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Architecture of Coastal Rural Houses in Thai Binh Province, Vietnam for Adaptation to Climate Change and Sea-Level Rise

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Abstract

In Thai Binh province, Vietnam, according to the RC4.5 climate change scenario by the end of the 21st century, sea levels are projected to rise by a maximum of 100 cm. This will result in the flooding of 22,313 hectares (66.13%) of Tien Hai District, 21,750 hectares (64.39%) of Kien Xuong District, and 26,756 hectares (47.94%) of Thai Thuy District. Such a rise in sea levels will significantly impact residential areas, housing, and agricultural production in the coastal villages of Thai Binh Province. The article's aim is to propose architectural models for rural housing in these coastal hazard areas, allowing communities to adapt to climate change and sea-level rise. The goal is to help coastal residents continue living with inundation while ensuring a good quality of life and sustainable working conditions. The study uses field survey methods, document collection, data analysis, evaluation and computer simulation based on actual sea level rise to propose housing solutions. The article contributes proposes housing and shelter models for communities affected by rising sea levels, including houses with horizontally integrated shelter spaces in estuary areas, as well as houses with raised platforms and those integrating vertical shelter spaces in alluvial land areas.

1. Introduction

Thai Binh, a province in the northern coastal plain of Vietnam, currently has 24 villages along the coast, which stretches over 50 km and belongs to two main districts, Thai Thuy and Tien Hai. These villages are heavily affected by climate change, wind, rain, storms, and sea-level rise annually. The topography of the case study area is relatively flat with a gentle slope of less than 1%, the elevation is 1-2 m above sea level, and the area gradually declines from northwest to southeast and toward the coast [15]. Given the terrain of the coastal rural areas in Thai Binh Province, all low-lying regions near river mouths are prone to seawater intrusion as sea levels rise. Besides, the survey of housing types in 24 coastal communes of Thai Binh province shows three main house types: traditional single-story houses built with brick walls, pitched roofs using tiled shingles, corrugated iron sheets, or fibro-cement panels (approximately 16.75%); one-story houses with brick walls, flat roofs (or part of the roof is flat) being reinforced with concrete (approximately 68.25%) and two-to-three-story houses built with a reinforced concrete column frame, brick walls, and a reinforced concrete flat roof (or corrugated iron roofs) (15%). Statistics of survey data on housing types according (Fig. 1).

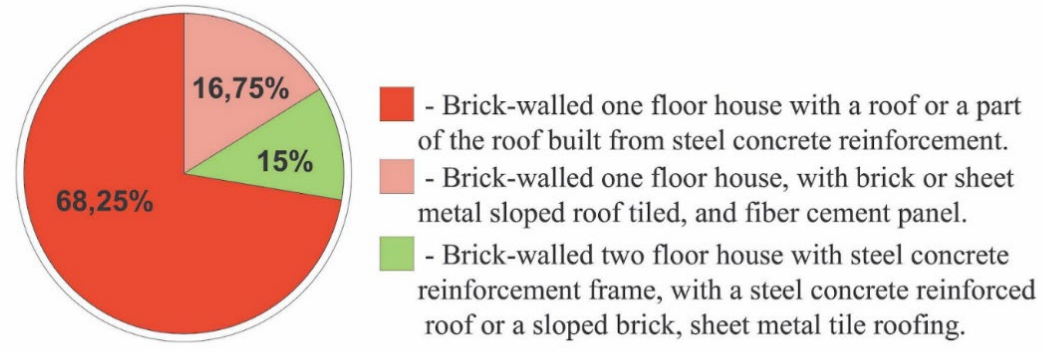

Fig. 1 *The proportion of housing types in 24 coastal villages of Thai Binh*

From these survey data, the proportion of traditional single-story houses remains large, which accounts for 85% of the total coastal houses in Thai Binh. These houses generally have low foundations, with an average height of 20-45 cm. As a result, single-story homes are vulnerable to flooding during high tides caused by storms and rising sea levels due to climate change. This will create significant challenges for residents in these coastal areas, impacting their daily lives and work. The first challenge is that rising sea levels will encroach on residential land, affecting people's living and dining spaces. The second challenge involves cultural, lifestyle, and customary disruptions. The third challenge concerns the impact on agricultural and rural economic production.

An overview of the research situation shows that existing studies mainly focus on several themes: proposing resilient and sustainable housing models in the context of climate change [5, 10, 17]; developing floating houses adapted to rising sea levels in Can Gio District [14, 26]; Introducing housing models and construction guidelines to minimize climate impacts [1, 13, 24, 32]; assessing the risks of coastal residential spaces [10,13 12, 22, 23]; suggesting planning and architectural solutions for reclaimed land [7, 25]; engaging communities to enhance adaptation and environmental restoration [11, 21, 27] and providing management strategies for local coastal authorities to cope with sea level rise and tidal flooding [4, 6, 16].

In summary, recent research emphasizes floating housing models for flood adaptation, housing modes with the ability to recover after floods and the management solution with the participation of coastal communities adapting to sea level rise. However, no study has specifically explored housing architecture that integrates shelter functions, tailored to the estuarine and coastal alluvial terrain of Thai Binh province that adapts to sea level rise. Accordingly, there is a need to develop housing models that not only meet residential and livelihood requirements in flood-prone areas but also serve as effective shelters during sea levels rise caused by storms and high tides in the context of climate change. The purpose of this study is to propose models of rural housing architecture in Thai Binh province that adapts to sea level rise and harmonizes with the changing environment. The specific goal is to identify architectural models suited to the socio-economic conditions, estuarine terrain, and coastal alluvial soil, allowing people to respond to challenges caused by climate change and rising sea levels.

2. Literature Review

The research team has reviewed scientific works on coastal housing architecture that adapts to climate change and sea-level rise to determine unresolved issues, specifically with the conditions of the coastal villages of Thai Binh Province. Michelle A. Ruiz and Yazmin L. Mack-Vergara [17] introduce concepts of urban resilience and sustainability while proposing three housing models that enhance resilience and four models that promote sustainability in the context of climate change. These housing models consider local climatic parameters, energy efficiency, indoor environmental quality, and the promotion of locally available materials and resources. Ngo et al. [14] examined the experiences of houses adapting to sea-level rise and proposed reinforced concrete frame floating floors and technical infrastructure systems for residential spaces in Can Gio District, Ho Chi Minh City. Sebastian Weissenverger and Omer Chouinard [27] authored a book providing an interdisciplinary perspective on the impacts of climate change on coastal areas and sea-level rise. Their work proposes strategies, tools, and community engagement methods to enhance climate adaptation and environmental resilience. Doug Ramsay and Rob Bell of NIWA, with contributions from Robin Britton [6], addressed three key issues in their study Preparing for Coastal Change: A Guide for Local Government in New Zealand. First, they developed planning strategies for sea-level rise in New Zealand, explaining the impacts of climate change on coastal hazards such as storm surges and tidal flooding. Second, they identified risks related to flooding, tsunamis, and coastal erosion while assessing saltwater intrusion into freshwater sources, including both surface and groundwater. Third, they outlined legal frameworks and management mechanisms for risk mitigation and disaster prevention in coastal areas. In her study Aquatecture: Architectural Adaptation to Rising Sea Levels, Erica Williams [8] further expanded on aquatecture as an adaptive housing and urban development strategy. Beyond residential structures, the study proposed integrated transport systems, renewable energy support, and livelihood activities tailored to flood-prone environments. Andrea Ward and Alex Wilson [1], in Design for Adaptation: Living in a Climate-Changing World, presented housing models and construction guidelines aimed at minimizing the impacts of climate change. Gordon McGranahan, Deborah Balk, and Bridget Anderson [12] evaluated the risks of climate change on settlements in coastal areas below 10 meters in elevation, analysing population distribution and coastal habitation patterns. Dinh-Van Nguyen [7] researched planning and designing residential clusters in reclaimed coastal land areas of northern Vietnam. His study provided planning and architectural solutions for housing in these reclaimed land areas, ensuring environmental compatibility and climate adaptability for the coastal regions of northern Vietnam.

Analysis of the aforementioned and several other significant studies [9, 18–20] reveals that, overall, these works have not specifically addressed rural coastal housing models adapted to sea-level rise in the alluvial and estuarine areas of Thai Binh Province. Consequently, further research is required to develop architectural models for rural housing that are suited to the unique land conditions of coastal villages in this region.

3. Research Methods

This study utilized a combination of fieldwork, document analysis, comparative research, and computer simulation to develop adaptive housing models suited to sea-level rise in coastal areas of Thai Binh Province.

Field research method: A qualitative field survey was conducted to observe and document the architectural characteristics of local residential buildings, focusing on structural layout, number of floors, and construction materials. The fieldwork followed a five-step process:

- Step 1: Develop survey plans and select participants.
- Step 2: Define the survey area, covering 24 villages along a 50 km coastal stretch of Thai Binh Province.
- Step 3: Collect data onsite using photography, measuring tapes, and sketching. A total of 7,679 houses were documented across the 24 villages.
- Step 4: Analyze the data to classify houses by floor count, wall materials, and roof types.
- Step 5: Evaluate the housing types for their capacity to withstand flooding and respond to sea-level rise.

Comparative research method: Lessons were drawn from indigenous construction practices and international examples of climate-resilient housing to inform design adaptability.

Document analysis synthesis method: Existing literature was reviewed to identify knowledge gaps and establish the research basis for proposing new architectural models.

Computer simulation method: Flooding scenarios were simulated to test the adaptive performance of proposed housing designs.

3.1 Practical Foundations and Lessons Learned

People in the coastal villages of Thai Binh province who build housing architecture to cope with flooding and sea-level rise have long-term experience in digging ponds, lakes, and canals and using the volume of excavated soil to raise the foundation of the house so that the floor is always higher than flooded water level. They also have experience in building houses on supported columns above the highest flood level in the year to ensure safety for people to live in and protect household properties (Fig. 1).

Experiences from some countries in the world on building houses on embankments by digging canals around to get the soil to build up the foundation, such as in the Netherlands, building houses on supported columns such as in the US, and floating houses such as houseboats (Fig. 2).

Vietnam's national criteria for new rural communes encompass 19 distinct criterial [2], notably:

- Criterion 1: Planning rural residential areas.
- Criterion 2: Traffic.
- Criterion 3: Irrigation and natural disaster prevention and control.
- Criterion 9: Residential housing.
- Criterion 13: Production organization and rural economic development.

These five criteria are pivotal in shaping coastal rural housing architecture, ensuring adaptability to climate change and sea-level rise. Therefore, when examining architectural models for coastal rural housing in Thai Binh province, emphasis on these criteria is essential to formulate proposals that met the required standards.

3.2 Current Status of the Study Area

3.2.1 System of Estuaries

Thai Binh Province is characterized by a semi-enclosed hydrological system, bordered by the sea and intersected by five major estuaries: Thai Binh, Diem Ho, Tra Ly, Lan, and Ba Lat (which account for nearly half of the 11 primary estuaries along the northern coastal zone of Vietnam). These estuarine systems are subjected to strong tidal influences, particularly during the summer months when tidal amplitudes increase, and sediment-laden flows become more intense. Under these conditions, saline water intrusion and tidal surges can penetrate 15–20 kilometers inland. Consequently, the combined impacts of sea-level rise and intensified tidal dynamics are expected to significantly disrupt residential stability, infrastructure resilience, and agricultural productivity across the province's coastal and near estuarine zones (Fig. 4).

Fig. 2 *Houses on high ground in the North and houses on columns in the South of Vietnam (Source: Author, 2024)*

Fig. 3 *Houses on high ground in the Netherlands and coastal areas in the United States (Source: Internet)*

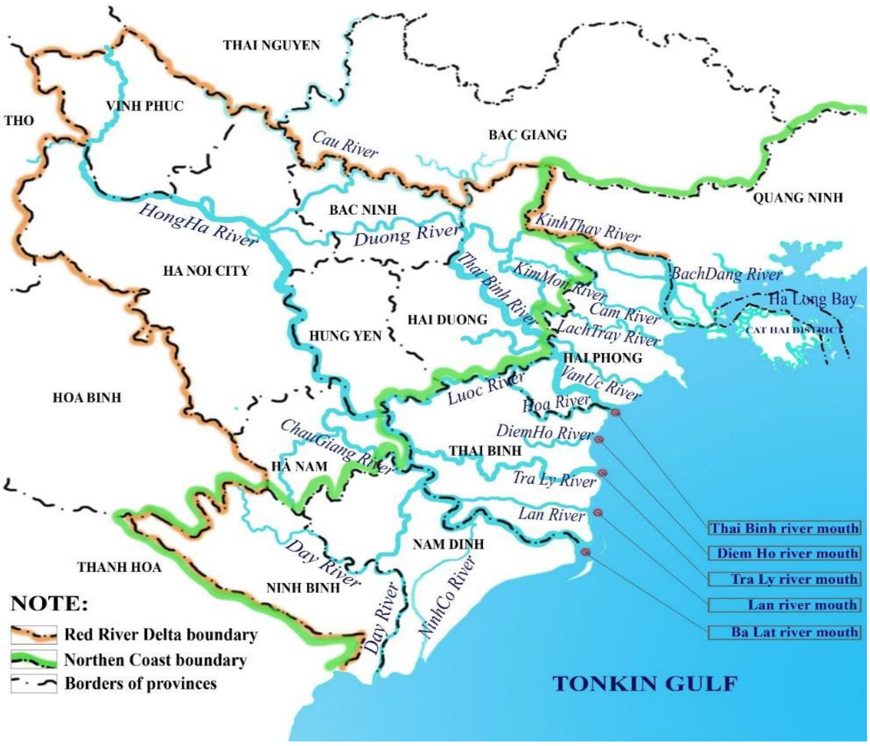

Fig. 4 *Location of 5 coastal estuaries in Thai Binh Province*
(Source: Google Map)

3.2.2 Topographic Characteristics

For the alluvial soil area, coastal alluvial soil is formed in estuarine transition zones. Dunes in estuaries extend parallel to the coastline with elevations of 1-2 m relative to sea level. After reaching a certain elevation, the dunes will expand and lengthen; then, the elevation is usually stable from 0.25 to 1 m above sea level [1]. Therefore, the average height of the alluvial land is approximately 0.75 m above sea level.

For estuarine land areas with complex topography and vulnerability to seawater intrusion, the highest level of sea-level rise by storms has occurred up to 3.5 m and could be up to 4.9 m with tidal amplitudes of 1.7-2 m [1]. Meanwhile, in the estuary land area, which is also densely populated, there are 16 villages with approximately 2.068 households.

3.2.3 Housing Architecture

A survey of 7,679 households in 24 coastal villages found that most of the family houses-built lakes and ponds to raise fish while helping to drain surface water, used excavated soil for embankments and raised the elevation of the campus to avoid flooding. With 85% of traditional one-story houses today with ground floors, pitched roofs or reinforced concrete roofs, the remaining structures such as kitchens, toilets, warehouses, and livestock barns are one-story houses with very sketchy construction and roofing material. Thus, when the sea level rises, most of the existing houses will be submerged in water. In terms of the need to renovate and build houses, all residents want to expand the space and add modern equipment to the houses to serve their lives and be ready to adapt to sea-level rise.

4. Research Results

Based on the lessons learned in Section 4 and the analysis of terrain characteristics and land conditions in the river estuaries and coastal alluvial areas of Thai Binh Province in Section 5, this study proposes four architectural housing models adapted to sea-level rise. These include two models for new housing construction and two models for the renovation of existing housing spaces: 1) Column-supported house models; 2) House models with integrated horizontal space; 3) House models with a raised foundation; 4) House models with integrated vertical space.

4.1 Column-supported House Model

The semi-opened or opened ground floor serves multiple purposes such as resting, production activities, sales transactions, or storage of tools (e.g. fishing or farming equipment). The upper floor functions as the main living and reception area for the family, while the attic is designated for storing food and valuable items. The height of the ground floor in the estuary land area must be 1 m higher than the sea-level rise because the highest storm that can occur is 3.5 m. Thus, depending on the location of housing construction, the appropriate ground floor height will be chosen, but the minimum compared to the average sea level in 2021 is 4.5 m. The upper floor is 2.7-3.3 m in height and the attic is 2.2 m in height (Fig. 5).

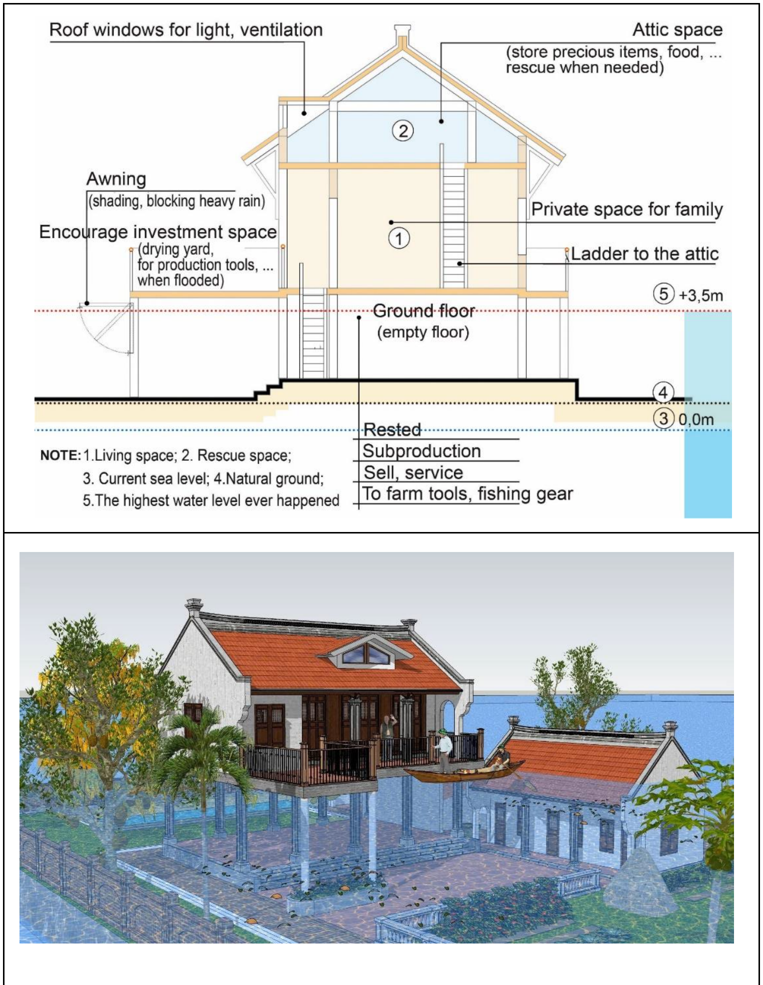

Fig. 5 *Model of column house in the estuary area and flooding scenario simulation (Source: Author, 2024)*

4.2 House Models with Integrated Horizontal Space

In this model, a structure is built next to the existing house to adapt to sea-level rise. In terms of function and architecture, the adaptive space has identical requirements to the model house on supported columns, but it is connected to the existing house to save space and to be usable even when the water recedes. The area of housing with integrated horizontal space ensures at least 4 people with an area of 15-16 m2 per house. The height of the ground floor must be 4.5 m or higher than the average sea level in 2021. Attic floors are recommended for the adaptive space to use for food storage. In addition to the adaptation space, it is advisable to build more space with an area of approximately 9-15 m2 for poultry farming when flooded (Fig. 6).

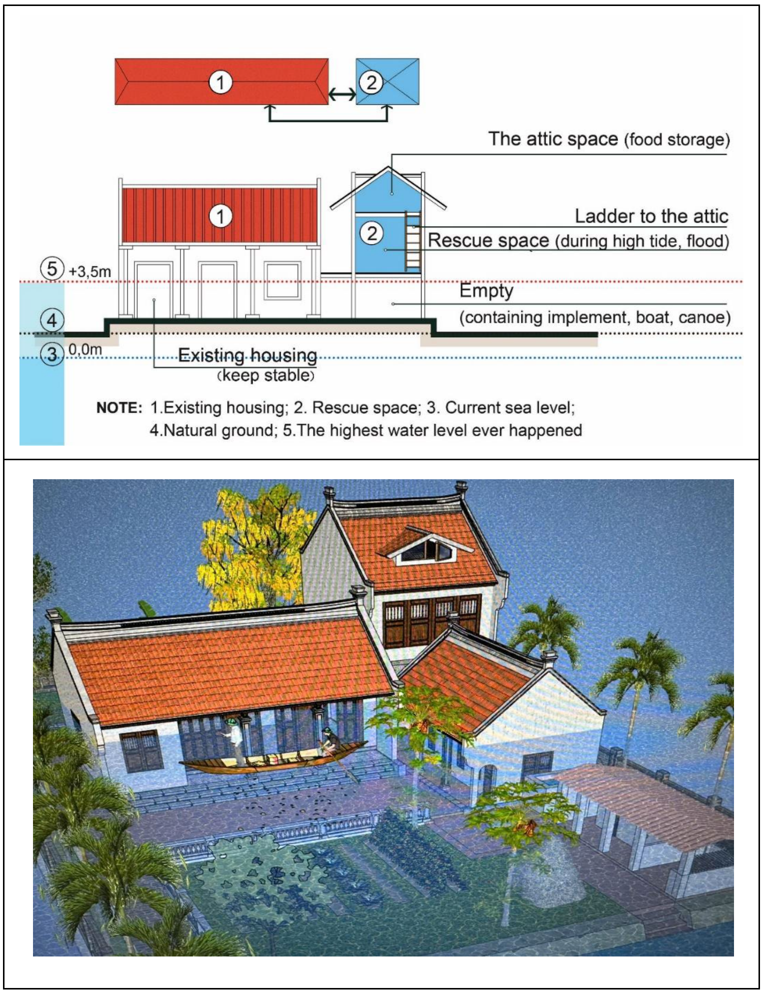

Fig. 6 *The house model integrates horizontal space in the estuarine land area and simulates a flooding scenario (Source: Author, 2024)*

4.3 House Models with a Raised Foundation

The foundation is embanked with solid rock, or embankment by closing the bamboo trees together, compacting the soil, and adding a layer of crushed stone every 0.5 m to make the ground stronger. On this high ground, houses will be built. The ground to be reinforced must be at least 1 m higher than the sea-level rise, so the minimum height of the foundation in the alluvial zone must be approximately 1.75 m compared to the average sea level in 2021. The height of the housing space is guaranteed to be 3.3-3.6 m, and it is recommended to build an additional attic to avoid sea-level rise when the highest storm has occurred up to 3.5 m (Fig. 7).

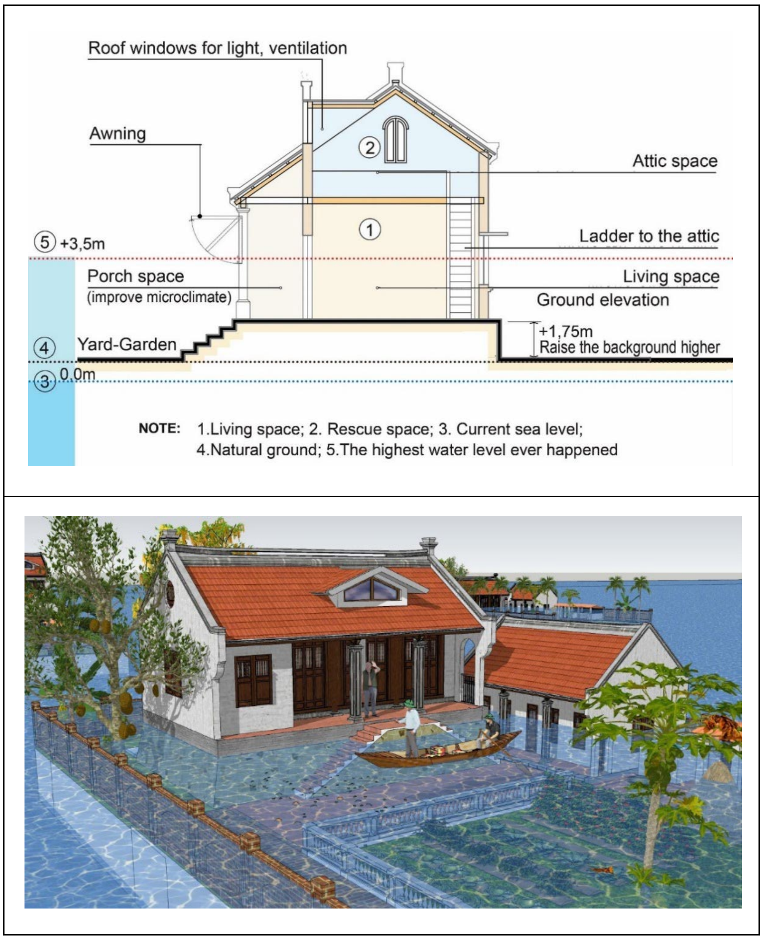

Fig. 7 *Model of high-floor houses in alluvial lands and simulation of flooding scenarios (Source: Author, 2024)*

4.4 House Models with Integrated Vertical Space

This housing model retains the existing architectural space structure of the existing house, renovates and raises the height of the existing house to add more attic space, and the space below must be at least 3.3-3.6 m. The average height of the attic is at least 2.2 m to ensure safety for users when sea-level rise occurs (the highest storm occurrence is 3.5 m). For adaptive space renovation, it is necessary to further enhance the roof by replacing the roof structures with lightweight, easily removable materials. For example, the roof sheet can be replaced with 3D panels. It is necessary to open roof windows to the south and southeast to receive cool winds blowing from this direction. The floor is tiled with moisture-proofing bricks and plastered with waterproofing in the wall footing to ensure protection when the house is flooded with seawater (Fig. 8).

5. Discussion

Some housing models capable of adapting to rising sea levels, such as houseboats and floating houses, are not suitable for the coastal areas of Thai Binh near river estuaries. These areas experience strong hydrodynamic currents and are frequently affected by storms, tidal surges, and high winds, making such housing models impractical in this region.

Among the four proposed adaptive housing solutions for coastal villages in Thai Binh Province, three innovative features have been newly introduced: 1) The addition of a flood-adaptive shelter space in the attic above existing traditional single-story houses; 2) A comprehensive analysis of typical land types in the coastal villages of Thai Binh Province, including alluvial land and river estuary land, which will facilitate the selection of appropriate housing models. This enables residents to choose housing solutions that align with their economic conditions and the specific land characteristics of their residential and production areas; 3) The proposed housing models inherit and enhance traditional local architectural values, ensuring they are culturally, socially, and economically suited to the lifestyle and production needs of coastal residents in Thai Binh Province.

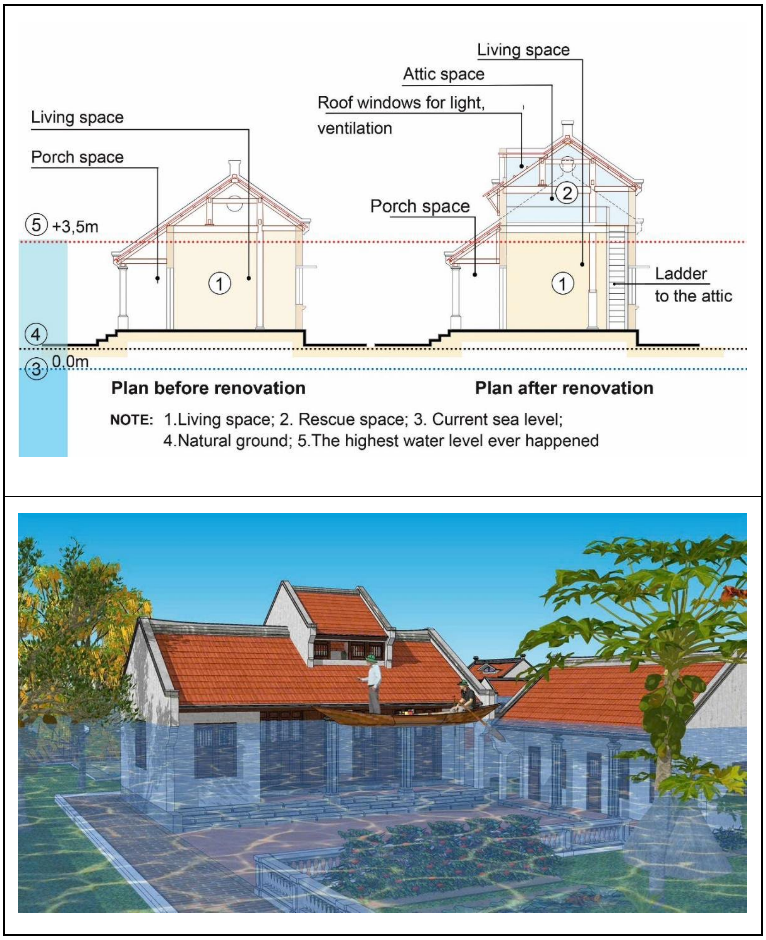

Fig. 8 *The house model integrates vertical space in alluvial land and simulates a flooding scenario (Source: Author, 2024)*

To assist residents in selecting suitable solutions for new constructions or housing renovations that fit their income levels, the research team has estimated construction costs for the four proposed housing solutions, considering the building's longevity, structural integrity, and material usage. The cost estimates, derived from investment rates published by Vietnam's Ministry of Construction, range from low to high:

- Renovating existing housing to integrate flood-adaptive shelter spaces horizontally and vertically, covering an area of 15-16m^2, for structures with a lifespan of up to 20 years, built with simple materials such as wood, brick, bamboo, nipa palm, and thatched roofs, costs between USD 650 and 1,200.
- Housing structures with a lifespan of over 50 years, built with reinforced concrete, brick walls, and tiled roofs, range from USD 1,500 to 2,500.
- New houses elevated on raised foundations or stilts, covering 50-60m^2, with a lifespan of up to 20 years, require an investment of USD 4,200 to 5,200.
- Newly constructed houses with a lifespan of over 50 years will cost approximately USD 8,500 to 15,000.

With the proposed investment costs, coastal residents in Thai Binh have the financial capacity to renovate and construct housing that adapts to climate change and rising sea levels, allowing them to coexist with the sea while maintaining their livelihoods from marine resources. However, to maximize support for residents, government authorities at all levels should implement policies that provide preferential investment funding and technical guidance for constructing housing resilient to storms, strong winds, and rising sea levels.

To facilitate the practical application of these architectural housing solutions, further research is needed to develop construction guidelines, prefabrication techniques, and the selection of sustainable, locally available building materials to reduce construction costs. Additionally, government authorities should issue supplementary regulations, standards, and guidelines for designing, constructing, and managing coastal housing that is resilient to rising sea levels.

6. Conclusion

The coastal villages of Thai Binh Province, Vietnam, face escalating threats from climate change, particularly sea-level rise, which jeopardizes housing, livelihoods, and cultural practices. With 85% of homes being low-elevation, single-story structures, residents remain highly vulnerable to flooding and storm surges. This study addressed this critical challenge by proposing adaptive housing models tailored to the socioeconomic and environmental conditions of Thai Binh's coastal communities. Through field surveys, analysis of local and international adaptation practices, and simulations of flooding scenarios, four resilient housing solutions emerged: (1) column-supported houses, (2) horizontally integrated extensions, (3) raised-foundation dwellings and (4) vertically renovated spaces. These models integrate traditional wisdom, such as elevating foundations using locally sourced materials with modern engineering to balance affordability, cultural relevance, and climate resilience. Notably, the solutions prioritize flexibility, enabling households to adapt incrementally based on financial capacity. For instance, renovating existing homes with elevated attics or extensions costs as little as USD 650–1,200, while new stilted or reinforced concrete structures range from USD 4,200-15,000. Such cost variability ensures accessibility across economic strata, empowering communities to coexist with rising seas without abandoning ancestral lands or marine-based livelihoods. The proposed models also align with Vietnam's national rural development criteria, emphasizing disaster resilience, infrastructure, and sustainable production. By avoiding impractical approaches like floating houses unsuitable for Thai Binh's dynamic estuaries, the study underscores the importance of context-specific solutions. Furthermore, it advances existing research by introducing flood-adaptive attic spaces, analyzing site-specific land typologies, and preserving vernacular architectural values. To maximize impact, collaboration between residents, policymakers, and technical experts is essential. Local authorities should prioritize subsidies, low-interest loans, and construction guidelines to scale these models. Future work must explore prefabrication techniques, sustainable material alternatives, and policy frameworks to standardize resilient design. By bridging research, tradition, and innovation, this study offers a pathway for Thai Binh and similar regions to transform vulnerability into resilience, safeguarding homes and heritage against an uncertain climatic future.

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Conflict of Interest

Authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

*The authors confirm contribution to the paper as follows: **study conception and design**: Nguyen Dinh Thi, Le Hong Dan; **data collection**: Nguyen Dinh Thi, Le Hong Dan; **analysis and interpretation of results**: Nguyen Dinh Thi, Le Hong Dan, Mai Quang Khai; **draft manuscript preparation**: Nguyen Dinh Thi, Le Hong Dan, Mai Quang Khai. All authors reviewed the results and approved the final version of the manuscript.*

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