By understanding resilience levels and resource availability, this study seeks to contribute to targeted strategies for enhancing the resilience capacity of coastal communities in Nghe An and potentially other Vietnamese coastal regions.

2. Literature review: the Climate Disaster Resilience Index (CDRI)

2.1. Resilience: a core concept

The concept of resilience originates from the physical sciences, initially describing a material's ability to return to its original state after deformation (Norris *et al* 2008). It has since been adopted across various fields to understand how systems, like ecosystems or communities, absorb disturbances while maintaining their structure and core functions (Adger 2000, Walker *et al* 2004).

In a human context, resilience refers to the capacity of individuals, groups, or entire communities to cope with disruptions caused by social, political, and environmental changes (Adger 2000, Tompkins and Adger 2004, Parry *et al* 2007). Enhancing community resilience (CR) is increasingly recognized as a key strategy for mitigating climate risks. The assumption is that resilient communities are less vulnerable to climate change impacts (Klein *et al* 2003). Building resilience involves various structural and non-structural actions undertaken by communities to minimize risks from environmental threats (Manyena 2006). However, these methods also have limitations.

Resilience in the context of climate change has evolved from its ecological origins to encompass various fields like psychology, policy, and urban planning (Rezaie *et al* 2021). It refers to the ability of social systems to prepare for, absorb, and adapt to risks induced by climate change, focusing on community readiness and response to natural disasters (Antronico *et al* 2023). The need for resilient landscapes and communities in the face of climate change is emphasized, highlighting the importance of innovative and flexible solutions to address socio-ecological challenges. Resilience-building investments play a crucial role in mitigating armed conflicts triggered by climate-related anomalies, emphasizing the significance of socioeconomic, institutional, and technological dimensions in preventing violent activities (D'Angeli *et al* 2022).

2.2. Assessing resilience: the CDRI approach

To comprehensively assess resilience and adaptation capacity, researchers need to consider various resources and how they change over time and space. CDRI is a valuable tool for this purpose. CDRI is a management tool used to analyze societal resilience to climate disasters at various levels. It provides crucial information for strategic planning and policy development, pinpointing vulnerable areas and sectors most susceptible to disasters (Almutairi *et al* 2020).

Developed over the past decade, the CDRI method has been applied in studies assessing the climate resilience of regions, communities, and ecosystems (Joerin *et al* 2014). Initially used for enhancing community disaster resilience, primarily in urban areas, it has been expanded to address disaster and climate resilience in vulnerable Asian cities (Shaw 2009). During 2008–2010, the Climate and Disaster Resilience Initiative conducted international research using the CDRI method to assess the disaster and climate coping capacities of 47 Asia-

Pacific cities, including four Vietnamese cities: Hanoi, Hue, Danang, and Ho Chi Minh City (Krishnamurthy *et al* 2011). The CDRI framework identifies five key system factors that influence resilience and recovery capabilities after natural disasters: Economic, Physical, Social, Natural, and Institutional (Krishnamurthy *et al* 2011). These factors will be further elaborated upon in the following section.

This study utilizes the CDRI tool due to its comprehensive and relevant approach, distinguishing it from other tools focused on vulnerability. First, CDRI evaluates resilience across five dimensions, offering a holistic perspective on a community's ability to withstand and recover from climate disasters. Unlike vulnerability assessments, which often emphasize exposure and sensitivity, the CDRI also considers the capacity for response and recovery, making it a more complete tool for resilience assessment (Hung *et al* 2024). Second, resilience centres on the ability to adapt and thrive under stress. The CDRI highlights the strengths and capacities communities can leverage to improve climate risk responses, contrasting with vulnerability assessments that primarily identify weaknesses (Akter *et al* 2024). Third, CDRI assessments are forward-looking, aiming to enhance future risk management. In contrast, vulnerability assessments are more reactive, focusing on current weaknesses (Paneru *et al* 2024). Given the rapidly changing climate, a resilience-focused approach is more advantageous for promoting long-term strategies. Fourth, the CDRI's results are directly applicable to local policy and planning, guiding climate adaptation and disaster risk reduction efforts (Paneru *et al* 2024). This is crucial for the study's goal of strengthening resilience in Nghe An's coastal communities. Fifth, the CDRI facilitates comparison across regions, enabling the study to benchmark resilience levels and identify best practices. This is particularly useful in assessing multiple districts with varying exposures and capacities.

In contrast to vulnerability assessments, which typically focus on identifying and quantifying risk factors (e.g., exposure, sensitivity), resilience assessments like the CDRI emphasize the capacity to manage and mitigate these risks. This shift in focus from vulnerability to resilience reflects a more dynamic and actionable approach to disaster risk management, one that is particularly suited to the complex and evolving challenges posed by climate change.

Thus, the CDRI tool is not only relevant but also crucial for this study, as it aligns to enhance the adaptive capacity and resilience of coastal communities in Nghe An province. By focusing on resilience, the study aims to empower communities to better prepare for and recover from climate-related disasters, ultimately contributing to more sustainable and resilient development outcomes.

3. Materials and methods

3.1. Study area

Nghe An province is located between 18°33′–20°01′ N and 103°52′–105°48′ E. The rainy season typically occurs from May to October, while the dry season spans from November to April. The average annual temperature ranges from 23 to 24 °C. There is a significant temperature difference between months throughout the year. The average temperature during the hottest months (June to July) is 33 °C, with an absolute high temperature of 42.7 °C. The average temperature during the coldest months (December of the previous year to February of the following year) is 19 °C, with an absolute low temperature of −0.5 °C. The average annual sunshine hours range from 1,500 to 1,700 h. The average annual rainfall varies from 1,200 to 2,000 mm $year^{-1}$ (NAPC 2021).

The research was conducted from 2022 to 2023 in Nghe An province, focusing on three typical districts representing coastal communities: Quynh Luu, Dien Chau, and Nghi Loc (figure 1). The coastal area of Nghe An, stretching 82 kilometres from Quynh Luu, Dien Chau, Nghi Loc, the town of Cua Lo to Vinh City, has been identified as a high-risk area due to natural disasters such as storms accompanied by storm surges, tropical depressions, heavy rainfall, coastal erosion, saline intrusion, and rising sea levels (Tran *et al* 2022). The total agricultural land area in the coastal districts of Nghe An province accounts for 70% of the natural land area (NAPC 2021). The research area is also situated in the lower reaches of the Ca River, which is frequently affected by major floods, such as those in 1978, 1998, and 2002, causing significant socio-economic impacts on the research area (Do and Tran 2017). Furthermore, the impacts of climate change resulting from rising global temperatures will have certain effects on water resources and water-related disasters such as floods and droughts in the research area (Thai *et al* 2015). Coastal districts in Nghe An province face serious flooding risks in the future, for both the 1% (100-year return period) and 5% (20-year return period) flood scenarios. Generally, the proportion of district areas at risk of flooding in the future may exceed 10% of the district area. By 2100, the coastal districts with the most severe flooding are Dien Chau (27.57%), while Quynh Luu and Nghi Loc have flooding levels ranging from 10% to 16% (Thai *et al* 2015, Do and Tran 2017).

3.2. Climate change context in study sites

Located in Vietnam's central region, Nghe An experiences a tropical monsoon climate. Its 82 km coastline exposes it to various natural disasters like typhoons, floods, and rising sea levels (Tran *et al* 2022). Climate change

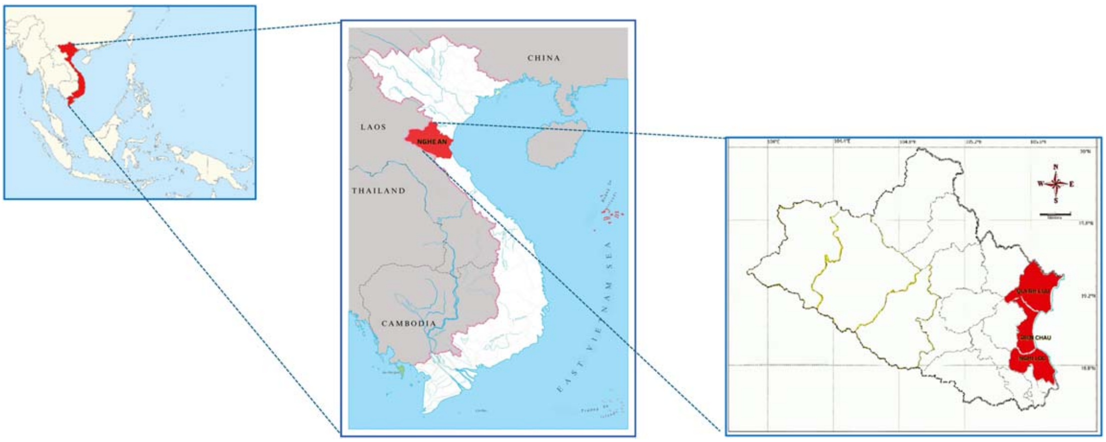

Figure 1. Study area.

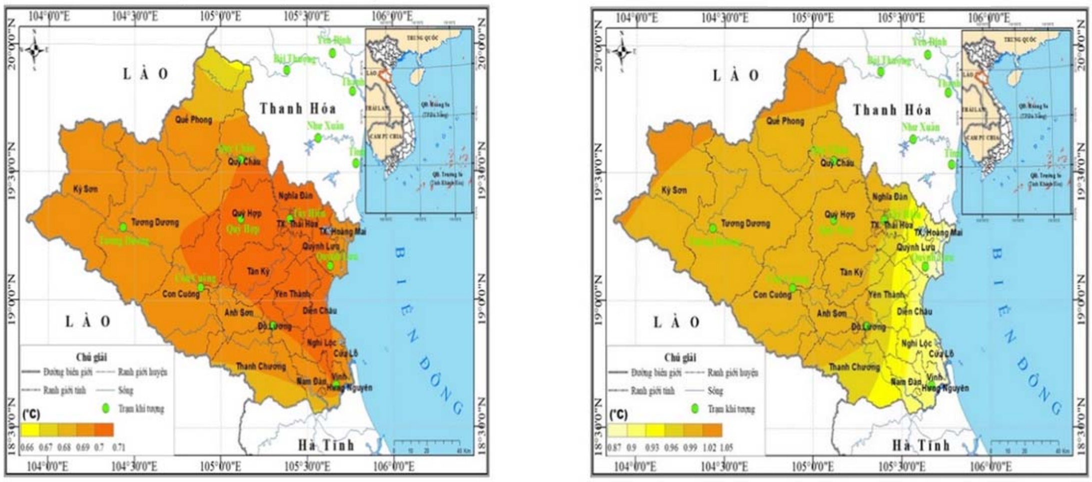

Figure 2. Level of change in average annual temperature (°C) for the period 2016–2035 in the Nghe An region according to RCP 4.5 and RCP 8.5 scenarios (Source: Pham 2022).

manifests in soil erosion, biodiversity loss, increasing saline intrusion and drought-prone areas, rising salinity, and more frequent extreme weather events. These threaten the province's socio-economic development (MONRE 2022).

The situation has worsened in the past decade. Climate change scenarios (RCP4.5 and RCP8.5) predict rising average annual temperatures across Nghe An by 0.8 to 4.1 °C by the early 21st century (MONRE 2020). This will potentially harm food production, increase energy consumption, damage infrastructure, and worsen droughts. Cold days are projected to decrease, while hot days are expected to significantly rise (0.8% to 109.5%). These trends pose significant challenges, particularly for agriculture (Thai *et al* 2015). See figure 2: Temperature Change and figure 3: Rainfall Change

Annual rainfall is expected to increase province-wide under all scenarios. The RCP4.5 scenario predicts a 5%–15% increase by the end of the century, while the RCP8.5 scenario suggests a possible increase exceeding 20% in most areas. However, dry season rainfall may decrease in some regions. Maximum daily rainfall is also projected to increase by 10%–70%. Droughts may become more severe due to rising temperatures and potential dry season rainfall decline. Sea level rise is a concern, with the lowest projected rise (53 cm) expected in the Hon Dau - Deo Ngang coastal region under the RCP4.5 scenario. Even with a 1-meter rise, 1.47% of coastal areas could be inundated (MONRE 2020).

Climate change is likely to increase the frequency and intensity of extreme weather events in Nghe An. This includes storms, tropical depressions, heavy rains leading to floods and landslides, heatwaves, reduced rainfall causing droughts, water shortages, and increased diseases. Sea level rise can cause flooding, salinization of water sources, and negatively impact agriculture and aquaculture. Storms and tropical depressions making landfall are

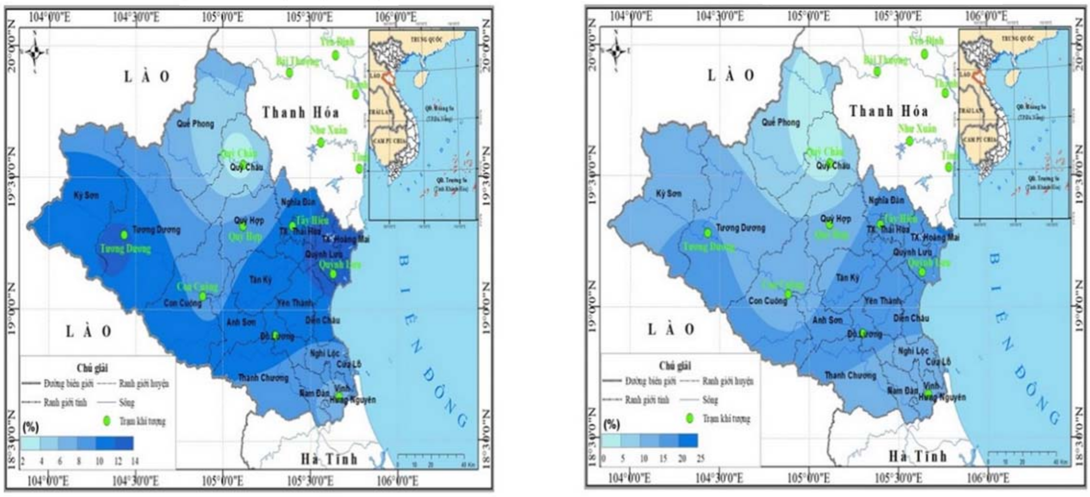

Figure 3. Level of change in rainfall (%) for the period 2016–2035 in the Nghe An region according to RCP 4.5 and RCP 8.5 scenarios (Source: Pham 2022).

projected to be more intense and pose greater danger. They are also expected to occur earlier and last longer, causing significant damage (NAPC 2022).

Residents have experienced losses in food security and income due to climate change impacts like heatwaves, droughts, storms, and sudden floods. These events are becoming more frequent. Historical disasters include the 1978 flood exceeding level 3 alerts, three storms within 10 days in 1989, historic heatwaves followed by heavy floods in 2010, and severe flash floods caused by typhoon circulation in 2007 (NAPC 2022). In 2023, despite no direct storms, Nghe An experienced extreme weather events like tornadoes, lightning, cold spells, heat waves, and heavy rains. These events caused significant damage to life, infrastructure, economy, and society, with 3 deaths, 5 injuries, and estimated economic losses of 667 billion VND (NAPC 2023).

Climate change impacts in Dien Chau, Nghi Loc, and Quynh Luu coastal districts of Nghe An province are significant, as highlighted in various research papers. The vulnerability of rice households in Nghe An province to climate-induced issues, especially floods and droughts, emphasizes the need for strengthening social networks between farmers, cooperatives, and local governments (Tran *et al* 2022). Additionally, the assessment of climate trends in Nghe An province shows an increase in annual temperature, which can exacerbate climate stresses in these coastal districts (Bien *et al* 2022). Furthermore, the study on coastal erosion in projected sea level rise scenarios emphasizes the need for countermeasures to protect against severe erosion and dike failure (Duc *et al* 2017), particularly in coastal areas like Dien Chau, Nghi Loc, and Quynh Luu. These findings underscore the urgency of implementing adaptation strategies, improving irrigation systems, and enhancing community resilience to mitigate the impacts of climate change in these vulnerable coastal districts.

3.3. Data collection

This study's primary data collection methods included survey questionnaires, interviews, and group discussions. The data collection process was carried out by a trained team of researchers from Vinh University and Hue University, collaborating with local partners and community leaders. The team consisted of 10 field researchers experienced in conducting surveys, interviews, and group discussions in the coastal region. All participants in this study were fully informed about the research's purpose and provided their consent before taking part. Consent was obtained through interviews and group discussions, ensuring that participants understood the research process and voluntarily agreed to participate. Before the surveys, participants received a consent form detailing the purpose and use of their responses. This form specified that the information and opinions shared would solely be used to analyze the impact of climate change on the socio-ecological system and the community's resilience. Participants were assured that their data would not be shared with any third party without their explicit consent, and their personal information would remain confidential. By signing the consent form, participants agreed to allow the use of the information they provided for this research.

Interviews: A total of 45 in-depth interviews were conducted from November to December 2022. The interviewees were selected based on their expertise, experience, and roles in their respective communities. This included district and commune-level managers, experts, elders, and knowledgeable community members. The district and commune-level managers were chosen for their decision-making roles in disaster management, while experts from universities provided academic and technical perspectives. The selection was made to ensure

Table 1. Information on the study area and the number of survey forms.

No.	District	Sample size	Percentage (%)	Area (km^2)	Population
1	Dien Chau	180	33.96	1,004	6,766.81
2	Nghi Loc	160	30.19	1,226	221,351.38
3	Quynh Luu	190	35.85	934	193,497.26
	Total	530	100	3164	421,615.45

Table 2. List of variables considered in CDRI's five dimensions.

Dimension	Parameters
Physical	Electricity; Water supply; Transportation infrastructure; Housing; Disaster response/climate change facilities and equipment
Social	Population; Health; Culture—Education; Social Capital; Willingness to Participate
Economic	Employment; Income; Financial capacity and budget; Assets and savings; Subsidies and resource mobilization
Institutional	Practicality and effectiveness of policies; Integration and coordination of implementation; Governance; Policy dialogue; Monitoring and evaluation
Natural	Geographical location; Natural resources; Natural hazards; Land use planning; Environmental pollution

a comprehensive understanding of the resilience framework from both practical and theoretical viewpoints. The semi-structured interviews allowed for in-depth exploration of specific resilience-related issues within each district. For example, these issues include the most pressing climate-related challenges their communities face, such as flooding, drought, and coastal erosion, to prioritize research areas; the specific vulnerabilities within the population, including economic, social, and infrastructure vulnerabilities, and how these have been affected by recent climate events; the extent of community participation in disaster prevention initiatives; the strength of local networks; and the level of social capital, etc.

Group discussions: A total of 180 people participated in 18 group discussions, six in each district. These discussions took place between January and February 2023. Each group consisted of 8–10 participants, including elderly people, women's associations, affluent households, impoverished ones, community leaders, and representatives from local authorities. The discussions focused on understanding the community's perception of resilience and identifying challenges and opportunities in disaster preparedness and response, etc. These discussions were guided by a moderator and were designed to complement the survey and interview data by providing qualitative insights into the community's resilience dynamics. Based on the insights gathered from these discussions, the research team selected villages and hamlets that represent different risk profiles and socio-economic conditions in the study area. The selected communes were Quynh Luu, Dien Chau, and Nghi Loc. The selection criteria included: (i) Exposure to climate risks; (ii) Socio-economic diversity; (iii) Infrastructure; and (iv) Accessibility and feasibility. This strategic selection process ensures that the study captures a comprehensive view of resilience and vulnerabilities across different types of communities in the coastal districts.

The interviews and group discussions in this study were designed to complement and clarify the results obtained from the survey questionnaires. The primary purpose was to provide contextual information and depth to the quantitative data, offering a deeper understanding of factors that could not be fully captured through the surveys alone.

Survey questionnaires: The surveys were conducted from March to July 2023. We employed a stratified random sampling strategy to ensure representation across different socio-economic and geographic profiles within the three districts of Dien Chau, Nghi Loc, and Quynh Luu. A total of 530 surveys were distributed, respondents included local government leaders (12%), scholars and researchers (10%), and coastal households (78%) (table 1). The survey targeted both individuals and households, depending on the context. In household surveys, the head of the household or an informed adult member was asked to respond on behalf of the household.

The survey aimed to assess various dimensions of resilience using the CDRI. The CDRI questionnaire consists of 125 variables (each dimension includes 5 parameters for consideration and assessment, each parameter has 5 representative variables - table 2), designed to assess the resilience of different areas within the study region ($5 \times 5 \times 5$ matrix). Respondents were asked to rate the variables using a five-point Likert scale, where 1 represents the lowest score/value and 5 represents the highest score/value. In other words, each variable is evaluated through five options, with 1 = Very Poor and 5 = Best, corresponding to levels $x_1, x_2, \ldots, x_5$ (table 3). Additionally, a weighting scheme requires that the variables within a parameter, comprising five variables, be ranked (w_1, w_2, w_3, w_4, w_5) according to their importance (with '1' indicating least important and '5' indicating

Table 3. An example of a survey questionnaire on the CDRI of the electricity parameter in the physical dimension.

No.	Please rate how effective the following electricity indicators are in your region during a climate disaster event	Very poor	Poor	Medium	Good	Best
1.1.1	Household electricity supply capacity/rate of households with regular electricity access	1	2	3	4	5
1.1.2	Capacity to supply electricity during storms, natural disasters/backup power supply system (generators)	1	2	3	4	5
1.1.3	The electrical system meets the technical standards of the electricity industry	1	2	3	4	5
1.1.4	Capacity to supply electricity for disaster response structures and equipment (storm shelters, loudspeakers, etc)	1	2	3	4	5
1.1.5	Situation of electricity usage or renewable energy usage	1	2	3	4	5
Weight factor: please rank the variables between 1 and 5 (5 = most important, 1 = least important)						
	1.1.1	1.1.2	1.1.3	1.1.4		1.1.5

most important) in shaping the final score of a specific parameter or dimension. Using data collected from the questionnaire surveys, the Weighted Mean Index (WMI) method is used to compute the scores for each parameter. The formula is shown below:

$$\mathrm{WMI} = \frac{\sum_{i=1}^{n} w_i x_i}{\sum_{i=1}^{n} w_i} = \frac{w_1x_1 + w_2x_2 + w_3x_3 + w_4x_4 + w_5x_5}{w_1 + w_2 + w_3 + w_4 + w_5} \quad (1)$$

where x represents variable, and w is the assigned weight.

3.4. Data analysis

This study employed a mixed-methods approach to analyze both quantitative and qualitative data collected through surveys, interviews, and group discussions. This approach allowed for a comprehensive assessment of the resilience of coastal communities in Nghe An province.

Quantitative data was collected from 530 completed surveys using the CDRI framework. The data was coded and entered into Microsoft Excel, where descriptive statistics were used to summarize demographic characteristics such as age, gender, education level, and occupation. Additionally, mean scores for each of the five CDRI dimensions—Physical, Social, Economic, Institutional, and Natural—were calculated to evaluate the overall resilience of the communities. For the qualitative data, thematic analysis was applied to the transcripts of interviews and group discussions. The research team reviewed and systematically coded the transcripts to identify recurring themes and patterns. These themes were categorized according to the five CDRI dimensions, with additional categories created for emergent themes not initially anticipated. The coding process involved several iterations to ensure consistency and accuracy in theme identification. A triangulation method was utilized to integrate quantitative and qualitative data. This involved cross-referencing and comparing findings from the surveys, interviews, and group discussions to validate the results. The quantitative data provided a broad quantitative assessment of resilience across the study areas, while the qualitative data offered deeper, context-specific insights into factors influencing resilience.

3.4.1. Calibration of the resilience scale

The scale was developed based on the CDRI model to assess the resilience of coastal communities to climate-induced disasters. The calibration of the scale was informed by standards and guidelines from previous studies in the field of disaster risk management and climate change adaptation (Joerin *et al* 2014, Imani *et al* 2021). Each indicator was assessed using a 1-to-5 scale, where 1 represents very poor resilience and 5 represents excellent resilience. The scale was further divided as follows: scores from 1 to 1.5 indicate very poor resilience, scores from 1.6 to 2 indicate low resilience, scores from 2.1 to 3 indicate moderate resilience, scores from 3.1 to 4 indicate good resilience, and scores from 4.1 to 5 indicate high resilience. Data from surveys and interviews were used to calculate scores for each indicator within the components of the CDRI.

4. Results

4.1. Descriptive statistics of sociodemographic characteristics of respondents

Table 4 provides an overview of the sociodemographic characteristics of households surveyed in the study area. The average age of respondents is 41.7 years, indicating that the majority are within the working age group. This is a positive factor in enhancing community resilience to disaster events, as this workforce can contribute to

Table 4. Sociodemographic characteristics of respondents (n = 530).

Variable	Frequency	%	Mean (SD)
Sociodemographic characteristics of respondents			
Mean age of respondents (year)	530	—	41.7 (11.8)
Gender			
- Male	273	51.6	—
- Female	257	48.4	—
Educational attainment of household heads			
- Primary school	48	9.1	—
- Secondary school	218	41.1	—
- High school	174	32.8	—
- Short-term training	40	7.5	—
- College and university	50	9.4	—
Average household size (persons)	2385	—	4.5 (1.6)
Labor force per household	1166	—	2.2 (1.4)
Average income (1000 USD/year)	530	—	2.4 (1.5)
Proportion of poor households	20	3.7	—
Proportion of middle-income households	275	51.9	—
Proportion of affluent households	235	44.4	—
Disaster factors			
Typhoon, tropical depression	530	60.8	—
Heavy rain, flooding	530	62.8	—
Sea level rise, saltwater intrusion	530	57.5	—
Drought	530	61.2	—
Severe cold, damaging cold	530	50.0	—
Thunderstorms	530	54.2	—
Others	530	60.5	—

economic activities and support recovery efforts following disasters. The gender distribution is relatively balanced, with males representing 51.6% and females 48.4%, ensuring gender balance in the survey. Educational attainment ranges from primary school to university level, with most respondents having completed at least secondary and high education (74%). The average annual household income is 2,400 USD, with a standard deviation of 1.5, reflecting significant variation in economic capability among households. Although the proportion of households classified as poor is relatively low (3.7%), these households exhibit lower resilience to climate shocks. The community shows notable economic stratification, with most households classified as middle-income or affluent.

Respondents report that the study area faces several severe disaster factors, including heavy rain and flooding (62.8%), typhoons and tropical depressions (60.8%), and drought (61.2%). These factors frequently cause significant damage to both livelihoods and agricultural production. Other disaster factors such as saltwater intrusion and sea level rise (57.5%), severe cold (50.0%), and thunderstorms (54.2%) also negatively impact household livelihoods.

4.2. Physical dimension

The CDRI assessment of physical components indicates that all three districts have good resilience to climate-induced disasters, with estimated average scores of 4.02, 3.95, and 3.97 for Dien Chau, Nghi Loc, and Quynh Luu, respectively (figure 4).

Electricity and water are noted to have higher resilience scores. This is explained by the continuous provision of these resources even during flooding events, thus enhancing their resilience. On the other hand, housing and land use are reported to have lower scores, indicating areas that require investment and improvement to enhance coping abilities with disasters and climate change. To achieve these results, in recent years, the People's Committee of Nghe An province has approved several coastal infrastructure development projects, such as the

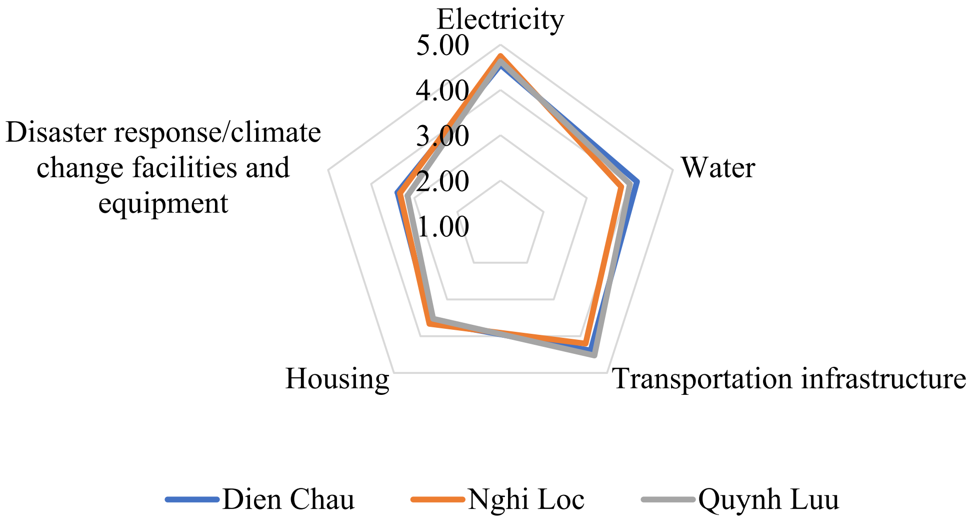

Figure 4. Climate Disaster Resilience Index (CDRI) analysis of physical dimension.

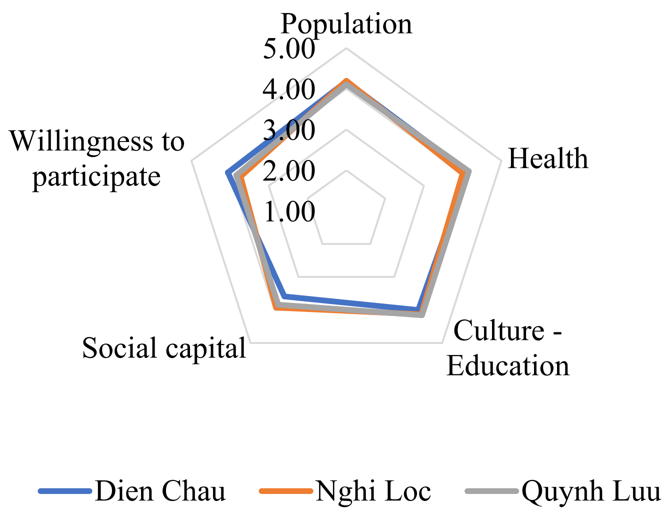

Figure 5. Climate Disaster Resilience Index (CDRI) analysis of social dimension.

Coastal Road Project from Nghi Son (Thanh Hoa) to Cua Lo (Nghe An) with a capital of 3.4 trillion VND; investment projects for coastal infrastructure development in the Southeast Economic Zone with over 1.05 trillion VND; the Vinh - Cua Lo Boulevard project with a capital of 465 billion VND; and the construction of a seawater supply system for industrial shrimp farming according to VietGAP standards in Quynh Bang commune, Quynh Luu district, with a capital of 43.5 billion VND (NAPC 2024). The Urban Infrastructure Improvement Project to minimize the impact of climate change on the four coastal provinces of North Central Vietnam (including Nghe An) is co-funded by a non-refundable grant from the European Union (EU) worth 5 million EUR and a concessional loan provided by the French Development Agency worth 123 million EUR; counterpart funding from the government and provinces amounts to 28 million EUR (VnEconomic 2024). Meanwhile, the Disaster Response/Climate Change Facilities and Equipment category has received the lowest scores across all dimensions, particularly in Quynh Luu (3.16). One possible reason for this low score is the inadequate availability and effectiveness of early warning systems. These systems, including communication channels like loudspeakers, telephones, and online platforms for weather and disaster forecasts, may not be fully developed or maintained, leading to delayed or inaccurate information dissemination. Additionally, the poor implementation of the '3 Ready' principle—proactive prevention, timely response, and effective recovery—may reflect a lack of organization, resources, and coordination among local agencies, weakening the community's overall disaster resilience (see appendix B).

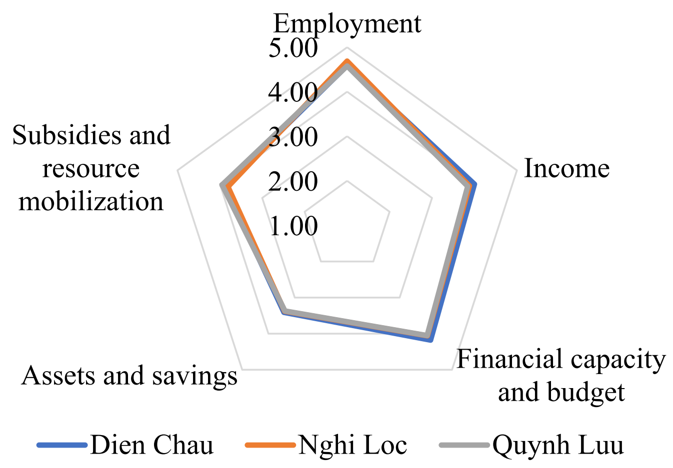

Figure 6. Climate Disaster Resilience Index (CDRI) analysis of economic dimension.

4.3. Social dimension

For the social dimension, the CDRI assessment includes parameters such as population, health, culture-education, social capital, and willingness to participate in case of disasters. The CDRI assessment of the social dimension shows that all three districts have good resilience to climate-induced disasters, with average scores estimated at 3.99, 4.00, and 4.02 for Dien Chau, Nghi Loc, and Quynh Luu, respectively (figure 5).

The population parameter is reported to have the highest score, with 4.18 (Dien Chau), 4.20 (Nghi Loc), and 4.11 (Quynh Luu). High scores in population indicate not only significant population size but also a high proportion of the working-age population, balanced birth and mortality rates, ensuring abundant human resources for economic, cultural, and social activities. The stability and potential for population development at a high level also reflect the effective population support policies and programs of the districts, thereby promoting sustainable and long-term development. The lowest reported score comes from the social capital aspect. Social capital includes community cohesion, level of trust, and cooperation among community members. Although there are no significant differences among the districts, this score indicates the need for more focus on building and developing social capital to enhance community relationships and cooperation among members.

4.4. Economic dimension

Overall, the economic resilience capacity of the three districts is reported to be good (figure 6). However, when compared to other dimensions, the economic component is reported to have the lowest ranking.

The employment rate is high across all three districts: Dien Chau (4.59), Nghi Loc (4.69), and Quynh Luu (4.58). The high employment rate contributes to financial stability and minimizes vulnerability. Income levels vary slightly across the districts, with Dien Chau at 4.00, Nghi Loc at 3.88, and Quynh Luu at 3.84. Although income levels in Nghi Loc and Quynh Luu are slightly lower, they still indicate relatively stable economic conditions. The scores for financial capacity and budget are relatively high across the districts: Dien Chau (4.18), Nghi Loc (4.06), and Quynh Luu (4.05). This reflects effective management of financial resources and budget allocation in the districts. Effective financial management is necessary for preparedness and response to disasters. Scores for assets and accumulation are somewhat lower, with Dien Chau at 3.41, Nghi Loc at 3.38, and Quynh Luu at 3.37. Although these scores indicate some areas for improvement in asset accumulation, they still show a level of economic stability in the districts. Scores for subsidies and resource mobilization are relatively high across the districts: Dien Chau (3.88), Nghi Loc (3.81), and Quynh Luu (3.95). This indicates the efficient use of subsidies and resources to support local economic activities and community development initiatives. Effective resource mobilization is an important factor in building stability against climate-induced disasters.

4.5. Institutional dimension

The parameters assessed in the institutional aspect all achieved relatively high scores. Specifically, the parameters indicate positive performance in policy implementation and management. Local policies are rated highly for practicality and effectiveness, with average scores ranging from 4.21 to 4.33 (figure 7). This suggests that local government agencies have implemented effective policy measures that address the specific needs and challenges of their regions.

Additionally, integration and coordination of policy implementation are also emphasized, with scores ranging from 4.06 to 4.11. This highlights the necessity of collaboration between government agencies and other

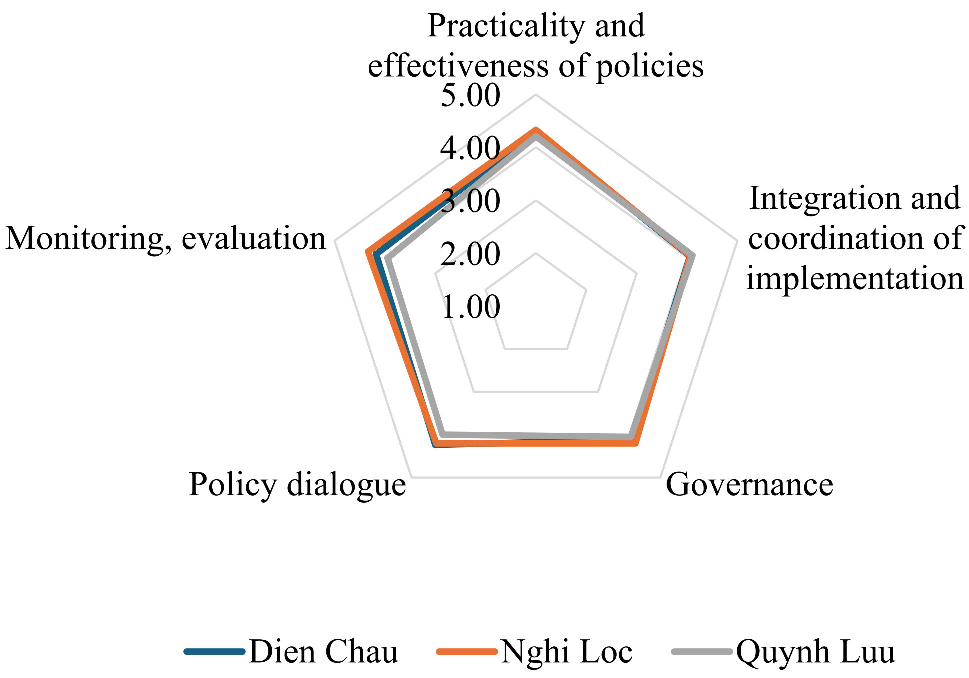

Figure 7. Climate Disaster Resilience Index (CDRI) analysis of institutional dimension.

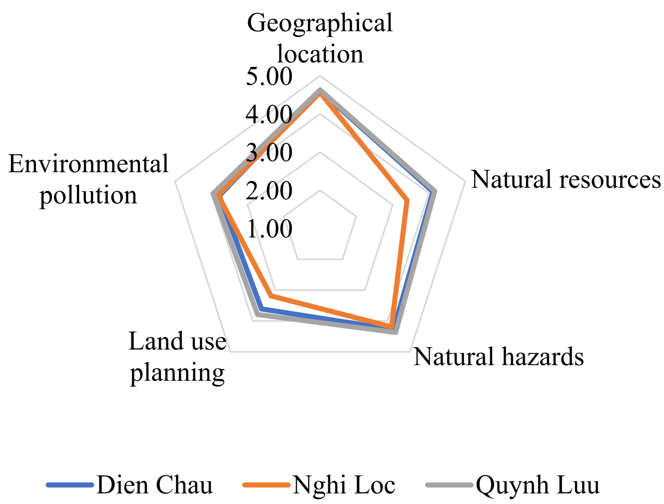

Figure 8. Climate Disaster Resilience Index (CDRI) analysis of natural dimension.

stakeholders, such as communities and businesses, to effectively implement climate change adaptation policies. Policy dialogue and monitoring and evaluation are also important aspects of the institutional dimension. While the scores may vary, they remain high, ranging from 4.00 to 4.24. This underscores the need for continuous assessment, updating, and adjustment of policies to ensure their effectiveness and adaptability to the changing local environment.

4.6. Natural dimension

The CDRI assessment of the natural dimension indicates that all three districts have good to high resilience against climate-induced disasters, with average scores estimated at 4.08, 3.94, and 4.18 for Dien Chau, Nghi Loc, and Quynh Luu, respectively (figure 8).

Based on information about the parameters in the natural dimension, it is evident that these districts have evaluated and implemented measures to protect and optimize natural resources, while also effectively responding to natural hazards and environmental pollution. Regarding geographic location, the districts are highly rated, indicating favorable geographic positions that can benefit from natural resources and have good

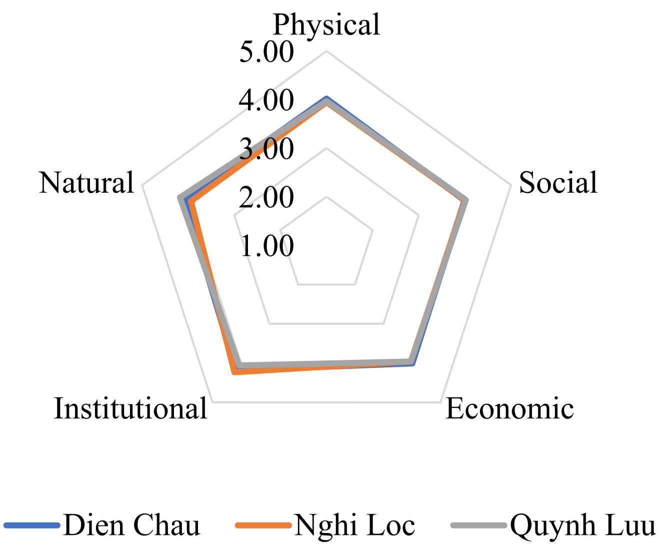

Figure 9. Overall CDRI analysis of Dien Chau, Nghi Loc, and Quynh Luu.

disaster response capabilities. However, the diversity in natural resources among the districts may require different management approaches. The districts have also recognized the importance of disaster preparedness and response, possibly through the development of warning and prevention systems. However, the quality of land use planning and management can vary, affecting the ability to cope with climate change and environmental hazards. The districts need to focus on controlling and mitigating environmental pollution to protect natural resources and community health.

4.7. Overall estimation of climate disaster resilience

Overall, the three case study districts show similar scores for the overall CDRI but different scores for the dimensions, ranging from 3.98 for the economic dimension to 4.15 for the institutional dimension (figure 9). Dien Chau has the highest overall CDRI score, and the average CDRI score for each district is estimated to be 4.06, 4.01, and 4.04 for Dien Chau, Nghi Loc, and Quynh Luu, respectively. In this scoring system, scores from 1–1.5 illustrate very poor resilience, 1.6–2 low resilience, 2.1–3 moderate resilience, 3.1–4 good resilience, and 4.1–5 high resilience. The overall CDRI analysis of the three districts indicates good resilience to climate change-induced disasters. Our research findings indicate higher CDRI scores compared to the results reported by Imani *et al* (2021) in Southern Taiwan, who stated that the average CDRI scores for each city were estimated to be 3.57, 3.95, and 3.20 for Tainan, Kaohsiung, and Pingtung, respectively.

Figure 9 illustrates that the economic aspect has the lowest resilience level among the physical, social, economic, institutional, and natural aspects. This result has been supported by Wan Mohd Rani *et al* (2018), who concluded that economic dimensions, particularly savings and finance, followed by budget and subsidies, were the most significant. Suryanto *et al* (2021) reported that the lack of credit and financial facilities for disaster risk indicates that credit facilities need improvement to enable local communities in vulnerable areas to have options for preparing to cope with any future disasters. A study conducted by Shaw (2009) measured the level of resilience in several cities with high vulnerability. From the experimental results, there is a tendency that areas with low resilience in the economic aspect will impact their overall resilience levels. This study also indicated similarly that the economic aspect still needs improvement to enhance resilience. Meanwhile, Frankenberg *et al* (2013) argued that institutional resilience needs to be emphasized and significantly supported by the economy, such as through diverse sources to increase income, budgets, and subsidies for risk reduction activities, and expanding savings and insurance facilities.

5. Discussion

This analysis of three coastal districts in Nghe An province, Vietnam (Dien Chau, Nghi Loc, and Quynh Luu), reveals valuable insights into their climate disaster resilience. The CDRI scores, ranging from 4.01 to 4.06, indicate good preparedness for climate-induced disasters. However, a deeper look into the individual CDRI dimensions exposes areas for improvement.

The highest scores were observed in the institutional dimension, suggesting effective policy measures implemented by local government agencies. These policies address the specific needs and challenges of each district, as evidenced by practices like establishing emergency response plans, building resilient infrastructure, and supporting disaster prevention and recovery (Phuong *et al* 2023, Tuan Hai and Kim Hoang 2023). Additionally, effective management by these agencies ensures policy enforcement and fosters collaboration with stakeholders (Alibašić 2018). Importantly, policies are tailored to local contexts, such as adjusting emergency plans based on geographical features (Tran and Bui 2023).

The physical dimension, encompassing factors like electricity, water systems, and transportation, plays a crucial role in minimizing disaster impacts and facilitating swift recovery. A stable electricity supply is vital for maintaining healthcare, transportation, and communication during emergencies (Do 2023). Similarly, a reliable water supply system is essential for post-disaster health, sanitation, and firefighting (Nguyen Trung 2023). Robust transportation infrastructure, including wide roads, efficient public transport, and supportive structures, ensures smooth daily mobility and timely emergency responses (Martello and Whittle 2023).

High scores in the social dimension highlight strong social cohesion, quality human resources, and active community participation in Dien Chau, Nghi Loc, and Quynh Luu. These factors are crucial for resilience against climate challenges (Phuong *et al* 2023). Diverse and densely populated communities foster motivation and a variety of perspectives when addressing environmental issues (Cuesta *et al* 2023). Active community engagement strengthens resources and promotes knowledge-sharing, essential for effective climate resilience programs. Additionally, robust healthcare systems and education equip communities with the necessary skills to cope with and adapt to climate change impacts (Do 2023).

A recurring weakness across all districts is the low score in the economic dimension. This reflects a relative weakness in financial preparedness, aligning with previous research on the importance of access to savings and credit facilities for coastal communities (Wan Mohd Rani *et al* 2018). Suryanto *et al* (2021) further emphasized the need for improved credit access to enable proactive investment in disaster preparedness measures. Strategies to address this vulnerability include: (1) Microfinance initiatives: Providing access to small loans and financial products tailored to the needs of coastal residents; (2) Livelihood diversification: Promoting alternative income sources beyond traditional fishing and agriculture; or (3) Social safety nets: Developing robust programs to provide financial assistance during and after disasters (Frankenberg *et al* 2013).

The assessment results of factors related to natural resources in Nghe An province, Vietnam, highlight the critical role of the natural dimension in climate change resilience (Wolff and Hamel 2023). Firstly, environmental protection is crucial for community health and sustainable development, emphasizing the need for careful consideration and mitigation of human activities impact on the environment (Do *et al* 2023). Secondly, optimizing natural resource use is essential, with fluctuations in scores indicating the necessity for specific conservation and utilization strategies to maintain ecological balance and support development (Do and Frör 2022). Thirdly, urban planning and land use adjustments are vital, requiring flexible strategies to ensure efficient and sustainable land use that aligns with community needs and potential (Duong Thi *et al* 2021).

In general, the CDRI tool enables comparisons between different regions; however, its application must be conducted with caution and based on solid data. Although comparisons may involve certain risks, this tool provides valuable information for assessing and comparing the resilience of various locations, thereby assisting in the formulation of appropriate policies. However, comparisons between regions may lead to misunderstandings if the specific conditions of each region are not thoroughly considered. The indices may offer a relative view of the situation but do not necessarily reflect the actual differences in resilience without accounting for local factors and specific conditions. Currently, the use of CDRI in climate change research in Vietnam is limited, resulting in insufficient data for effective comparisons. In the near future, we plan to extend our research to other regions to establish a comparative basis. Once results from different or similar regions are available, they will provide a foundation for developing policies that integrate economic and social development with climate change adaptation. Research at the commune level will also serve as a basis for scaling up to larger units such as districts and provinces, generating data for broader studies. This study provides a valuable snapshot of climate disaster resilience in these coastal districts. While areas for improvement exist, particularly in economic preparedness, the overall findings offer a positive outlook. By addressing these vulnerabilities and capitalizing on existing strengths, these communities can further enhance their resilience to climate change impacts.

6. Conclusion

This study evaluated the resilience of the three districts of Dien Chau, Nghi Loc, and Quynh Luu to climate-induced disasters using the overall CDRI index and specific dimensions such as economic, social, institutional, physical, and natural. The results indicate that all three districts have good to high recovery capacities, with Dien Chau having the highest overall CDRI score. However, the economic dimension has the lowest resilience level. Economic variables such as savings, finance, and subsidies need improvement to enhance economic resilience.

In the physical dimension, all three districts show good to high recovery capacities, with electricity, water, and transportation infrastructure scoring higher, while housing and land use need improvement. The social dimension's resilience is also high, particularly in the population parameter, but social capital requires more attention. Institutionally, the policies and government management in the districts have been effectively implemented, with a focus on integrating disaster risk reduction and climate change adaptation actions into development plans. Regarding the natural dimension, the districts have effectively utilized natural resources and demonstrated strong resilience to natural hazards and environmental pollution. However, the quality of land use planning and management still needs improvement to ensure sustainability.

The results of this study not only provide an overview of the resilience levels of the districts in the face of climate-induced disasters but also suggest specific directions for enhancing recovery capacity through improvements in economic factors, investment in infrastructure, and strengthening social capital. This will help the districts not only to better cope with current disasters but also to prepare for future challenges.

7. Limitations and future research directions

This research provides a valuable snapshot of climate disaster resilience in three coastal districts of Central Vietnam. However, some limitations are worth acknowledging. The CDRI framework focuses primarily on objective factors. Incorporating qualitative data, such as community perceptions of resilience, could offer a more nuanced understanding. Additionally, future research could explore the effectiveness of existing disaster risk reduction policies and programs in these districts. By addressing these limitations and building upon the findings presented here, we can contribute to a comprehensive understanding of coastal community resilience and develop effective strategies to enhance their preparedness for climate change impacts.

Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

Funding

No funding was received for conducting this study.

CRediT authorship statement

Nguyen Thi Huong Giang: Conceptualisation, Methodology, Investigation, Formal Analysis, Writing-Original Draft.

Tran Xuan Minh: Conceptualisation, Methodology, Investigation, Formal Analysis, Writing-Original Draft, Writing-Review & Editing.

Hoang Dung Ha: Conceptualisation, Supervision, Writing-Review & Editing.

Nguyen Thi Kim Chung: Methodology, Investigation, Formal Analysis.

Conflict of interest

The authors declare there is no conflict.

ORCID iDs

Nguyen Thi Huong Giang https://orcid.org/0009-0002-0927-8263
Tran Xuan Minh https://orcid.org/0000-0003-3674-686X
Hoang Dung Ha https://orcid.org/0000-0002-4539-8740

References

Adger W N 2000 Social and ecological resilience: are they related? *Progress in Human Geography* **24** 347–64

Akter M M, Hosen M I and Nasher N M R 2024 Assessing household resilience to climate extremes using indicator-based index in hazard-prone areas; evidence from Bangladesh *Environmental Challenges* **15** 100957

Alibašić H 2018 Leading climate change at the local government level *Global Encyclopedia of Public Administration Public Policy and Governance* ed A Farazmand (Springer) (https://doi.org/10.1007/978-3-319-31816-5_3428-1)

Almutairi A, Mourshed M and Ameen R F M 2020 Coastal community resilience frameworks for disaster risk management *Nat. Hazards* **101** 595–630
Antronico L, Carone M T and Coscarelli R 2023 An approach to measure resilience of communities to climate change: a case study in Calabria (Southern Italy) *Mitigation and Adaptation Strategies for Global Change* **28** 20
Bien V T, Tien H N D, Son N T, Vinh B L, Quan N V, Hanh D T D, Khanh P D and Phuong T T 2022 Climate change and farmers' adaptation strategies: the case of rice producers in Nghe An province Vietnam *Vietnam Journal of Agricultural Sciences* **5** 1359–74
Cuesta J, Cai L, Madrigal L and Pecorari N 2023 Exposure to climatic risks and social sustainability in Vietnam *Sustainability* **15** 3260
D'Angeli M, Marin G and Paglialunga E 2022 Climate change armed conflicts and resilience *FEEM Working paper* 4 4 48 8
Do H H and Frör O 2022 River ecosystem resilience: applying the contingent valuation method in Vietnam *Sustainability* **14** 12029
Do L H T 2023 Household adaptation to climate change in the coastal Mekong Delta province: the case of Tra Vinh provinceEGU General Assembly Vienna Austria 24-28 Apr 2023 EGU23-1921 (https://doi.org/10.5194/egusphere-egu23-1921)
Do T D and Tran H T 2017 Assessment of the impact of flooding to arable land usage in the coastline of Nghe an in the context of climate change *Vietnam Journal of Hydro–Meteorology* **674** 1–7 (in Vietnamese)
Duc D M, Yasuhara K, Hieu N M and Lan N C 2017 Climate change impacts on a large-scale erosion coast of Hai Hau district Vietnam and the adaptation *Journal of Coastal Conservation* **21** 47–62
Duong Thi T, Do Minh D and Tran Thi L 2021 Building climate change resilience indicators for the rural commune in the northern delta Vietnam *Proceedings of the International Conference on Innovations for Sustainable and Responsible Mining Lecture Notes in Civil Engineering* 108 ed B D Tien, H T Tran and X N Bui (Springer) 396–428
Frankenberg E, Sikoki B, Sumantri C, Suriastini W and Thomas D 2013 Education vulnerability and resilience after a natural disaster *Ecology and society: a journal of integrative science for resilience and sustainability* **18** 16
Hoang H D, Momtaz S, Schreider M, Nguyen C V and Nguyen T D 2022 The resilience of fisheries households to climate shock in Tam Giang-Cau Hai Lagoon Vietnam *Climate Change and Risk in South and Southeast Asia* (Routledge) 6 23
Hoang L T T 2019 Assessing the vulnerability of the agricultural sector in Nghe An province due to the impact of climate change taking into account the weight of indicators *VNU Journal of Science: Earth and Environmental Sciences* **35** 57–67 (in Vietnamese)
Hung C H, Hung H C and Hsu M C 2024 Linking the interplay of resilience, vulnerability, and adaptation to long-term changes in metropolitan spaces for climate-related disaster risk management *Climate Risk Management* **44** 100618
Imani M, Fakour H and Lo S L 2021 Exploring climate disaster resilience: insight into city and zone levels of Southern Taiwan *Agriculture* **11** 107
Joerin J, Shaw R, Takeuchi Y and Krishnamurthy R 2014 The adoption of a climate disaster resilience index in Chennai India *Disasters* **38** 540–61
Klein R J, Nicholls R J and Thomalla F 2003 Resilience to natural hazards: how useful is this concept? *Global Environmental Change Part B: Environmental Hazards* **5** 35–45
Krishnamurthy R J J, Shaw R and Takeuchi Y 2011 *Second National Research Conference on Climate Change ReportApplying a Climate Disaster Resilience Index (CDRI) to enhance planning decisions in Chennai India (IIT Delhi, November 5-6)* 24
Manyena S B 2006 The concept of resilience revisited *Disasters* **30** 434–50
Martello M V and Whittle A J 2023 Climate-resilient transportation infrastructure in coastal cities *Adapting the Built Environment for Climate Change* ed F P Torgal and C G Granqvist (Elsevier) 73–108
MONRE 2020 *Climate Change Scenarios* (Ministry of Natural Resources and Environment (MONRE)) 286 (in Vietnamese) http://vnmha.gov.vn/upload/files/kich-ban-bien-doi-khi-hau-phien-ban-cap-nhat-nam-2020.pdf
MONRE 2022 *National Adaptation Plan for the Period 2021–2030* with a vision to 2050(Ministry of Natural Resources and Environment (MONRE)) 173 https://undp.org/vietnam/publications/national-adaptation-plan-period-2021-2030-vision-2050
NAPC 2021 *Report on planning of Nghe An province for the period 2021 - 2030 vision to 2030 (in Vietnamese)* Available at: https://storage-vnportalvnptvn/nan-ubnd/2815/quantritintuc/1-Bao-cao-tom-tat-quy-hoach-tinh_in637852033657879567pdf
NAPC 2022 *Solutions for Storm and Flood Prevention and Control in Nghe An in the Face of Extreme Weather Trends Due to Climate Change (in Vietnamese)* Available from:https://dbndngheanvn/giai-phap-phong-chong-bao-lut-tai-nghe-an-truoc-xu-the-thoi-tiet-cuc-doan-do-bien-doi-khi-hau-7334htm (accessed on March 6 2024)
NAPC 2023 *Nghe An Suffered Nearly 700 billion VND in Damage Due to Natural Disasters in 2023 (in Vietnamese)* Available from: https://baonghean.vn/nam-2023-nghe-an-thiet-hai-gan-700-ty-dong-do-thien-tai-post286407.html (accessed on March 18 2024)
NAPC 2024 *Many Infrastructure Development Projects in the Coastal Areas of Nghe An (in Vietnamese)* Available from: https://baongheanvn/nhieu-du-an-phat-trien-ha-tang-vung-ven-bien-nghe-an-10246032html (accessed on March 18 2024)
Nguyen Q, Ngo H and Vu M 2023 Advantages of altering cropping schedules in the face of climate variability: a case study of Tan Ky sugarcane cultivation area Nghe An province *Research on Crops* **24** 132–8
Nguyen Trung K 2023 *OSFpreprints* 10.31219/osf.io/fu487 Jan 7thExamining disaster and climate change studies using the funnel of multiple capital deployment (FMAD) framework: a review of Vietnamese literature
Norris F H, Stevens S P, Pfefferbaum B, Wyche K F and Pfefferbaum R L 2008 Community resilience as a metaphor theory set of capacities and strategy for disaster readiness *American journal of community psychology* **41** 127–50
Paneru S, Feng Y, Xia C, Hu Y and Wang J 2024 An exploratory investigation of social vulnerability from the building resilience perspective *Construction Research Congress* 2 ed S S Jennifer, M M Katherine, M Yunjeong, P Cristina and E S Roy (American Society of Civil Engineers) 156–164
Parry M L, Canziani O F, Palutikof J P, van der Linden P J and Hanson C E 2007 *Climate Change 2007: Impacts Adaptation and Vulnerability Contribution of Working Group ii to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (Cambridge University Press) p 982
Pham T T M 2022 Nghe An's efforts to respond to climate change (in Vietnamese)Available from: https://m.khxhnvnghean.gov.vn/?chitiet=2631&nghe-an-nhung-n%E1%BB%97-luc-ung-pho-voi-bien-doi-khi-hau.html (accessed on March 18 2024)
Phan T T H and Nguyen H A 2023 Spatial and temporal distributions of temperature and rainfall on tropical islands of Vietnam *Journal of Water and Climate Change* **14** 1395–412
Phuong T T, Tan N Q, Hai N T and Ngu N H 2023 Reframing climate change resilience: an intersectional perspective of ethnicity and gender from Vietnam *Climate* **11** 85
Rezaie A M, Ferreira C M, Walls M and Chu Z 2021 Quantifying the impacts of storm surge sea level rise and potential reduction and changes in wetlands in coastal areas of the Chesapeake Bay region *nat. Hazard. Rev.* **22** 04021044
Shackleton R T, Malherbe W and Biggs R 2024 96: Resilience *In Elgar Encyclopedia of Interdisciplinarity and Transdisciplinarity Cheltenham UK* Edward Elgar Publishing

Shaw R and Team I 2009 Climate disaster resilience: focus on coastal urban cities in Asia *Asian Journal of environment and disaster Management* **1** 101–16

Suryanto, Arrasyid P and Choya T A 2021 Implementation of climate and disaster resilience initiative (CDRI) in kampung sewu surakarta central java Indonesia *IOP Conf. Ser.: Earth Environ. Sci.* **724** 012104

Tan N Q, Dinh N C, Linh N H K, Hung P X, Kien N D, Phuong T T and Tinh B D 2023 Climate change vulnerability and poverty nexus: evidence from coastal communities in central Vietnam *Journal of Agriculture and Environment for International Development (JAEID)* **117** 61–84

Thai T H, Van Dai H and Dung L D 2015 Assessment of climate change on inundation in Nghe An *Scientific and Technical Hydro-Meteorological Journal* **660** 1–4 (in Vietnamese)

Tompkins E L and Adger W N 2004 Does adaptive management of natural resources enhance resilience to climate change? *Ecology and society* **9** 10

Tran C T and Bui P P T 2023 Research how to establish a policy to respond to climate change in Vietnam *Thu Dau Mot University Journal of Science* **5** 200–9

Tran P T, Vu B T, Ngo S T, Tran V D and Ho T D 2022 Climate change and livelihood vulnerability of the rice farmers in the North Central Region of Vietnam: a case study in Nghe An province Vietnam *Environmental Challenges* **7** 100460

Tran-Anh Q, Ngo-Duc T, Espagne E and Trinh-Tuan L 2022 A high-resolution projected climate dataset for Vietnam: construction and preliminary application in assessing future change *Journal of Water and Climate Change* **13** 3379–99

Tuan Hai D and Kim Hoang N 2023 Maintenance policies and practices on resilient houses: case study from a coastal resilience project in Vietnam *Sustainability* **15** 5842

VnEconomic 2024 Enhancing Climate Change Resilience Capacity for Four Coastal Provinces in North Central Vietnam (in Vietnamese) Available from: https://vneconomyvn/tang-cuong-nang-luc-chong-chiu-bien-doi-khi-hau-cho-4-tinh-ven-bien-bac-trung-bohtm(accessed on 18 May 2024)

Walker B, Holling C S, Carpenter S R and Kinzig A 2004 Resilience adaptability and transformability in social-ecological social-ecological systems *Ecology and society Society* **9** 5

Wan Mohd Rani W, Kamarudin K, Razak K, Hasan R C and Mohamad Z 2018 Measuring urban resilience using Climate Disaster Resilience Index (CDRI) *The International Archives of the Photogrammetry Remote Sensing and Spatial Information Sciences* **42** 237–42

Wolff E and Hamel P 2023 *Measuring the Effects of Nature-Based Solutions for Climate Resilience in Informal Settlements in the Asia-Pacific EGU23-4594 (Vienna, Austria, 24–28 Apr)* (EGU General Assembly) (https://doi.org/10.5194/egusphere-egu23-4594)