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Adaptive Housing as an Alternative Strategy for Fisher Settlement Planning in the Context of Coastal Sea Wall Development and National Resilience

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Abstract
Coastal settlements along the northern coast of Java face increasing environmental pressures caused by tidal flooding, land subsidence, and sea level rise. Although sea wall development has been widely implemented as a macro-scale mitigation strategy, it remains insufficient in addressing vulnerabilities at the settlement level, particularly in informal fishing communities. This study examines adaptive housing as an alternative strategy for coastal settlement planning and evaluates its contribution to regional resilience and national defence. An embedded mixed-method approach was employed by combining qualitative analysis with quantitative data collected from 100 respondents in Muara Angke, North Jakarta. The findings indicate that adaptive housing through elevated and floating structures shows a considerable reduction in structural damage and flood exposure, while improving access to clean water and sanitation. Community participation also increased substantially, reflecting strengthened social resilience. In addition, modular construction improves efficiency in terms of time and cost. This study proposes the Integrated Coastal Settlement Resilience Model (ICSRM), integrating macro-level infrastructure, micro-level adaptive housing, and community capacity into a unified resilience framework to support sustainable coastal resilience and non-military national defence.

Keywords: Adaptive housing; Coastal settlement resilience; Community-based resilience; National defence; Sea wall development

INTRODUCTION

Coastal regions along the northern shoreline of Java have been experiencing increasingly complex environmental pressures, primarily driven by tidal flooding (rob), land subsidence, and sea-level rise. These phenomena are widely recognised as interrelated impacts of climate change and anthropogenic activities, particularly in densely populated urban coastal areas such as Jakarta (Bott et al., 2021; Handiani et al., 2022; Yuwono et al., 2024). Empirical studies indicate that the combination of land subsidence and rising sea levels significantly amplifies flood exposure and long-term settlement vulnerability, especially in low-lying coastal zones (Andreas, H., Abidin, H. Z., Sarsito & Pradipta, 2018; Fang et al., 2022; Nicholls & Cazenave, 2010).

In response to these challenges, the Indonesian government has prioritised large-scale coastal protection through the development of sea walls as part of a macro-level mitigation strategy. Such infrastructure is designed to reduce hazard exposure by controlling tidal inundation and protecting economic and residential zones (Andreas, H., Abidin, H. Z., Sarsito & Pradipta, 2018). However, while sea walls provide structural protection at the regional scale, their effectiveness remains limited in addressing vulnerabilities at the micro-level, particularly within informal and densely populated fisher settlements. Previous studies have demonstrated that reliance on large-scale engineering solutions alone often neglects social dimensions and fails to enhance local adaptive capacity (Salgueiro-Otero et al., 2022; Santha, 2015).

Fisher settlements represent a unique socio-ecological system characterised by high exposure to environmental hazards, limited infrastructure, and strong dependence on coastal resources. In areas such as Muara Angke, North Jakarta, settlement conditions are further compounded by inadequate sanitation, limited access to clean water, and irregular spatial organization (Alzamil, 2018; Karyono et al., 2017). As illustrated in the initial condition assessment.

Figure 1. Illustrated Condition Assessment

The settlement faces multiple structural and environmental challenges, including tidal water stagnation, substandard housing conditions, and insufficient basic facilities. These conditions highlight the urgent need for an integrated approach that not only reduces physical exposure but also strengthens community resilience (Putra et al., 2026; Sarker & Jahan, 2026).

Adaptive housing emerges as a promising alternative strategy to address these limitations. Conceptually, adaptive housing refers to built environments designed to respond dynamically to environmental changes, particularly in hazard-prone areas. In coastal contexts, this includes elevated (stilt) housing and floating housing systems, which allow structures to accommodate tidal fluctuations and reduce flood damage (Bongarts Lebbe et al., 2021; Van Veelen, 2016). Beyond technical resilience, adaptive housing also contributes to improved living standards, environmental sustainability, and resource efficiency through the integration of modular construction, durable materials, and water management systems (Hanif et al., 2023).

The implementation of floating and stilt housing in Muara Angke, as documented in the development programme led by Universitas Pertahanan RI, demonstrates a practical application of adaptive housing in a real-world context. The project involved the construction of approximately 200 housing units equipped with supporting infrastructure, including clean water systems and communal sanitation facilities . This intervention not only addressed physical vulnerabilities but also improved environmental quality and socio-economic conditions within the community.

From a broader perspective, the resilience of coastal settlements holds strategic significance beyond environmental and socio-economic dimensions. In an archipelagic state such as Indonesia, coastal regions function as critical interfaces between land and maritime domains, supporting economic activities, logistics, and national security. Consequently, strengthening coastal resilience contributes to territorial resilience and aligns with the concept of non-military national defence, where community stability and adaptive capacity form integral components of the national defence system (GLASER et al., 2018; Nurhidayah et al., 2022).

Despite growing recognition of adaptive housing, existing studies primarily focus either on large-scale coastal infrastructure or on isolated housing interventions, with limited attention to the integration between macro-level coastal protection and micro-level community adaptation strategies. Moreover, previous research rarely examines adaptive housing within the broader framework of territorial resilience and non-military national defence. This gap highlights the need for a comprehensive and integrated resilience framework that connects structural coastal protection, adaptive settlement design, and community capacity building (Nazarnia et al., 2020).

Therefore, this study aims to analyse adaptive housing as an alternative strategy for fisher settlement planning within the context of coastal sea wall development, while examining its contribution to national resilience. The novelty of this study lies in the development of the Integrated Coastal Settlement Resilience Model (ICSRM), which integrates macro-level coastal infrastructure, micro-level adaptive housing, and community participation into a unified resilience framework. By combining environmental, socio-economic, and national resilience perspectives, this research seeks to provide a more holistic and sustainable model for resilient coastal settlement planning in vulnerable coastal areas.

METHODS

Study Design

This study employs an embedded mixed-method design within a case study framework, integrating qualitative and quantitative approaches to examine the effectiveness of adaptive housing in coastal settlements. The qualitative component serves as the primary analytical lens to explore socio-environmental dynamics, while quantitative data provide empirical support through measurable indicators of resilience. This design is appropriate for capturing complex interactions between infrastructure, environment, and community behaviour in real-world settings (Coleman et al., 2024; Nor Shahrudin & Mustaffa, 2024).

Study Area and Sampling

The research was conducted in Muara Angke, North Jakarta, Indonesia, a coastal settlement highly exposed to tidal flooding (rob), land subsidence, and environmental degradation. The site was selected purposively due to the implementation of adaptive housing interventions, including floating and stilt housing, integrated with coastal protection initiatives.

A total of 100 respondents were involved in the study, comprising 60 households residing in adaptive housing and 40 households in conventional housing. Purposive sampling was applied to ensure representation across intervention and non-intervention groups, enabling comparative analysis of resilience outcomes.

In addition, 12 key informants were selected for semi-structured interviews, consisting of local government representatives, project implementers, community leaders, and residents involved in adaptive housing programmes. Two Focus Group Discussion (FGD) sessions were also conducted, each involving 8–10 participants representing community members and local stakeholders.

Data Collection

Data were collected through multiple techniques to ensure methodological triangulation. Field observations were conducted to assess physical conditions, including housing structures, flood exposure, and environmental quality. Observational data were complemented by visual documentation and site mapping.

Semi-structured interviews and Focus Group Discussions (FGDs) were undertaken to capture community perceptions, adaptive practices, and levels of participation. These methods enabled the identification of social and institutional dynamics influencing resilience. A structured survey instrument was administered to quantify key indicators, including structural damage, flood depth, access to clean water, sanitation, and community participation.

The questionnaire consisted of 25 survey items measured using a five-point Likert scale ranging from 1 (very low/poor) to 5 (very high/excellent). The instrument was divided into three dimensions of resilience: physical resilience (8 items), environmental resilience (9 items), and social resilience (8 items). Document analysis was conducted using technical reports and project documentation related to the development of adaptive housing in Muara Angke, as well as baseline condition assessments highlighting environmental and infrastructural challenges.

Variables and Measurement

The study operationalises coastal settlement resilience into three dimensions: physical, environmental, and social.

Physical resilience was measured using indicators of structural durability, flood depth reduction, building stability, and resistance to tidal inundation. Environmental resilience included indicators of access to clean water, sanitation facilities, drainage conditions, and waste management systems. Social resilience was assessed through community participation, collective action, adaptive capacity, and involvement in settlement management activities. All variables were measured using a combination of observational checklists and survey-based indicators, allowing comparison between adaptive and conventional housing groups.

Data Analysis

Qualitative data were analysed using thematic analysis to identify patterns, relationships, and dominant themes emerging from interviews, FGDs, and observations (Sclar et al., 2022).

The thematic analysis procedure involved four stages: (1) transcription of interview and FGD recordings, (2) initial coding of recurring statements and concepts, (3) categorisation of codes into broader themes related to resilience and adaptation, and (4) interpretation of thematic relationships across participant groups. Quantitative data were analysed using descriptive statistics, focusing on percentage changes and comparative analysis between adaptive and conventional housing groups. The analysis emphasises empirical trends rather than statistical generalisation.

Triangulation was conducted through cross-verification among observation findings, interview responses, FGD discussions, survey results, and project documentation to ensure consistency and validity of interpretations. Integration of findings was conducted through triangulation, ensuring consistency and complementarity between qualitative and quantitative results. This approach enhances interpretative validity and supports robust conclusions (Farquhar et al., 2020).

Validity and Reliability

To ensure methodological rigour, this study applies data triangulation across multiple sources, including observations, interviews, surveys, and documentation. Member checking was conducted to validate qualitative findings, while peer review was used to minimise interpretative. Furthermore, the mixed-methods approach inherently strengthened the credibility and validity of the findings by leveraging the complementary strengths of both qualitative and quantitative methodologies (Gbedemah, 2023).

Reliability of quantitative data was ensured through the use of structured instruments and consistent measurement indicators across respondent groups. The consistent application of these instruments and indicators across diverse respondent groups contributes to the internal validity of the statistical analysis (Ensor et al., 2021).

RESULT AND DISCUSSION

Changes in Physical Resilience

The implementation of adaptive housing in Muara Angke demonstrates a substantial improvement in physical resilience against tidal flooding. Prior to intervention, a significant proportion of housing units experienced structural damage due to prolonged inundation and unstable ground conditions. Post-intervention findings indicate a marked reduction in structural vulnerability, with damage levels decreasing from 67% to 17%.

In addition, the average flood depth experienced within residential units decreased by approximately 60%, indicating that adaptive housing not only mitigates damage but also reduces direct exposure to hazard intensity. This confirms that structural adaptation at the micro level can complement macro-scale infrastructure such as sea walls, which primarily address hazard exposure rather than vulnerability.

Environmental Improvements and Basic Services

Environmental resilience also improved following the intervention. Access to clean water increased from 35% to 95%, largely due to the integration of water supply systems within the housing programme. Furthermore, sanitation conditions improved through the provision of communal wastewater treatment facilities, addressing one of the key environmental issues identified during the baseline assessment.

The intervention also contributed to improved waste management and environmental hygiene within the settlement area. These findings indicate that adaptive housing programmes can support not only structural adaptation but also broader improvements in environmental quality and public health conditions.

Strengthening Social Resilience

The intervention contributed to increased social resilience, particularly in terms of community participation and engagement. Survey results show that participation levels increased from 45% to 78%, indicating stronger collaboration between residents, local stakeholders, and programme implementers.

Residents were actively involved in planning discussions, housing management activities, and environmental maintenance initiatives. This participatory process strengthened community ownership and collective responsibility toward settlement sustainability.

Efficiency of Construction and Implementation

From an implementation perspective, adaptive housing demonstrated notable efficiency in both time and cost. Construction time was reduced by approximately 50%, while implementation costs were reduced by 20–25% compared to conventional housing approaches.

The efficiency was largely associated with the use of modular construction systems and prefabricated components, which accelerated the construction process and reduced material waste during implementation.

Comparative Analysis of Resilience Indicators

To provide a clearer overview of the intervention outcomes, Table 1 presents a comparative analysis of key resilience indicators before and after the implementation of adaptive housing.

Table 1. Comparative Resilience Indicators Before and After Intervention

Indicator	Before Intervention	After Intervention	Change (%)
Structural Damage	67%	17%	-50%
Flood Depth	High	Reduced	-60%
Access to Clean Water	35%	95%	+60%
Sanitation Access	Limited	Improved	Significant
Community Participation	45%	78%	+33%
Construction Time	Standard	Faster	-50%
Construction Cost	Baseline	Reduced	-20–25%

The results demonstrate that improvements occurred across physical, environmental, and social dimensions simultaneously, indicating the multidimensional contribution of adaptive housing interventions in coastal settlements.

Integration with Coastal Protection Policy

The findings indicate that adaptive housing complements macro-level coastal protection policies, particularly sea wall development. While sea walls function to reduce regional-scale hazard exposure, adaptive housing addresses settlement-level vulnerabilities through direct adaptation at the household and community scales.

Implications for Regional Resilience and National Defence

The improvement of coastal settlement resilience also has broader implications for national resilience. Strengthened housing systems, improved environmental quality, and increased community adaptive capacity contribute to territorial resilience (*ketahanan wilayah*) within vulnerable coastal regions. These conditions support the concept of non-military national defence by enhancing community stability and reducing socio-environmental vulnerability.

Integrated Coastal Settlement Resilience Model (ICSRM)

The findings support the development of the Integrated Coastal Settlement Resilience Model (ICSRM), which integrates macro-level infrastructure such as sea walls, micro-level adaptive housing strategies, and community-based capacity building to strengthen the resilience of coastal settlements against environmental risks and climate-related hazards.

This integrated framework positions adaptive housing as a connecting element between structural protection and community resilience in coastal settlements.

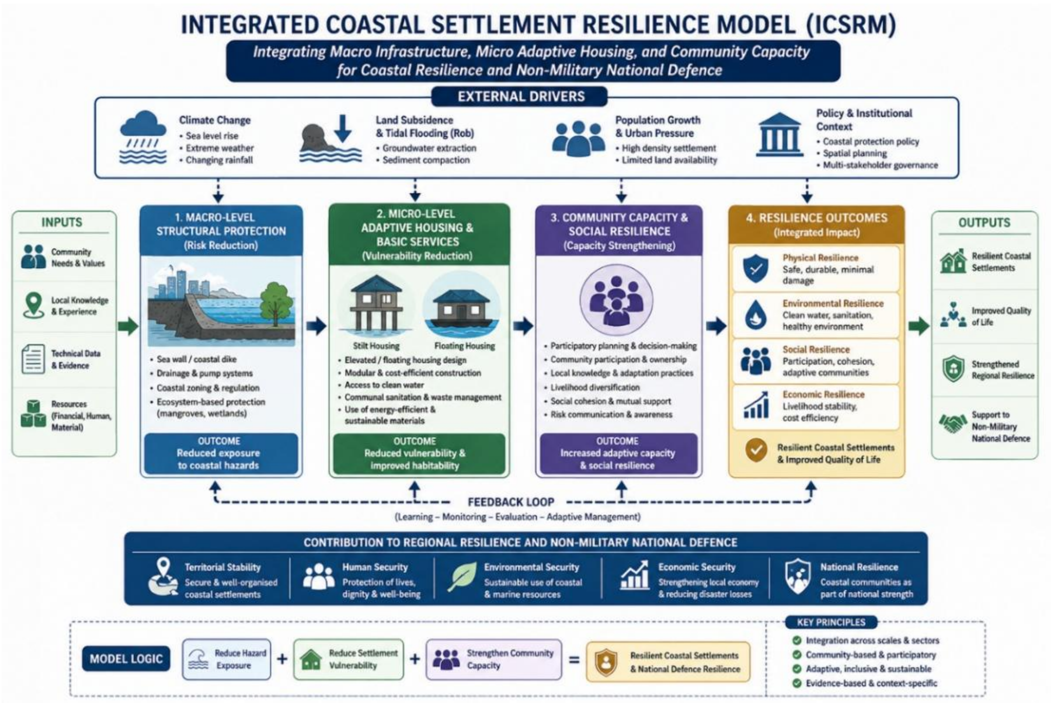

Figure 2. Integrated Coastal Settlement Resilience Model

Discussion

The findings demonstrate that adaptive housing can serve as an effective strategy for improving resilience in vulnerable coastal settlements. The reduction in structural damage and flood exposure confirms that elevated and floating housing systems provide practical protection against recurring tidal flooding. This improvement is closely associated with the structural design of adaptive housing, particularly the use of elevated (stilt) and floating systems that decouple the building from direct water exposure. These findings align with previous studies suggesting that elevation-based housing significantly reduces flood-related damage in coastal settlements (Srirangam & Sheng, 2024).

The improvement in environmental conditions further indicates that adaptive housing should not be understood solely as a technical housing intervention. The integration of clean water systems, sanitation infrastructure, and waste management contributed substantially to settlement habitability and environmental sustainability. The improvement in environmental conditions reflects the importance of integrating housing design with basic service infrastructure. Adaptive housing in this context is not merely a structural solution but a holistic intervention that enhances habitability and environmental sustainability. Similar findings have been reported in coastal upgrading programmes, where infrastructure provision significantly contributes to long-term resilience (Chin et al., 2025; Suntoro et al., 2025).

From a social perspective, increased community participation suggests that resilience is strongly influenced by social processes and local involvement. The participatory approach adopted during planning and implementation encouraged stronger community ownership and collective responsibility toward settlement sustainability. This increase can be attributed to the participatory approach adopted during planning and implementation, where residents were actively involved in decision-making processes. As suggested by Arnstein's ladder of participation, higher levels of citizen involvement are associated with greater programme acceptance and sustainability (Herman et al., 2026). Moreover, the strengthening of social cohesion indicates that resilience is not solely a technical outcome but also a socially constructed process shaped by community interaction and adaptive capacity.

However, despite these positive outcomes, several limitations and challenges remain in the implementation of adaptive housing. One major challenge relates to long-term maintenance costs, particularly for floating housing systems that require regular inspection, material replacement, and technical maintenance to ensure structural safety in coastal environments. Without sustainable financial support and maintenance mechanisms, the long-term effectiveness of such housing may decline over time.

Community acceptance also represents an important consideration. Although participation increased during the programme, not all residents may fully adapt to new housing models, especially floating housing systems that differ from conventional settlement patterns and cultural living preferences. Resistance to relocation or adaptation may therefore affect implementation sustainability.

Land legality and coastal spatial planning policies also present significant institutional challenges. Many informal coastal settlements, including parts of Muara Angke, are characterised by unclear land ownership status and overlapping coastal zoning regulations. These conditions may complicate the large-scale implementation of adaptive housing and limit integration with formal coastal development policies.

In addition, floating housing systems may face technical risks associated with extreme weather events, wave dynamics, corrosion of materials, and infrastructure stability. These technical considerations require continuous monitoring and adaptation to ensure safety and long-term resilience under changing climate conditions.

The findings also highlight the importance of integrating adaptive housing within broader coastal spatial planning and sea wall development policies. Relying solely on macro-scale infrastructure such as sea walls may reduce hazard exposure but may not adequately address social vulnerability and settlement-level resilience. Therefore, adaptive housing should be positioned as a complementary strategy within integrated coastal resilience planning.

This tripartite framework demonstrates a synergistic relationship where macro-level infrastructure, adaptive housing, and community participation reinforce one another, leading to a more robust and sustainable resilience outcome against both environmental and socioeconomic stressors (Tanvir et al., 2022). Such a holistic strategy is crucial for avoiding maladaptation and addressing the multifaceted human security risks prevalent in vulnerable coastal areas (Eggert, 2024). This comprehensive approach diverges from conventional single-solution strategies, such as relying solely on extensive gray infrastructure, which often overlooks crucial socio-political and ecological feedback mechanisms and can lead to maladaptive outcomes (David et al., 2021; Medina Hidalgo et al., 2021). For instance, while hard protection measures like seawalls and dikes offer localized defense against coastal hazards, they can inadvertently exacerbate erosion in adjacent areas and foster a false sense of security, encouraging continued development in high-risk zones (Hawken et al., 2022; Sohaana & Rahman, 2021).

This synthesis forms the basis for the proposed Integrated Coastal Settlement Resilience Model (ICSRM), which positions adaptive housing as a central element linking structural protection with social resilience. This model emphasizes the interplay between technological innovations, flexible operational procedures, and enhanced interagency collaboration to address multifaceted challenges and foster long-term self-sustenance in vulnerable coastal communities (Sarjito, 2024; Sohaana & Rahman, 2021). This integrated systems approach is essential for understanding the complex dynamics and feedback loops inherent in coastal urban systems, thereby allowing for the transformation of challenges into opportunities for innovation and sustainable living (Niamir & Pachauri, 2023). Overall, this study demonstrates that adaptive housing has considerable potential as an alternative strategy for fisher settlement planning within the context of coastal sea wall development and national resilience. Nevertheless, successful implementation requires not only technical innovation but also institutional support, long-term maintenance strategies, community acceptance, and integration with coastal governance and spatial planning systems.

The novelty of this study lies in the development of the Integrated Coastal Settlement Resilience Model (ICSRM), which positions adaptive housing as a central strategy connecting macro-level coastal protection, micro-level settlement adaptation, and community-based capacity building. Unlike conventional coastal resilience approaches that tend to emphasize large-scale infrastructure such as sea walls, this study demonstrates that physical protection alone is insufficient to address the multidimensional vulnerabilities faced by fisher settlements. The proposed model contributes to the literature by offering an integrated socio-technical framework in which sea wall development, elevated or floating housing systems, environmental service improvement, and community participation are treated as interconnected components of coastal resilience. This contribution is particularly relevant for vulnerable coastal settlements in Indonesia, where environmental risks, informal settlement conditions, land legality issues, and socioeconomic vulnerability often overlap.

Despite its contributions, this study has several limitations that should be acknowledged. First, the findings are context-specific and derived from the characteristics of vulnerable coastal settlements, particularly those facing tidal flooding and settlement informality; therefore, the generalizability of the proposed model to other coastal regions requires further validation. Second, this study has not yet fully examined the long-term technical performance, maintenance costs, economic feasibility, and social acceptance of floating and elevated housing systems across different coastal contexts. Future research should conduct longitudinal and comparative studies in various coastal settlements to evaluate the durability, affordability, and adaptability of the ICSRM. Further studies are also encouraged to integrate hydrodynamic analysis, cost-benefit assessment, policy evaluation, and participatory community-based research to strengthen the empirical validity and practical applicability of the model in broader coastal resilience planning.

CONCLUSION

This study examined adaptive housing as an alternative strategy for fisher settlement planning within the context of coastal sea wall development and national resilience. The findings demonstrate that elevated and floating housing systems can reduce structural vulnerability and flood exposure while improving environmental quality through better access to clean water, sanitation, and waste management. The results also show that adaptive housing strengthens social resilience by increasing community participation, collective responsibility, and adaptive capacity. These findings answer the central research concern by confirming that macro-scale coastal protection, such as sea walls, is insufficient when implemented without settlement-level adaptation. Adaptive housing therefore functions as a critical intermediary strategy that connects large-scale infrastructure with household and community resilience. Theoretically, this study contributes to coastal resilience scholarship by proposing the Integrated Coastal Settlement Resilience Model (ICSRM), which integrates macro-level infrastructure, micro-level adaptive housing, and community-based capacity building into a unified socio-technical framework.

Practically, the study highlights the need for coastal settlement planning to move beyond conventional engineering-based solutions toward more integrated, participatory, and community-sensitive approaches. The findings also have educational and capacity-building implications, particularly in strengthening community awareness, disaster literacy, environmental responsibility, and local participation in coastal adaptation programmes. From a policy perspective, adaptive housing should be incorporated into coastal spatial planning, housing policy, sea wall development, and non-military national defence strategies. However, this study is limited by its case study context, descriptive analytical approach, and limited examination of long-term technical durability, economic feasibility, and social acceptance across diverse coastal settings. Future research should conduct longitudinal, comparative, and multidisciplinary studies to evaluate the sustainability, affordability, and scalability of adaptive housing models in different coastal regions. Further studies may also integrate hydrodynamic modelling, cost-benefit analysis, policy evaluation, and participatory action research to strengthen the empirical robustness of the ICSRM. Overall, this study advances an integrated understanding of coastal settlement resilience and offers a forward-looking framework for designing safer, more adaptive, and more sustainable coastal communities.

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