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COASTAL RESILIENCE IN SEMARANG CITY: FINDINGS FROM A FOCUS REVIEW

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ABSTRACT

Semarang City, a rapidly urbanizing coastal city on the northern coast of Java, Indonesia, faces escalating threats from tidal flooding (rob), land subsidence, sea level rise, and climate change. This article synthesizes findings from four peer-reviewed studies addressing community adaptation strategies, barriers to climate adaptation, probabilistic flood forecasting systems, and the role of community leadership in strengthening adaptive capacity. Using a purposive focused review approach, the study identifies cross-cutting insights into how coastal communities respond to recurring environmental hazards. The analysis is framed by socio-ecological resilience theory, adaptive governance, and community-based adaptation perspectives. The findings show that most residents prefer in-situ adaptation rather than relocation due to strong social attachment and livelihood dependence. Institutional and financial constraints remain the main barriers to effective climate action at the city level. The review also highlights the potential of a pre-running database probabilistic flood forecasting framework as a scalable and resource-efficient early warning system for data-scarce environments. In addition, community leaders play a critical role in linking households with information, resources, and collective action. Overall, the study emphasizes the importance of integrated, multi-level governance combining infrastructure development, adaptive planning, community empowerment, and early warning systems to strengthen long-term coastal resilience in Semarang and other Global South coastal cities.

Keywords: *Climate change adaptation, Coastal flooding, Community leadership, Flood early warning system, Semarang city.*

INTRODUCTION

Coastal cities in developing nations are among the most vulnerable landscapes on Earth, facing a convergence of rapid urbanization, population pressure, and climate change-induced hazards. In Indonesia, a country with over 88,000 kilometers of coastline and more than 17,500 islands, this vulnerability is particularly acute (Buchori et al., 2018). Semarang City, the capital of Central Java Province and home to approximately 1.66 million inhabitants,

exemplifies the compounding challenges faced by tropical coastal cities (BPS, 2023). Situated on low-lying terrain with elevations of only five to ten metres above sea level, the city endures persistent tidal flooding locally termed *rob*, accelerating land subsidence of up to 20 centimeters per year, seawater intrusion into freshwater systems, and the escalating impacts of climate-induced sea level rise (Handayani et al., 2023; Semarang City Government, 2019). Indonesia's coastal regions are among the most climate-vulnerable globally: by 2050, up to 12 million people could be exposed to severe coastal floods, and more than 90 percent of the country's disasters over the past decade have been linked to climate-related hazards (Suntoro et al., 2025).

Theoretically, this paper is grounded in three intersecting frameworks. Socio-ecological resilience theory provides the conceptual scaffolding for understanding how coupled human-environment systems absorb, adapt to, and transform in response to chronic and acute stressors, a dynamic particularly evident in coastal cities where physical hazards interact deeply with social inequality and governance deficits (Kanan & Giupponi, 2024; Wannewitz et al., 2024). Adaptive governance theory offers a framework for examining how multi-level institutions enable or constrain collective responses to climate-driven hazards; scholars argue that resilience at the city scale requires not just technical solutions but institutional redundancy and cross-scale coordination capacity (Biggs et al., 2024; Sethi et al., 2021). Community-based adaptation (CBA) literature contextualizes household and neighbourhood-level responses within the broader political economy of urban vulnerability, emphasizing that the poorest and most exposed communities are often the most innovative adapters yet the least supported by formal governance structures (Adger et al., 2024; Mubaya & Mafongoya, 2023). Together, these frameworks position the present synthesis at the intersection of governance, social capital, and technical innovation, the three axes along which Semarang's resilience challenges and opportunities are most clearly legible.

The intersection of these hazards with socio-economic inequality, limited institutional capacity, and gaps in spatial planning has created a crisis of resilience that demands scholarly attention. A growing body of literature has examined Semarang as a case study for coastal adaptation, generating valuable yet often fragmented insights. Recent scholarship has increasingly recognized that resilience in rapidly urbanizing coastal cities of the Global South cannot be reduced to any single dimension, it requires simultaneous attention to household behaviour, institutional design, social capital, and technological innovation (Driskell, 2025; Wannewitz et al., 2024). Four studies in particular offer complementary lenses: Buchori et al., (2018) explore community mitigation strategies and migration patterns among rob-affected households; Putri et al., (2025) systematically assess barriers to climate change adaptation across sectoral agencies; Suwarman et al., (2025) develop and validate a novel semi-online probabilistic flood forecasting framework tailored to resource-constrained areas such as Suwarman et al., (2025) examine the critical role of community leaders in building neighbourhood-level adaptive capacity.

Despite the richness of these individual contributions, no synthesis has been undertaken to identify the cross-cutting, interconnected findings that emerge when these studies are read together. Individually, each paper addresses a specific dimension of coastal resilience; collectively, they tell a more complete and revealing story about how a city and its communities navigate slow-onset climate disaster. The absence of such synthesis is particularly significant given the growing scholarly consensus that fragmented, single-dimension analyses systematically underestimate the structural interdependencies that determine whether adaptation efforts succeed or fail at city scale and that incremental, sector-based responses frequently result in maladaptation, particularly for marginalized populations (Driskell, 2025; Wannewitz et al., 2024). This article aims to fill that gap through a purposive focused review (Aveyard & Bradbury-Jones, 2019; Varsha et al., 2024) that extracts, compares, and synthesizes the most significant findings across these four studies. The central research question guiding this paper is: what do these four studies, taken together, reveal about the state of coastal resilience in Semarang that none reveals alone?

The novelty of this contribution lies not in generating primary data, but in the analytical

synthesis that uncovers emergent patterns, tensions, and policy implications invisible at the level of individual studies. The findings are organized thematically from household behaviour and institutional barriers to early warning technology and social leadership and are followed by an integrated discussion of their implications for theory and practice. Positioned at the intersection of socio-ecological resilience, adaptive governance, and community-based adaptation (Adger et al., 2024; Biggs et al., 2024; Kanan & Giupponi, 2024), this paper contributes to broader debates about community-based adaptation, multi-level governance, flood risk management, and the governance of slow-onset disasters in the Global South. It does so by demonstrating that the household, institutional, and technical dimensions of resilience in Semarang are not independent but structurally interdependent, a finding with direct implications for how coastal cities across the Global South design, evaluate, and sustain their climate adaptation strategies (Suntoro et al., 2025; Wannewitz et al., 2024).

RESEARCH METHODS

This study employs a purposive focused review methodology, a theoretically informed approach to evidence synthesis that prioritizes depth of analytical engagement over breadth of corpus (Aveyard & Bradbury-Jones, 2019; Varsha et al., 2024). Unlike a systematic review, which aims for exhaustive coverage of a defined literature space through replicable search protocols, a focused review is justified when the research question demands intensive cross-study analytical synthesis within a well-bounded empirical and theoretical domain (Barry et al., 2022). In this case, the domain is defined by a single case city (Semarang), a shared thematic focus (coastal resilience and climate change adaptation), and a common temporal scope (post-2018 primary empirical research, with one foundational study from 2018). This methodological choice reflects a deliberate epistemological positioning: rather than mapping the breadth of a literature, this study interrogates a tightly scoped corpus to surface emergent patterns that are invisible at the level of individual studies.

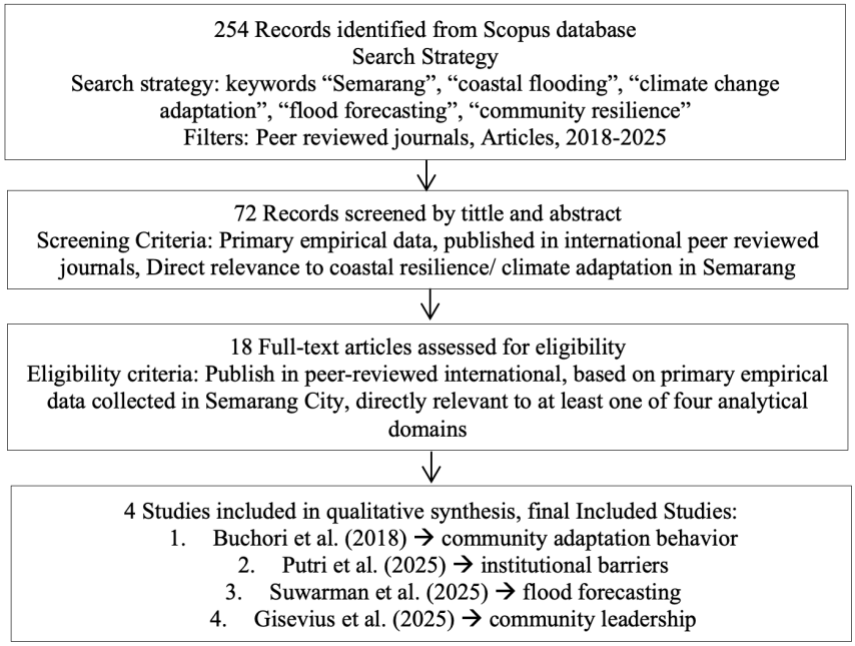

Figure 1. Prisma Flow. Source: Author, 2026

The four articles were identified through targeted searches of Scopus using keyword combinations including "Semarang", "coastal flooding", "climate change adaptation", "flood forecasting", and "community resilience". Selection criteria required that each article be: (1) published in a peer-reviewed international journal; (2) based on primary empirical data collected in Semarang City; and (3) directly relevant to at least one of four analytical domains which are community adaptation behaviour, institutional barriers, flood early warning and forecasting, or social capital and leadership. Articles that addressed Semarang only peripherally, relied solely on secondary

data, or duplicated the empirical focus of a selected article were excluded.

The four selected articles are: (1) Buchori et al., (2018), *Adaptation to coastal flooding and inundation: Mitigations and migration pattern in Semarang City, Indonesia*, published in *Ocean and Coastal Management*; (2) Putri et al., (2025), *Examination of barriers to climate change adaptation: Experience from Semarang city, Indonesia*, published in *Urban Governance*; (3) Suwarman et al., (2025), *Development of probabilistic flood forecast based on ensemble weather forecast and historical flood simulation database for resource-constrained area. Case study: Semarang City, Indonesia*, published in *Environmental Challenges*; and (4) Gisevius et al., (2025), *The role of community leadership in building community adaptive capacity to coastal hazards, Insights from neighborhood networks in Semarang, Indonesia*, published in *Environmental Science and Policy*.

The purposive logic of this selection is methodologically defensible on three grounds. First, these four articles represent the most recent, empirically grounded, and thematically complementary primary studies on Semarang's coastal resilience available at the time of writing. Second, their combination covers the household, institutional, technical, and social dimensions of adaptation in a genuinely complementary rather than redundant manner, each study addresses a dimension that the others do not. Third, the small corpus size is a deliberate analytical choice, not a limitation of search coverage: focused review methodology explicitly privileges analytical depth over numerical comprehensiveness (Barry et al., 2022; Varsha et al., 2024).

Each article was read in full and subjected to thematic content analysis (Kuckartz & Rädiker, 2023; Mayring, 2010). Key findings were extracted using a structured coding template covering: (a) empirical findings identified by authors as counterintuitive or policy-critical; (b) data and indicators supporting each finding; (c) explicit or implicit theoretical framings; and (d) policy implications articulated by authors. Coding was conducted independently by the lead author and verified through discussion among all co-authors to ensure inter-coder consistency, thereby strengthening the reliability of the analytical synthesis (Kuckartz & Rädiker, 2023). Emergent thematic clusters were identified through an iterative process of within-study coding and cross-study comparison. Cross-study comparisons were then performed to identify convergences, divergences, and complementary insights, with particular attention to findings characterized by the authors themselves as surprising, counterintuitive, or policy-critical, what this paper terms 'remarkable findings'. Results are presented thematically, rather than article-by-article, to maximize synthetic insight and foreground findings that are invisible at the level of individual studies.

The analytical framework guiding the synthesis is organized around three levels, household, institutional, and technical, derived inductively from the thematic content analysis and deductively from the three theoretical frameworks introduced in the Introduction: socio-ecological resilience (Kanan & Giupponi, 2024; Wannewitz et al., 2024), adaptive governance (Biggs et al., 2024; Sethi et al., 2021), and community-based adaptation (Adger et al., 2024; Mubaya & Mafongoya, 2023). This three-level framework is presented visually in Table 2 of the Results section and serves as the primary organizational logic for the cross-study synthesis.

RESEARCH RESULTS

Finding 1: The Paradox of Place Attachment (Staying Despite Suffering)

Perhaps the most provocative finding to emerge from the literature is the overwhelming preference of *rob*-affected households to remain in their flood-prone homes rather than relocate to safer areas. Buchori et al., (2018) found that 81 percent of surveyed residents in Semarang's northern coastal zone chose to stay and adapt, with only 19 percent willing to consider migration. Among those opting to remain, emotional attachment to their place of residence was cited as the primary motivator by 41 percent of respondents, followed by proximity to workplaces at 34 percent and the value of inherited property at 10 percent. This pattern is illustrated more clearly in Figure 2.

This finding is remarkable because it directly challenges the assumption embedded in many disaster relocation programmers that economic and physical rationality drives household decision-making. The phenomenon is further explained by the chronic, predictable nature of rob in Semarang: because flooding is

slow-onset rather than catastrophic, households have become psychologically and financially calibrated to endure and adapt rather than flee (Buchori et al., 2018). Communities have developed sophisticated coping mechanisms, raising floor levels, elevating furniture during floods, and saving money specifically for future structural improvements, that effectively convert an extreme hazard into a manageable, if deeply uncomfortable, routine.

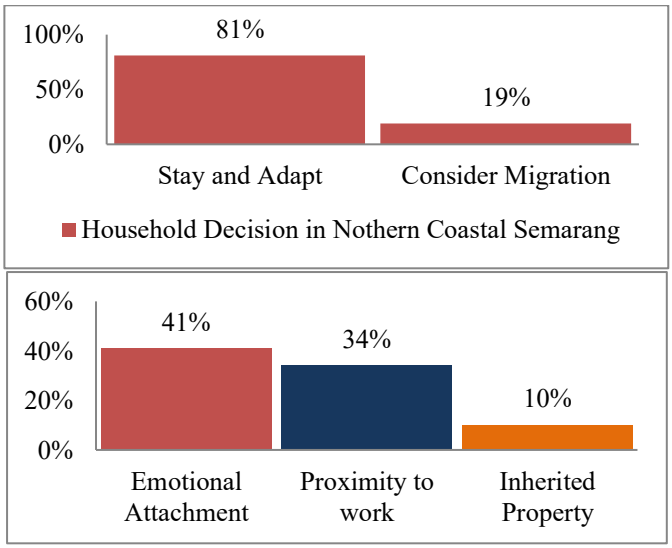

Figure 2. Primary Reasons for Remaining in Rob-Affected Areas Source: Buchori et al., (2018), visualization by the author (2026).

Among the minority who preferred to move, the desire to escape rob entirely was the dominant motivation, cited by 54 percent of potential migrants. Notably, preferred destinations were concentrated in Semarang's hilly southern sub-districts such as Banyumanik, Tembalang, Gunungpati, and Mijen, rather than areas near workplaces or city services, in contrast to patterns observed in other Global South contexts (Buchori et al., 2018). This spatial preference for safety over convenience represents an important departure from prior migration literature and signals that when the hazard pressure becomes intolerable, safety becomes the overriding criterion. A more detailed depiction is presented in Figure 3.

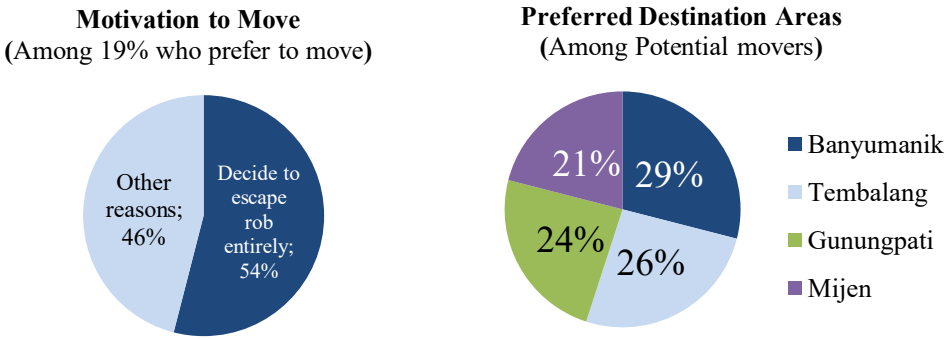

Figure 3. Motivations and Preferred Destinations of Potential Movers in Rob-Affected Areas (Nothern Coastal Semarang). Source: Tacoli, 2009 as cited in Buchori et al., 2018

Simultaneously, Gisevius et al., (2025) confirm from a different methodological angle that community characteristics, including high flood exposure, actually paradoxically reduce long-term preparedness in areas that have received protective infrastructure. In better-protected neighbourhoods, declining risk perception leads to reduced participation in disaster preparedness activities and a gradual dismantling of communal adaptation arrangements, a form of resilience complacency that may leave communities

dangerously exposed when infrastructure fails or extreme events exceed its design parameters.

Finding 2: Structural Mitigation Creates New Vulnerabilities

A second striking finding concerns the unintended consequences of government structural mitigation. Buchori et al., (2018) document how repeated road elevation by the Semarang City government, a primary structural response to rob has created a perverse secondary hazard for households unable to afford raising their floor levels correspondingly. As road surfaces rise, houses that once sat at or above road level become progressively submerged relative to the street, transforming them into natural basins that collect both floodwater and runoff. This phenomenon, visually documented in the study, represents a governance failure of significant proportions: infrastructure intended to protect the public systematically disadvantages the poorest and most vulnerable residents who cannot keep pace with the rising road surface.

Furthermore, the installation of pumping systems and the construction of embankments, while effective in the short term, are identified as fundamentally temporary solutions that do not address the underlying drivers of land subsidence and sea level rise. The authors argue persuasively that without a comprehensive, long-term spatial planning response, continued investment in reactive structural mitigation represents a costly and ultimately self-defeating cycle (Buchori et al., 2018). This finding resonates strongly with Suwarman et al., (2025) observation that Semarang has had worsening flood damage despite a decreasing trend in flood occurrences, and that the city's minimal monitoring infrastructure, only one rainfall station and two river discharge stations, severely constrains its capacity to implement effective flood early warning systems.

Finding 3: A Tale of Two Sectors, Asymmetric Barriers to Adaptation

Putri et al., (2025) contribute a highly granular and institutionally revealing analysis of climate change adaptation barriers in Semarang. Their most significant finding is the sharp asymmetry between priority sectors such as water, coastal, and marine. Non-priority sectors are agriculture, health, and social welfare, in both the height and nature of barriers encountered. Priority sectors, which have benefited from years of targeted international programming through initiatives such as the Asian Cities Climate Change Resilience Network (ACCCRN) and the Rockefeller Foundation's 100 Resilient Cities programme, recorded an average barrier score of 2.74 on a five-point scale, while non-priority sectors averaged 3.00. This trend is further illustrated in Figure 4.

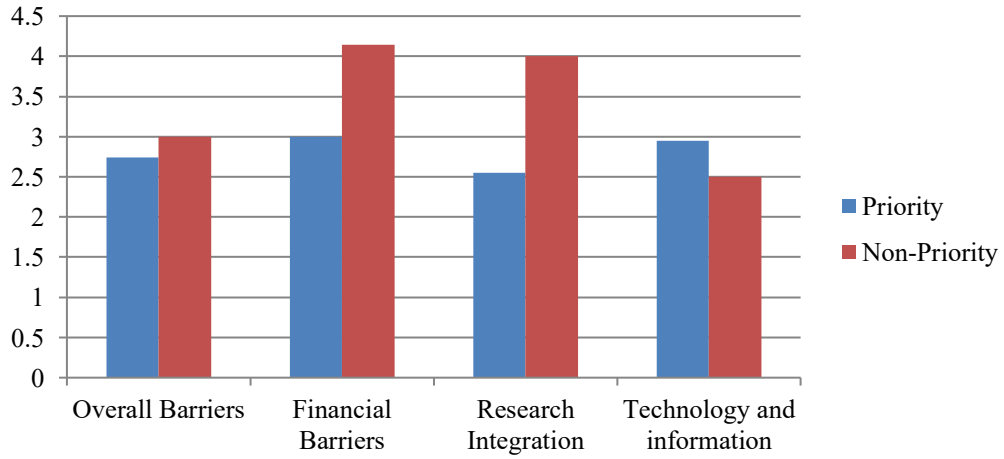

Figure 4. Climate Change Adaptation Barriers in Semarang. Source: Putri et al., (2025), visualization by the author, (2026)

Based on Figure 4, the sectoral divergence is most extreme in two dimensions. First, financial barriers are dramatically higher in non-priority sectors, with non-priority agencies

reporting a mean score of 4.14 for limited funding, compared to 3.00 for priority sectors. The underlying reason is structural: climate adaptation expenditure in non-priority departments is neither mandated nor budgeted, leaving health and agricultural agencies entirely dependent on discretionary allocations that are routinely redirected during budget refocusing exercises. Critically, the COVID-19 pandemic and subsequent recovery-related budget reductions disproportionately eliminated non-priority climate programmers, widening an already substantial adaptation gap (Putri et al., 2025).

Second, the utilization of research evidence for policymaking shows an extraordinary divergence: priority sectors score 2.55 for the barrier of 'lack of research integration in policymaking', while non-priority sectors score 4.00, nearly twice as high. This means that for non-priority departments, available scientific knowledge about climate risks is essentially disconnected from the planning process, not because the knowledge does not exist, but because there are no institutional channels, incentives, or mandates compelling its uptake. Research remains an academic exercise without policy translation.

Paradoxically, technology and information barriers are higher for priority sectors (2.95) than non-priority sectors. Putri et al., (2025) explain this counterintuitive finding by noting that priority sectors operate more sophisticated technological systems, early warning systems, pumping networks, GIS-based flood modeling, whose maintenance and operational continuity are persistently underfunded, generating larger performance gaps relative to their greater ambition. Non-priority sectors, by contrast, have lower technological expectations and therefore record lower perceived barriers in this domain.

Finding 4: The 'City Team' Model When Trans disciplinarity Works

One of the most actionable and internationally relevant findings in the reviewed literature concerns Semarang's Climate Change Resilience Task Force, colloquially known as the 'City Team'. Established in 2009 following the city's entry into ACCCRN, this multi-stakeholder coordination platform brought together government agencies, academic institutions, water supply companies, NGOs, and community representatives under a unified mandate to mainstream climate resilience into urban governance (Putri et al., 2025).

The City Team's measurable impact is remarkable for its breadth and institutionalizing effect. During its active years from 2009 to 2016, the team successfully embedded climate adaptation considerations into Semarang's Regional Medium-Term Development Plan (RPJMD) for 2016–2021, securing a degree of policy continuity that survived changes in municipal leadership. It initiated and oversaw projects ranging from community-based flood early warning systems in the Beringin watershed to mangrove and wave retention infrastructure in Tugurejo, while simultaneously building the technical capacity of participating agencies (Putri et al., 2025). The governance barrier scores recorded by priority sectors, the lowest among all four barrier categories are in large part attributable to the institutional learning and coordination capacity generated by the City Team experience.

Critically, however, the City Team was dissolved after 2016 when its functions were formally internalized into sectoral agency responsibilities. Putri et al., (2025) identify this as a double-edged outcome: institutionalization represents genuine mainstreaming success, but the loss of a dedicated coordination platform has fragmented the transdisciplinary exchange that was the team's greatest asset. The lesson for other cities is that transdisciplinary climate governance platforms require sustained structural support beyond individual programme cycles if their collaborative energy is to be preserved.

Finding 5: Community Leaders as Brokers of Adaptive Capacity

Gisevius et al., (2025) provide the most theoretically sophisticated contribution in the reviewed set, empirically demonstrating through a mixed-methods approach, 330 household surveys and 19 qualitative interviews that community leaders in Semarang's coastal neighbourhoods function not merely as administrators but as indispensable brokers of adaptive capacity. Drawing on Cinner et al., (2018) five-domain framework of adaptive capacity such as assets, flexibility, social organization, learning, and agency, the authors show that community

leaders exert significant influence across all five domains.

Several specific findings stand out for their policy relevance. First, households with members in leadership positions were five times more likely to have personally interacted with influential external individuals, 29 percent compared to 6 percent for non-leader households, demonstrating that leadership positions provide qualitatively different access to bridging and linking social capital. Second, 74 percent of surveyed households have access to communal funds managed by neighbourhood leaders, funds that serve as informal microfinance and emergency relief systems in a context where formal credit access is severely restricted for low-income coastal residents. Third, 64 percent of respondents stated that RT and RW neighbourhood meetings meaningfully increase environmental awareness, and 48 percent reported gaining new practical knowledge through these meetings (Gisevius et al., 2025).

These findings establish community leaders as critical infrastructure, as essential to resilience as dykes or pumps, but far less visible in planning documents and budgets. Yet the study also reveals the structural fragility of this system. Leadership positions are frequently assumed involuntarily due to limited competition, many low-level leaders lack relevant skills and motivation, and the highly hierarchical Javanese administrative structure prevents lower-level leaders from initiating contacts with external organizations without approval from higher administrative tiers. This bureaucratic bottleneck inhibits precisely the kind of boundary-spanning behaviour that makes leaders most effective as adaptive capacity brokers (Gisevius et al., 2025).

Finding 6: A Novel Probabilistic Flood Forecasting Framework for Resource-Constrained Areas

Suwarman et al., (2025) offer a finding of significant technical and operational importance for flood risk governance in Semarang: a novel semi-online, pre-running database probabilistic flood forecasting system that circumvents the prohibitive computational demands facing data-scarce cities. The study documents Semarang's stark monitoring deficit, a city of over 1.66 million inhabitants served by just one meteorological station and a single water elevation gauge and proposes a framework that transforms this limitation from an insurmountable barrier into a design constraint to be engineered around.

The framework operates through two parallel processes: the construction of a historical database from satellite rainfall data (GSMaP), hydrological simulations (HEC-HMS), and hydraulic inundation modelling (HEC-RAS) covering flood events from 2000 to 2020; and an operational prediction system that integrates daily ensemble weather forecasts from eight model members, comprising four Global Forecast System (GFS) cycles and four Weather Research and Forecasting (WRF) downscaled outputs at 9-km and 3-km resolution. Ensemble outputs are then calibrated through Bayesian Model Averaging (BMA) before being combined with the historical flood database to produce daily probabilistic inundation maps at three flood depth categories: low (below 0.5 m), medium (0.5–1.2 m), and high (above 1.2 m) (Suwarman et al., 2025).

The remarkable dimension of this finding is not merely technical but operational and scalable. The system achieves a 14-hour forecast lead time while requiring only a moderate server with 64 processing cores, vastly less infrastructure than conventional full-online numerical approaches. Forecast evaluation over seven months of the rainy season yielded Brier Scores of 0.20–0.25 for rainfall thresholds of 1–8 mm/day, confirming forecast skill close to zero (the ideal). ROC curve analysis further demonstrated the system's ability to discriminate between flood events and non-events with a high hit rate and low false alarm rate. Qualitative comparison with observed flood events, including the large inundation recorded on 4 November 2021 as confirmed by GSMaP satellite monitoring and local news sources, validated the forecast's responsiveness to actual rainfall patterns (Suwarman et al., 2025).

This finding is policy-critical because it establishes that effective flood early warning need not await the development of expensive sensor networks or high-performance computing facilities. The pre-running database approach effectively separates the computationally intensive hydraulic simulation phase from the operational forecasting phase, enabling near-real-time probabilistic flood

guidance at minimal marginal cost once the database is established. Suwarman et al., (2025) explicitly frame the system as replicable across other resource-constrained regions by constructing new databases tailored to local conditions, a scalability dimension of direct relevance to the many Indonesian coastal cities that share Semarang's monitoring deficit.

Matrix of Key Findings and Policy Implications

Seven remarkable findings emerge from the cross-study synthesis, each carrying specific policy implications that demand responses across multiple governance levels. A detailed summary of these findings is provided in Table 1.

Table 1. Matrix of Key Findings and Policy Implications

Key Finding	Core Data / Figure	Source	Policy Implication
Place attachment paradox: residents stay despite chronic flooding	81% chose in-situ; 41% cited emotional attachment	Buchori et al. (2018)	Relocation programmes must respect social geographies, not just economic rationality
Structural mitigation creates new vulnerabilities for the poorest	Road elevation traps water inside households left below street level	Buchori et al. (2018)	Subsidise floor-raising for economically marginal households
Sharp financial barrier gap between priority and non-priority sectors	Financial: priority 3.00 vs non-priority 4.14 (5-point scale)	Putri et al. (2025)	Cross-sectoral climate budgeting mechanisms are urgently needed
Research is disconnected from policy in non-priority sectors	Research integration: 2.55 (priority) vs 4.00 (non-priority)	Putri et al. (2025)	Formal pathways for translating research into agency programming
The "City Team" model worked, but was dissolved in 2016	Successfully embedded CCA in RPJMD 2016–2021	Putri et al. (2025)	Institutionalise a permanent transdisciplinary coordination platform
Community leaders are critical social infrastructure	74% household access to communal funds; 5× more external contacts than non-leaders	Gisevius et al. (2025)	Formal recognition, training, and financial support for RT/RW leaders
Pre-running probabilistic flood forecast: effective FEWS for data-scarce cities	Brier Score 0.20–0.25; 14-hour lead time; only 64-core server required	Suwarman et al. (2025)	Deploy pre-running database flood forecast systems in other resource-constrained coastal cities; integrate with spatial planning and BPBD protocols

Source: Authors' synthesis from the four reviewed studies, 2026.

Analytical Synthesis Framework: Three Level Resilience Architecture

To move beyond a finding-by-finding inventory and toward a theoretically grounded synthesis, the cross-study analysis reveals that the six findings can be organized within a three-level resilience architecture such as household, institutional, and technical. Each corresponding to one of the three theoretical frameworks introduced in the Introduction. This framework is presented in Table 2.

Table 2. Three-Level Analytical Synthesis Framework

Level	Theoretical Framework	Key Finding(s)	Core Mechanism	Critical Gap
Household	Socioecological resilience (Wannewitz et al., 2024; Kanan & Giupponi, 2024)	F1: Place attachment paradox; F2: Structural mitigation creates vulnerability	Social capital and adaptive coping buffer physical hazard, but produce resilience complacency	Lack of transformative options that respect social geography
Institutional	Adaptive governance (Biggs et al.,	F3: Asymmetric sectoral barriers; F4: City Team	Transdisciplinary coordination platforms and bridging leaders	Dissolution of coordination platforms and absence of formal

Level	Theoretical Framework	Key Finding(s)	Core Mechanism	Critical Gap
	2024; Sethi et al., 2021)	model; F5: Community leaders as brokers	enable multi-level governance, but both are structurally underfunded	community leader recognition
Technical	Community-based adaptation (Adger et al., 2024; Mubaya & Mafongoya, 2023)	F6: Probabilistic flood forecasting	Pre-running database approach dissolves cost barrier to early warning in data-scarce contexts	Absence of integration with BPBD protocols and community dissemination networks

F= Finding
Source: Author's synthesis, 2026

Critically, this three-level architecture is not merely descriptive, it reveals a structural interdependence among the three levels that has direct implications for policy sequencing. Household-level adaptation (F1, F2) is constrained by the quality of institutional coordination (F3, F4, F5): without cross-sectoral financing and recognized community leadership, individual households are left to navigate chronic hazards with only informal coping mechanisms. Institutional capacity, in turn, is both enabled and limited by technical infrastructure (F6): the absence of real-time probabilistic flood guidance prevents agencies from transitioning from reactive emergency response to anticipatory adaptive governance. The three levels thus form an interdependent system, strengthening any single level without the others risks maladaptation rather than resilience.

DISCUSSIONS

Read together, the four studies generate a picture of coastal resilience in Semarang that is simultaneously more nuanced and more alarming than any individual study conveys. Three cross-cutting tensions emerge from the synthesis, each of which can be theorized through the frameworks of socio-ecological resilience, adaptive governance, and community-based adaptation and each of which finds resonance in, yet also departs meaningfully from, the global literature on coastal cities in the Global South.

Tension 1: Reactive Adaptation versus Transformative Resilience

The first tension is between short-term adaptive efficiency and long-term structural vulnerability reduction. Households raise their floors; the government raises the roads; sea levels continue to rise. Communities build embankments; land subsidence continues; embankments become insufficient. Community leaders mobilize communal funds; households remain too financially precarious to contribute consistently. Each adaptation measure is rational at its own scale and time horizon, yet the cumulative effect is a city progressively deeper in deficit relative to its hazard environment (Buchori et al., 2018; Gisevius et al., 2025).

This pattern resonates strongly with what (Adger et al., 2024) term 'adaptation lock-in': situations in which short-term coping measures reduce the immediate costs of hazard exposure but simultaneously foreclose transformative options by generating path dependencies and sunk-cost investments. Theorized through socio-ecological resilience frameworks (Kanan & Giupponi, 2024; Wannewitz et al., 2024), Semarang's situation exemplifies a system that has maximized absorptive capacity at the household level developing sophisticated coping routines while failing to build the transformative capacity necessary to alter the trajectory of its relationship with chronic hazards. Comparative evidence from other coastal cities in the Global South reinforces this reading: (Broto et al., 2015) found comparable adaptation lock-in dynamics in informal settlements in Maputo, where incremental household investments in flood protection paradoxically reduced community pressure for systemic infrastructure improvements. Similarly, (Revi et al., 2014) in the IPCC Fifth Assessment Report identified that the majority of adaptation action in Asian coastal cities remains reactive and incremental rather than anticipatory and transformative, a pattern that Semarang exemplifies but does not uniquely constitute.

Critically, Suwarman et al., (2025) document that between 2008 and 2021 there were over 130 recorded flood events in Semarang resulting in economic losses of approximately 16 billion IDR, underscoring the urgency of moving beyond reactive adaptation toward proactive, technology-enabled early warning and anticipatory spatial planning. The probabilistic flood forecasting framework they develop represents precisely the technical infrastructure that could catalyze this transition, yet its effectiveness depends on institutional integration that the current governance architecture does not yet provide.

Tension 2: Siloed Sectoral Governance versus Integrated Resilience

The second tension concerns the governance architecture of climate adaptation. The ACCCRN and 100 Resilient Cities programmes have generated genuine institutional learning and planning capacity in water and coastal management (Putri et al., 2025). A remarkable achievement that demonstrates the replicability of transdisciplinary coordination models by other cities in the Global South. However, these gains remain deeply siloed. Health, agriculture, and social welfare sectors whose populations bear disproportionate climate burdens, remain financially and technically disconnected from the mainstreaming gains achieved in priority sectors. A city-wide resilience strategy that leaves non-priority sectors behind constitutes a partial and structurally inequitable resilience strategy.

This finding engages directly with the adaptive governance literature's emphasis on institutional redundancy and cross-scale coordination as prerequisites of systemic resilience (Biggs et al., 2024; Sethi et al., 2021). Semarang's experience with the City Team model offers both an existence proof and a cautionary tale: transdisciplinary platforms can successfully embed climate considerations into formal planning documents, but their dissolution after programme funding ends reveals a governance architecture that remains programme-dependent rather than institutionally self-sustaining. This dynamic has been documented elsewhere: (Bulkeley & Kern, 2006) found that climate governance innovations in European cities similarly struggled to survive beyond their initiating programme cycles without structural mainstreaming into core budgetary and planning processes. In the Global South context, Anguelovski et al., (2016) have identified a related phenomenon they term 'resilience gentrification' where climate adaptation investments in priority areas produce governance attention asymmetries that deepen inequality between priority and non-priority communities. While the Semarang case does not exhibit gentrification per se, the financial barrier asymmetry documented by Putri et al., (2025) non-priority sectors scoring 4.14 compared to priority sectors' 3.00 on a five-point financial barrier scale reveals a structurally analogous dynamic of unequal governance attention with equity consequences.

Tension 3: Underinvestment in Social and Technical Resilience Infrastructure

The third tension concerns the systematic undervaluation of both social capital and technical early warning systems in formal planning and budgeting. Community leaders in Semarang's coastal neighbourhoods manage emergency funds, disseminate hazard knowledge, organise collective infrastructure maintenance, and advocate upward to government for resources all without formal salary, dedicated budget, or recognition in spatial or climate planning documents (Gisevius et al., 2025). This finding resonates with the community-based adaptation literature's well-established argument that social capital constitutes a form of infrastructure as important to resilience as physical infrastructure, yet systematically absent from the calculus of formal climate planning (Adger et al., 2024; Mubaya & Mafongoya, 2023).

From a socio-ecological resilience perspective, Gisevius et al., (2025) finding that community leaders function as brokers of all five dimensions of adaptive capacity such as assets, flexibility, social organization, learning, and agency (Cinner et al., 2018), establishes them as irreplaceable nodes in Semarang's resilience network. Comparative evidence from other Indonesian cities and coastal communities in Southeast Asia reinforces this: studies in Bangkok (Lebel et al., 2011) and Manila (Bankoff, 2015, as cited in (Mubaya & Mafongoya, 2023) found similarly that neighbourhood-level social leadership functions as a critical buffer between

household vulnerability and institutional support, but only when those leaders are embedded in functional multi-level governance networks rather than isolated at the community tier. Semarang's highly hierarchical Javanese administrative structure, which prevents lower-level RT/RW leaders from initiating contacts with external organizations without higher-tier approval, represents a structural bottleneck that directly undermines the boundary-spanning function that makes community leaders most resilience-relevant (Gisevius et al., 2025).

Similarly, the probabilistic flood forecasting system developed by Suwarman et al., (2025) demonstrates that technically sophisticated, policy-relevant flood risk intelligence can be generated at low marginal cost once the pre-running database is established, yet such systems remain absent from most Indonesian coastal cities' formal governance frameworks. The finding that the system achieves 14-hour lead times using a 64-core server dissolves the most commonly cited justification for inaction on early warning in resource-constrained contexts, namely the prohibitive cost of real-time numerical modelling. Globally, comparable pre-running database approaches have been successfully deployed in flood-prone cities of South Asia (Cloke & Pappenberger, 2009; Pappenberger et al., 2015), confirming the framework's technical maturity and scalability. What Suwarman et al., (2025) contribute beyond these precedents is an adaptation of the approach to a data-scarce monitoring environment, a contribution of direct relevance to the majority of Indonesian coastal cities that share Semarang's monitoring deficit.

Synthesis: Toward a Transdisciplinary, Multi-Level Governance Response

These three tensions, reactive versus transformative adaptation, siloed versus integrated governance, and underinvestment in social and technical infrastructure are not independent but structurally interdependent. Household adaptation options are constrained by institutional coordination quality; institutional capacity is limited by technical infrastructure availability; and technical systems cannot translate into resilience outcomes without the social capital networks that community leaders embody. This interdependence has a direct methodological implication: single-dimension analyses systematically underestimate the structural determinants of adaptation success or failure, precisely the analytical gap that the cross-study synthesis presented in this paper is designed to address.

The practical research and policy agenda that emerges from these tensions is clear. How can place attachment be channeled toward transformative relocation rather than mere persistence? How can sectoral budgets and mandates be restructured to incorporate non-priority sectors into climate planning on equitable terms? How can community leaders be formally recognized, resourced, and connected to higher governance levels without compromising their community-level legitimacy? And how can flood early warning systems such as that developed by Suwarman et al., (2025) be operationally linked to local government response protocols and community dissemination networks? Answering these questions will require longitudinal, comparative, and co-designed research that goes beyond the individual study scale confirming that the analytical synthesis approach adopted in this paper represents not only a methodological contribution but a necessary next step in the research agenda on coastal resilience in the Global South.

CONCLUSIONS

This synthesis of four empirical studies on Semarang's coastal resilience yields several conclusions of theoretical, methodological, and practical significance.

Substantive Conclusions

The overwhelming preference of coastal residents to adapt in place rather than relocate driven by social attachment rather than economic calculation, demands that both planning instruments and relocation programmes be radically reconceived to work with, rather than against, the social geographies of coastal communities. Structural mitigation measures, while necessary, produce unintended secondary vulnerabilities for the most economically marginal residents if implemented without integrated socioeconomic support: road elevation in the absence of floor-raising subsidies transforms public infrastructure investment into a private hazard for the poorest households.

At the institutional level, the asymmetry between priority and non-priority sectors in

climate change adaptation capacity represents a critical equity deficit that undermines the coherence of city-level resilience efforts. The Semarang City Team model demonstrates that transdisciplinary governance platforms can generate genuine mainstreaming gains successfully embedding climate adaptation into formal planning instruments such as the RPJMD 2016–2021 but their dissolution risks reversing those gains unless replaced by equally robust, institutionally self-sustaining coordination mechanisms.

The probabilistic flood forecasting framework developed by (Suwarman et al., 2025) holds exceptional scalable potential as a technical solution for resource-constrained flood early warning. By pre-computing inundation databases and integrating them with daily ensemble weather forecasts through Bayesian calibration, the system generates actionable probabilistic flood guidance at a fraction of the cost of conventional full-online numerical approaches. Realizing this potential, however, requires integration with government emergency response protocols, community dissemination pathways, and resolution of outstanding questions about probability thresholds for triggering counter-measure actions and the frequency of database updates as urbanization and land subsidence alter the hydrological landscape.

Community leaders constitute a form of social infrastructure that is as important to coastal resilience as physical infrastructure, yet remains almost entirely absent from formal planning documents, budgets, and technical assistance programmes. Formally recognizing, resourcing, and connecting community leadership networks to multi-level governance structures without co-opting their community-level legitimacy, is among the highest-leverage interventions available to policymakers seeking to build durable resilience in Semarang and comparable coastal cities across the Global South.

Methodological Contribution

This paper makes an explicit methodological contribution to the growing literature on evidence synthesis in climate adaptation research. By employing a purposive focused review (Aveyard & Bradbury-Jones, 2019; Varsha et al., 2024) rather than a systematic review, this study demonstrates that analytical depth, achieved through theoretically grounded, cross-study comparison of a tightly scoped corpus, can surface emergent patterns that are invisible at the level of individual studies. The three-level analytical synthesis framework (household, institutional, technical) developed in this paper provides a replicable template for comparable synthesis work on coastal resilience in other Global South cities. The use of thematic content analysis with inter-coder verification (Kuckartz & Rädiker, 2023) further strengthens the reliability of the synthesis and offers a procedural model for qualitative evidence integration in urban climate research.

Study Limitations

Several limitations of this study warrant explicit acknowledgment. First, the purposive corpus of four articles, while analytically sufficient for the focused review methodology, limits the generalizability of the synthesis to the full range of dynamics operating in Semarang's coastal system. Key dimensions including gendered dimensions of adaptation, the role of informal economies in hazard coping, and the spatial heterogeneity of resilience capacity across the city's northern coastal zone are not addressed by the selected studies and therefore remain outside the scope of this synthesis. Second, the geographic specificity of the synthesis to Semarang means that caution is required in extrapolating findings to other Indonesian coastal cities, each of which has distinct institutional histories, hazard profiles, and governance architectures. Third, the temporal scope of the selected studies (post-2018) means that longer-term dynamics of adaptation trajectory, including whether the institutional gains of the ACCCRN programme persist over the medium term cannot be assessed from the available evidence base. Fourth, the focused review methodology, while epistemologically defensible, does not produce the exhaustive coverage of a systematic review, and there may be relevant primary studies not captured by the selection criteria that would alter or enrich the synthesis. Future research should address these limitations through longitudinal comparative studies, gendered analyses of adaptive capacity, and expanded corpus synthesis that incorporates grey literature and non-Anglophone sources.

Future research priorities include: longitudinal studies tracking whether adaptive

capacity gains generated by international programmes persist after those programmes conclude; comparative analyses of non-priority sector adaptation experiences across Indonesian coastal cities; development of community dissemination protocols that translate probabilistic flood forecasts into actionable community-level guidance; and systematic integration of flood early warning output into formal spatial planning and BPBD emergency response architectures.

RECOMMENDATIONS

For city government:

(1) Revise the Spatial Plan (RTRW) and RZWP3K within the next planning cycle to formally incorporate social vulnerability maps that identify neighbourhoods where community leadership capacity is weakest and where road elevation programmes create secondary flooding hazards for low-income households, and mandate that all future structural mitigation projects include a complementary floor-raising subsidy component for households below the city poverty line.(2) Mandate Strategic Environmental Assessment (SEA) implementation for all major spatial planning documents by establishing a permanent, multi-stakeholder SEA team that includes at least one university partner and one registered NGO, with annual public reporting on implementation progress.

(3) Institutionalise a permanent, cross-sectoral climate adaptation coordination platform, modelled on the City Team (2009–2016) but embedded within the Mayor's Office rather than tied to external programme funding, with a dedicated annual budget line in the APBD, a formal mandate to convene all sectoral agencies quarterly, and a performance evaluation mechanism linked to the RPJMD mid-term review. (4) Formally adopt and operationalize the probabilistic flood forecasting system developed by Suwarman et al. (2025) by: (a) commissioning BPBD to develop Standard Operating Procedures that translate the system's three flood depth categories into tiered community alert levels; (b) integrating forecast outputs into the existing Semarang Early Warning System dashboard; and (c) scheduling annual re-calibration of the forecast database to account for ongoing land subsidence and urban expansion.

For sectoral agencies:

(5) Develop cross-sectoral climate budgeting mechanisms by requiring that all SKPD budget proposals include an explicit climate co-benefit justification, and by establishing a joint climate adaptation fund, co-managed by the Environment and Finance offices, to which non-priority sectors (health, agriculture, social welfare) may apply for ring-fenced adaptation financing, with a target of reducing the financial barrier score gap between priority and non-priority sectors from the current 1.14-point differential to below 0.5 within one RPJMD cycle.

(6) Create formal science-policy translation pathways by requiring each non-priority sectoral agency to designate a dedicated climate focal point officer responsible for: (a) maintaining a living evidence register of relevant academic studies; (b) convening at least one annual science-policy dialogue with local university partners; and (c) submitting an annual research integration report to the cross-sectoral coordination platform.

For community-level governance:

(7) Develop a formal RT/RW Leader Capacity Development Programme, administered by BPBD in partnership with local universities, that provides structured training in disaster risk communication, communal fund management, and multi-level government liaison, with completion certificates recognized in the formal municipal governance system and a modest operational allowance to defray leaders' out-of-pocket coordination costs.

(8) Design relocation incentive programmes that respect place attachment by: (a) offering priority access to subsidised housing units in proximate, safe southern sub-districts (Banyumanik, Tembalang, Gunungpati) rather than distant peripheral locations; (b) preserving existing RT/RW social unit boundaries in receiving areas; and (c) providing transitional social support to maintain employment and school access during the resettlement period, addressing the 41% who cite emotional attachment and 34% who cite workplace proximity as primary reasons for remaining.

For researchers:

(9) Prioritise longitudinal panel studies (minimum five-year tracking) that follow the

same households and institutional actors across RPJMD cycles to empirically assess whether adaptation capacity gains generated by international programmes, such as ACCCRN and 100 Resilient Cities, persist or erode after those programmes conclude, with particular attention to non-priority sectors. (10) Develop co-designed community flood communication protocols by partnering with RT/RW leader networks to test, iterate, and validate simple visual tools (colour-coded inundation maps, SMS-based alert templates) that translate the probabilistic flood forecasting outputs of (Suwarman et al., 2025) into actionable early warning guidance for non-technical audiences, measuring uptake and behavioural response as primary outcomes.

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