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The governance paradox: why polycentric systems fail to mitigate urban vulnerability in the global south

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The global reliance on Polycentric Governance (PCG) for climate adaptation in rapidly urbanizing coastal cities frequently fails to achieve transformative outcomes, a paradox this research addresses by identifying institutional friction as the core impediment. Using a mixed-methods approach in Semarang, Indonesia, we combined Q-methodology with Cellular Automata–Markov chain (CA-Markov) LULC modeling to relate institutional dynamics to physical land-use outcomes. The Q-methodology analysis of 58 key stakeholders revealed a deep institutional rift characterized by an Adaptation Tempo Dilemma and Trust Deficit, with stakeholders divided between advocates of transformative change and a prevailing preference for incremental adaptation. In parallel, the CA-Markov modeling documented the physical trajectory associated with this governance context: impervious surface areas are projected to increase dramatically from 39% in 2009 to over 51% by 2039, substantially accelerating the city's vulnerability to flooding in high-risk zones. We conclude that, in the context of the Urban Global South, institutional trust-building and policy coherence are not merely desirable but necessary pre-emptive conditions for PCG to catalyze transformative climate adaptation successfully.

KEYWORDS
flood resilience, incremental adaptation, polycentric governance, stakeholder perceptions, transformative adaptation, urban flooding

1 Introduction

Urban flooding represents one of the most critical and rapidly escalating threats to global societal stability and economic productivity in the 21st century. Driven by the synergistic pressures of climate change, specifically, sea-level rise and intensified rainfall and explosive, often unregulated, urbanization, the challenge is disproportionately acute in the Global South (Burch et al., 2017; Zain et al., 2022). Coastal and waterfront cities in this region, such as Jakarta, Manila, and Semarang, are highly vulnerable not only due to their low-lying topography but also due to socio-economic factors, including densely populated informal settlements, strained infrastructure, and limited fiscal capacity for large-scale adaptation (Irawan et al., 2021; Khoirunisa and Yuwono, 2023; Kurniawati et al., 2020; Laeni et al., 2020; Marfai and King, 2008). The consequences are immense, moving beyond mere infrastructural damage to encompass systemic disruptions: displacement of millions, outbreaks of disease, and significant negative impacts on national Gross Domestic Product (GDP). Current estimates place the global cost of urban flood damage in the trillions of dollars over the coming decades, with the Global South bearing the brunt of the human and financial toll (Hamdani et al., 2021; Leeonis et al., 2024; Neise et al., 2021; Prime et al., 2015). Addressing this complexity demands adaptation strategies that are not merely technical but are deeply institutional and governance oriented. These strategies must navigate competing demands and mobilize resources across diverse sectors, requiring a fundamental rethink of how stakeholders formulate, enforce, and perceive adaptation policy across the urban hierarchy.

In response to the limitations of centralized, state-led approaches to complex problems such as flood risk, scholarly consensus has largely converged on the framework of Polycentric Governance (PCG) (Anwana and Owojori, 2023; Wolff et al., 2021). PCG is rooted in the idea that effective management of shared resources and societal risks requires a system where multiple, functionally distinct, and semi-autonomous centers of authority interact, coordinate, and sometimes compete to set and enforce rules. This distributed system, involving government agencies at national and local levels, private-sector entities, and civil society organizations, is theoretically superior for climate adaptation because it fosters flexibility, redundancy, the mobilization of local knowledge, and innovation, all of which are essential for navigating uncertain environmental futures. In the context of urban flooding, a polycentric system should ideally integrate national policy mandates (e.g., land-use planning guidelines), regional infrastructure projects (e.g., coastal defenses and reservoirs), and community-level actions (e.g., early warning systems and localized green infrastructure) into a coherent, adaptable network (Ambrose and Imperial, 2025; Garschagen, 2018; Zhou et al., 2026). This theoretical promise has made PCG the normative ideal in global policy recommendations for climate resilience.

Despite the theoretical merits and widespread institutional endorsement of PCG, empirical evidence of its success in achieving transformative, system-wide flood adaptation remains scarce, particularly in fast-growing cities of the Global South (Birkholz et al., 2014; Fox-Rogers et al., 2016; Morrison et al., 2017; Saikia and Jiménez, 2023). A persistent paradox exists: while polycentric structures are frequently adopted, the resulting adaptation measures remain largely incremental (e.g., building higher dikes, short-term pumping) and consistently fail to address the root causes of vulnerability, such as the continued expansion of impervious surfaces and encroachment into critical flood zones (Bhanye, 2025; Love et al., 2024; Mees et al., 2014; Salet et al., 2013; Wang and Wall, 2010). This suggests that the mere existence of multiple governing nodes does not guarantee coherence or accountability. The existing literature fails to adequately identify the structural friction points that consistently undermine polycentric effectiveness in this context. Specifically, we hypothesize that two neglected yet critical institutional mechanisms underpin PCG's operational failure. First, a pervasive public trust deficit results from historical failures, corruption, and policy volatility, rendering citizens and local stakeholders unwilling to support politically costly or transformative adaptation measures. Second, endemic policy inconsistency occurs when mandates from different governing centers (e.g., national economic development goals versus local environmental protection laws) are contradictory or selectively enforced, thereby paralyzing collective action. Without addressing these deeply rooted institutional deficits, PCG becomes a fragmented system of competing interests rather than a resilient network.

Further, this study integrates institutional perspectives with spatially explicit LULC projections to diagnose Semarang's coastal governance holistically and directly shows how governance deficits reproduce the city's evolving environmental risks (Matczak et al., 2018; Shakeri Rostami and Bagheri, 2026). To address this critical empirical and theoretical gap, we conducted an in-depth mixed-methods analysis focused specifically on Semarang City, Indonesia, a rapidly developing waterfront city experiencing acute flooding, severe land subsidence, and the formal implementation of PCG policies. Our approach combines Q-methodology to map the perspectives of 58 key institutional stakeholders, quantitatively revealing profound trust deficits, fragmented coordination, and resistance to policy change, with Cellular Automata (CA)–Markov chain Land Use/Land Cover (LULC) predictive modeling, which provides measurable, spatially grounded evidence of how governance shortcomings manifest in future land-use trajectories (Taloor et al., 2024; Walder and Kantelhardt, 2018). Together, these methods offer a rigorous, multi-dimensional assessment of why Semarang's coastal risks persist despite ongoing policy reforms. The empirical conclusions drawn here are therefore limited to Semarang as a case study and should be interpreted as context-specific rather than automatically generalisable. At the same time, the study advances a broader institutional-precondition framework as a theoretically transferable proposition, while its applicability to other rapidly urbanizing Global South cities remains to be tested through further comparative research.

2 Conceptual framework

This section establishes the theoretical foundation for investigating the functional breakdown of Polycentric Governance (PCG) in achieving transformative climate adaptation, particularly in the rapidly urbanizing Global South. We move beyond simply describing PCG structures to identifying and empirically testing the critical institutional frictions that undermine its effectiveness.

2.1 Polycentricity and climate adaptation

Ostrom (2009, 2010) introduced a novel and influential perspective, arguing that the global climate challenge is best understood through the lens of polycentric governance. At its core, the polycentric ideal assumes that multiple, semi-autonomous centers of authority will generate learning, innovation, collaboration, and productive competition, thereby improving governance performance across complex climate and urban risk systems. In the context of flooding and climate adaptation, this model is especially attractive because it promises to mobilize diverse resources and knowledge across multi-level and multi-sectoral institutions. Rooted in Ostrom's seminal work on common-pool resources, Polycentric Governance (PCG) is often presented as the preferred architecture for climate adaptation because it enables decentralization, flexibility, and coordinated action. Its distributed structure is presumed to activate local knowledge, strengthen vertical alignment, and build institutional redundancy (Kellner et al., 2024; Wiering et al., 2017).

Yet these mechanisms depend on conditions that PCG frequently presupposes but does not itself guarantee: trust among actors, information sharing, consistent rule enforcement, and the capacity to reconcile overlapping mandates. Where these conditions are weak, polycentric systems tend to fragment rather than coordinate, and cooperation becomes selective or strategic rather than transformative. This gap between ideal and practice is especially visible in the Global South, where many arrangements remain trapped in incremental, reactive responses such as routine pumping, temporary drainage fixes, or isolated infrastructure works instead of systemic adaptation. Evidence from Jakarta, for example, shows that flood governance is fragmented across levels of government, with overlapping institutions and weak coordination undermining integrated flood-risk management, while adaptation efforts remain heavily oriented toward engineering works such as sea walls, river dredging, retention ponds, and pumping systems rather than transformative institutional change (Frimpong Boamah, 2023). More broadly, scholarship on climate governance warns that polycentric arrangements can be dominated by powerful actors, reproduce inequality, and fail to correct structural power imbalances when enforcement and accountability are uneven (Morrison et al., 2017; Okereke, 2018). The resulting pattern reveals not a failure of the polycentric idea itself, but a failure of the institutional environment required for it to function as intended.

2.2 Defining adaptation outcomes: incremental vs. transformative

The extreme increase in climate-related disasters, including floods, with significant socio-economic losses, necessitates a clear understanding of the adaptation response required (IPCC, 2014). Adaptation is defined as an adjustment in the social, economic, and ecological systems to respond to actual and expected climatic stimuli, consisting of changes in processes, practices, and structures to reduce unintended consequences and generate benefits (Nelson et al., 2007; Eriksen et al., 2015; Singh et al., 2022). Adaptation is framed as a continuum, ranging from resilience to transition and ultimately transformation (Pelling, 2010). In dealing with profound uncertainty, simply building resilience is insufficient; ensuring future sustainability requires transformative action (Mechler and Deubelli, 2021; Garschagen et al., 2018).

Transformative adaptation is recognized as the necessary solution when "business as usual" adaptation plans are no longer sufficient to respond to environmental changes that have reached an alarming level (Garschagen et al., 2018; Gordon, 2018; Mechler and Deubelli, 2021; Nelson et al., 2007). It represents fundamental changes in social-political and economic aspects, manifesting in integrated elements of vision, planning, institutional framework, and intervention (Dobbin et al., 2007). This approach requires sufficient financial resources and a strong political commitment from various parties (Ayers and Huq, 2009; Filho et al., 2022).

In contrast, Incremental Adaptation represents marginal changes, focusing primarily on surface-level conditions such as policies, practices, and resource flows (Folke et al., 2005; Haider et al., 2021; Wilson et al., 2020). The preference for incremental adaptation is often based on the consideration of avoiding disruptions by taking well-known, successful actions from past extreme events. Incremental adaptation is typically less complex in the decision-making process, often operating at the individual level with simple regulations and a higher possibility of achievement, largely dependent on market dynamics. While incremental actions aim to maintain the capacity for building resilience by keeping the system within a stable domain, transformative adaptation seeks to cross a critical threshold into an entirely new, more sustainable trajectory (Mach and Siders, 2021; McNamara et al., 2018; Shi and Moser, 2021). The challenge for PCG in the Global South is that, due to limited funds and an unsupported governance system, the incremental approach remains the default alternative (Moftakhari et al., 2024), despite the evident need for transformative action to avoid maladaptation (Dolšak and Prakash, 2018; Klöck et al., 2022).

2.3 The institutional friction hypothesis

We hypothesize that the failure of PCG to deliver transformative adaptation outcomes is driven by two critical and interdependent forms of institutional friction that undermine trust and coherence within the system: a pervasive Trust Deficit and endemic Policy Inconsistency (Carter et al., 2021; Challinor et al., 2018; Haasnoot et al., 2024). These are the missing theoretical links required to explain system paralysis. Detailed description shown below:

Trust Deficit: While PCG assumes collaborative nodes, real-world governance, particularly in contexts characterized by rapid change, limited transparency, and historical corruption, suffers from low trust. This deficit manifests in two dimensions: vertical trust (state institutions to citizens) and horizontal trust (agency-to-agency). When public trust is low, citizens and local stakeholders are unwilling to accept or cooperate with politically costly, high-impact measures necessary for transformative change (e.g., land acquisition for retention ponds, relocating communities, or strict building code enforcement) (Aerts et al., 2018; Berman et al., 2017; Dias et al., 2021; Durand and Ruin, 2018; Viglione et al., 2014). Furthermore, low horizontal trust breeds protective, siloed behavior among agencies, leading to information hoarding and a refusal to delegate or cede authority, which paralyzes joint decision-making. This deficit effectively prevents the necessary social capital required for collaborative governance from forming.

Policy inconsistency arises when regulatory signals from different governing centers conflict, creating institutional ambiguity (Bergsma, 2018; Bolognesi et al., 2021; Mishra et al., 2022; Zarb and Taylor, 2023). For example, national economic development mandates may prioritize infrastructure expansion, such as new ports or large-scale housing, even when these projects conflict with local environmental protection laws or regional spatial planning intended to reduce flood risk. This inconsistency can give private-sector actors, especially those with political and financial power, room to exploit legal loopholes or ambiguous mandates (Kaufmann and Wiering, 2022). In Semarang's northern coastal zone, large-scale infrastructure and industrial investments have reshaped land-use priorities and often required revisions to spatial planning and environmental management frameworks. Notable examples include the Semarang–Demak Toll Road, which has been framed as an integrated infrastructure project for mitigating tidal flooding and improving regional connectivity, alongside related coastal development works along the northern coast of Java. These projects have transformed areas previously designated for coastal protection, fisheries, aquaculture, and coastal-buffer functions under spatial plans for Semarang and Central Java (Suroso and Firman, 2018). In parallel, continued expansion of Tanjung Emas Port has increased demand for port-related logistics and industrial land, while the Kendal Industrial Park has reinforced the industrial and logistics orientation of the northern coastal corridor. The environmental implications of these developments have been addressed through project-specific environmental assessment and mitigation measures, including coastal flood management and infrastructure design intended to reduce exposure to sea-level rise and tidal inundation (Andriani, 2025). Together, these investments demonstrate how nationally prioritized infrastructure and economic development projects have increasingly reconfigured coastal land use, often superseding earlier conservation, aquaculture, and hazard-sensitive zoning designations through spatial planning revisions and implementation of integrated infrastructure models. Such selective enforcement allows non-compliant land use, including the continued construction of impervious surfaces in flood-risk areas, because short-term economic incentives often outweigh long-term environmental risks. Explicitly, these two frictions undermine the core functions of PCG, namely information sharing, mutual monitoring, and effective rule enforcement.

2.4 Linking governance failure to physical vulnerability

To move beyond abstract institutional critique, it is necessary to establish a clear, measurable causal link between the hypothesized institutional frictions and the ultimate physical indicator of adaptation failure: the expansion of urban flood vulnerability. We contend that the weak or selective enforcement of coherent land-use regulations is a direct consequence of high institutional friction, manifesting as the physical expansion of impervious surfaces into critical flood zones. This forms the analytical link we examine; we treat it as an interpretive relationship rather than one that is statistically estimated, since the two methods are applied in parallel. This framework justifies our interdisciplinary methodological approach. We employ Q-methodology to quantitatively map and categorize the subjective perspectives of key stakeholders (the *institutional friction*), providing empirical evidence of the trust deficit and resistance to transformative policy. We then couple this with Cellular Automata (CA)-Markov chain Land Use/Land Cover (LULC) predictive modeling to quantify the physical *consequence* of this governance failure. The projected expansion of vulnerability provides the objective, environmental metric against which the political and institutional failures are measured. As illustrated in our conceptual model, failing to address the institutional preconditions (trust and coherence) prevents PCG from producing transformative outcomes, thereby accelerating physical vulnerability and completing a damaging feedback loop in which increased flood risk further erodes public confidence.

3 Study area and methods

3.1 Study area

Semarang City (Figure 1), the capital of Central Java Province, has experienced rapid urbanization, with a population of 1.69 million in 2023 (Aditiya and Ito, 2023) Semarang has also experienced high economic growth (Zain et al., 2022), which has changed the city's landscape, raising concerns about sustainable development and environmental preservation that cannot be fully achieved. As in other cities in the Global South, rapid urbanization in Semarang has led to the adoption of a fragmented green city concept, focusing on green open spaces that have not significantly improved urban sustainability. In addition, urban growth corridors in the Semarang Metropolitan Area have caused significant vegetation degradation, contributing to environmental degradation due to uncontrolled urban sprawl (Dewa et al., 2024).

Flood risk governance in Semarang City involves a multifaceted approach that integrates resilience, local institutional capacity building, and community engagement to address the challenges posed by frequent flooding. Semarang has incorporated resilience into its flood disaster planning, focusing on reducing exposure to hazards, reducing vulnerability, and improving land and environmental management. This approach requires both short-term initiatives and a long-term framework to be effective (Handayani et al., 2019). The existing legal framework for adaptation in Indonesia, including Semarang, is limited in addressing the burdens borne by communities due to climate change and rising sea levels. A more inclusive approach could improve

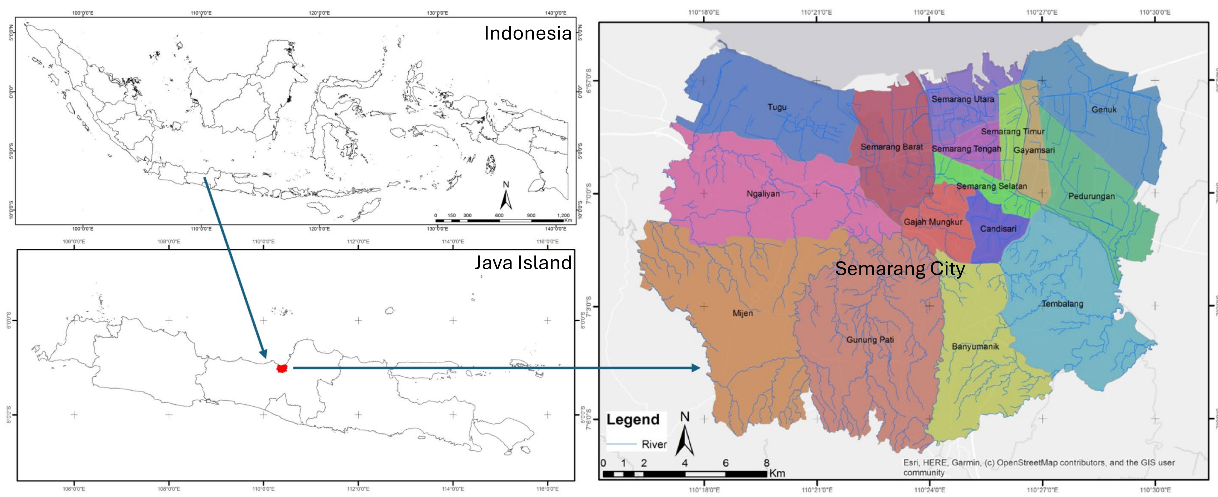

FIGURE 1
Study area in Semarang City, Indonesia.

social equity outcomes for vulnerable communities (Nurhidayah and McIlgorm, 2019). Community engagement also shows great potential, especially among micro, small, and medium enterprises, which are ready to contribute to collective flood risk reduction if costs are shared fairly. This condition shows the importance of social motivation in collective adaptation efforts (Neise et al., 2021).

3.2 Methods

Our study employed a robust, interdisciplinary mixed-methods approach to jointly examine institutional friction (Trust Deficit and Policy Inconsistency) alongside the projected physical expansion of flood vulnerability (LULC change). The overall methodology involved two distinct but integrated components: qualitative-quantitative mapping of stakeholder perspectives via Q-Methodology and predictive spatial analysis via CA-Markov modeling. The two components are analysed in parallel and triangulated rather than fitted within a single causal model: the CA-Markov projection is driven by historical land-use transition probabilities (2009–2014) and a distance-from-road covariate, and therefore does not encode trust or policy variables directly. The relationship between the institutional friction identified through Q-methodology and the projected land-use change is consequently interpretive rather than statistically estimated, and is read alongside other plausible drivers (e.g., demographic and spatial-planning dynamics) that the projection does not explicitly model.

3.2.1 Quantifying institutional friction: Q-methodology

Q methodology has gained prominence as a mixed-methods approach for exploring risk perceptions (Tuler et al., 2005; Venables et al., 2009)and addressing conservation and land-use conflicts (Albizua and Zografos, 2014; Epstein et al., 2018; Jenkins, 2017). Developed in the 1930s by Stephenson, Q methodology was designed to study individuals' beliefs and attitudes. It provides a structured approach to examining qualitative data, enabling researchers to identify subjective viewpoints that might otherwise remain hidden. Based on its mathematical foundation in person-factor analysis, which reverses the logic of conventional factor analysis, it enables the grouping and comparison of participants who share similar social perspectives on the topic under investigation. Analysts commonly rely on specialized software to process Q-method data, such as PQMethod, PCQ, Ken-Q/KADE, Q Method Software, or R.

Q methodology has been effectively utilized in flood governance research to uncover diverse perspectives and address governance challenges. In the French Alps, Q methodology revealed tensions in flood risk governance, highlighting friction between local municipalities and regional agencies due to the upward transfer of risk management responsibilities, which complicates crisis management at the municipal level (Arik et al., 2023; Sneegas et al., 2021). Similarly, in Austria, Q methodology was used to assess homeowners' opinions on flood risk management, revealing a preference for face-to-face risk communication and a desire for participatory decision-making processes (Attems et al., 2020). The methodology's ability to blend qualitative and quantitative data makes it a valuable tool for understanding complex governance issues, as demonstrated in studies of corporate and disaster governance, where it helps elucidate stakeholder perspectives and governance dynamics (Gober et al., 2013).

In this study, Q-Methodology was employed to quantitatively map and categorize the diverse subjective perspectives of 58 key institutional stakeholders, thereby providing empirical evidence of the hypothesized Trust Deficit and resistance to Transformative Adaptation.

The Q-set serves as a representative sample of the concourse, encompassing a comprehensive array of possible expressions on the topic, gathered from various perspectives (Mukherjee et al., 2018; Zabala et al., 2018). Using a structured approach, we refined the concourse by consolidating statements with similar meanings or arguments. This process allowed us to identify recurring themes and organize 57 statements into five categories at the city level, and 25 statements into three categories at the sub-district level.

At the city level, the course can be categorized into five main areas. First, the role of stakeholders is crucial, with local governments identified as key players in adaptation efforts, supported by NGOs, and emphasizing community-led development. Second, the governance and policy landscape highlights the need for consistent, well-enforced government policies, structured decision-making, and collaborative planning that incorporates community input and decolonizes planning policies for informal settlements. Third, adaptation strategies are vital; there is a call to prioritize innovative technologies, recognizing that while gradual adaptation allows for adjustments, it may be too slow to address urgent flooding risks. Fourth, community involvement and cooperation are essential, as evidenced by the strong sense of collective action in response to floods and the importance of local wisdom in developing adaptive settlements. Finally, emergency preparedness and response are emphasized with well-coordinated emergency systems and effective flood early warning systems that play critical roles in reducing impacts, along with the integration of global and local knowledge to enhance flood adaptation efforts (Alaerts and Kaspersma, 2022; Driessen et al., 2016).

At the subdistrict level, the course can be organized into three main areas. First, governance and responsibility highlight the importance of collaboration between local, regional, and national governments for effective flood management. Local governments are seen as crucial players in flood adaptation, whereas policies often suffer from inconsistencies and poor enforcement. There is also a call for greater private-sector involvement in funding flood-adaptation projects. Second, adaptation strategies and planning emphasize the need for long-term planning and radical changes to manage flood risks effectively. This includes redesigning urban areas to enhance resilience while acknowledging that gradual adaptation measures may fall short in addressing the severity of floods. Transformative adaptation is recognized for its potential to displace communities and cause social disruptions. Finally, the impact and community engagement category emphasizes the significant economic losses from floods in Semarang, while flooding may not necessarily increase due to climate change. Central to successful flood adaptation is the critical role of community involvement, essential for fostering resilience and effective response strategies (Afsari et al., 2022; Cea and Costabile, 2022; Fuchs and Thaler, 2017).

The differing concourses at the city and subdistrict levels likely reflect the varying scales of flood management challenges and adaptation strategies (Karimi et al., 2015; Restrepo-Osorio and Brown, 2018). This distinction allows for more targeted, context-specific approaches to flood resilience, acknowledging that urban centers and smaller communities may face unique vulnerabilities and possess different resources. Tailoring flood adaptation measures to specific geographical and socio-economic contexts can lead to more effective and sustainable outcomes, enhancing overall community resilience.

Further, Q-methodology was used to gather and analyze expert opinions on consensus and challenges in polycentric governance for urban flood management, complemented by qualitative interview data. This approach enables the identification and quantification of stakeholder perspectives. However, this study had some limitations. While the Q-methodology excels at uncovering prevalent viewpoints within a chosen group, it cannot determine how these views are distributed across a larger population. Furthermore, the results are primarily case-specific, reflecting the experiences of the stakeholders in Semarang City. Although the participant sample may not be representative of waterfront cities in developing countries, the selected statements were considered comprehensive. These statements were derived from semi-structured interviews with flood risk management experts and a literature review of waterfront cities in the Global South, ensuring that they encompass the full spectrum of the debate and are relevant to decision-makers across the Global South.

To ensure a comprehensive representation of viewpoints, a total of 58 stakeholders were invited to participate in the study (see Table 1). The participants reflected a balanced composition of city-level government officials, sub-district authorities, local residents, and civil society members. Deliberate consideration was given to achieving strict gender balance among the respondents to ensure diverse perspectives across all demographic groups. The consultation was conducted sequentially across two separate sessions:

a. Session 1 (17 June 2024): Dedicated to city-level government officials.
b. Session 2 (18 June 2024): Combined sub-district authorities, local residents, and civil society representatives.

Given the involvement of multiple tiers of governance, local community members, and civil society groups, potential conflicts of interest—particularly regarding power asymmetries and professional hierarchies—were explicitly mitigated. To ensure data integrity, all participation was entirely voluntary, and full anonymity was guaranteed. Respondents were assured that their Q-sort configurations and post-sort explanations would not be tied to their names, specific institutional titles, or official positions in any public reporting. Furthermore, the two consultation sessions were separated by administrative levels specifically to prevent the presence of higher-ranking city officials from influencing, biasing, or constraining the responses of sub-district officers and local community residents.

Within the research methodology, execution was divided into two distinct phases: the definition of the Q-Sample and P-Set, followed by the Q-Sort administration and statistical analysis. The research began with the development of a structured discourse on flood governance and climate adaptation. From this discourse, two definitive Q-samples were derived to match the scope of each stakeholder group: a comprehensive set of 57 statements for city-level officials, and a targeted set of 25 statements for the sub-district level. Together, these samples represented the full range of consensus, conflict, and ambiguity surrounding climate adaptation strategies in Semarang.

The consultation sessions and the Q-sorts were conducted entirely in Bahasa Indonesia. At the sub-district level, each participant committed approximately 60 min to complete the sorting process. During this single session, participants ranked their designated 25 statements (provided in the Supplementary Appendix) according to a specific condition of instruction:

> *"Which of the statements are most like your perspective regarding flood management governance in your sub-district, and which are most unlike your perspective?"*

During the sorting process, participants were required to arrange the 25 statements into a "forced" Q-sort distribution layout (see Figure 2). This forced distribution design systematically required participants to make deliberate, comparative choices across all responses.

Upon completing the layout, brief post-sort interviews were conducted. Focus was placed on the extreme ends of the distribution grid (ranging from −4 to +4); participants were asked to explain the underlying rationale for the specific statements they identified as being the "most unlike" (−4) and "most like" (+4) their personal perspectives on flood management governance in their sub-district.

The following day, at the city level, another set of respondents was asked to commit 90 min to complete the Q sorts. During a single session, each participant ranked the 57 statements (Supplementary Appendix) according to the following condition of instruction: Analysis of Perspectives on Flood Management Governance in Semarang City (City Level). Which of the statements are most like your perspective (regarding flood management governance in Semarang City)? Which of the statements are most unlike your perspective?. During the sorting of the 57 statements, participants were expected to complete the Q-sort layout (see Figure 2) that "forced" choices across their responses. At the ends of a wide distribution (−5 to +5), participants were asked in the discussion to explain why those statements were identified as the most unlike and most like their perspective regarding flood management governance in Semarang City. Both the discussion and the Q-sorts are presented in Bahasa Indonesia.

Participants were instructed to review all statements printed on the cards and categorize them into three groups based on their level of concurrence. Subsequently, they arranged these statements on a gridded display board spanning from strong opposition to firm support. Stakeholders were required to occupy every position on the ranking grid using a forced distribution method to ensure complete coverage of the Q grid.

Participants were given time to examine and adjust their statement of placements, provided that each grid square contained only one statement.

TABLE 1 Composition and schedule of stakeholder consultation sessions.

Group of respondents	Time of Q-sorting	Number of statements	Total addressed	Number of responses
Sub-district authorities, local residents, and civil society	Session 17 June 2024	25	40	40
City-level government officials	Session 18 June 2024	57	58	58
Total			98	98

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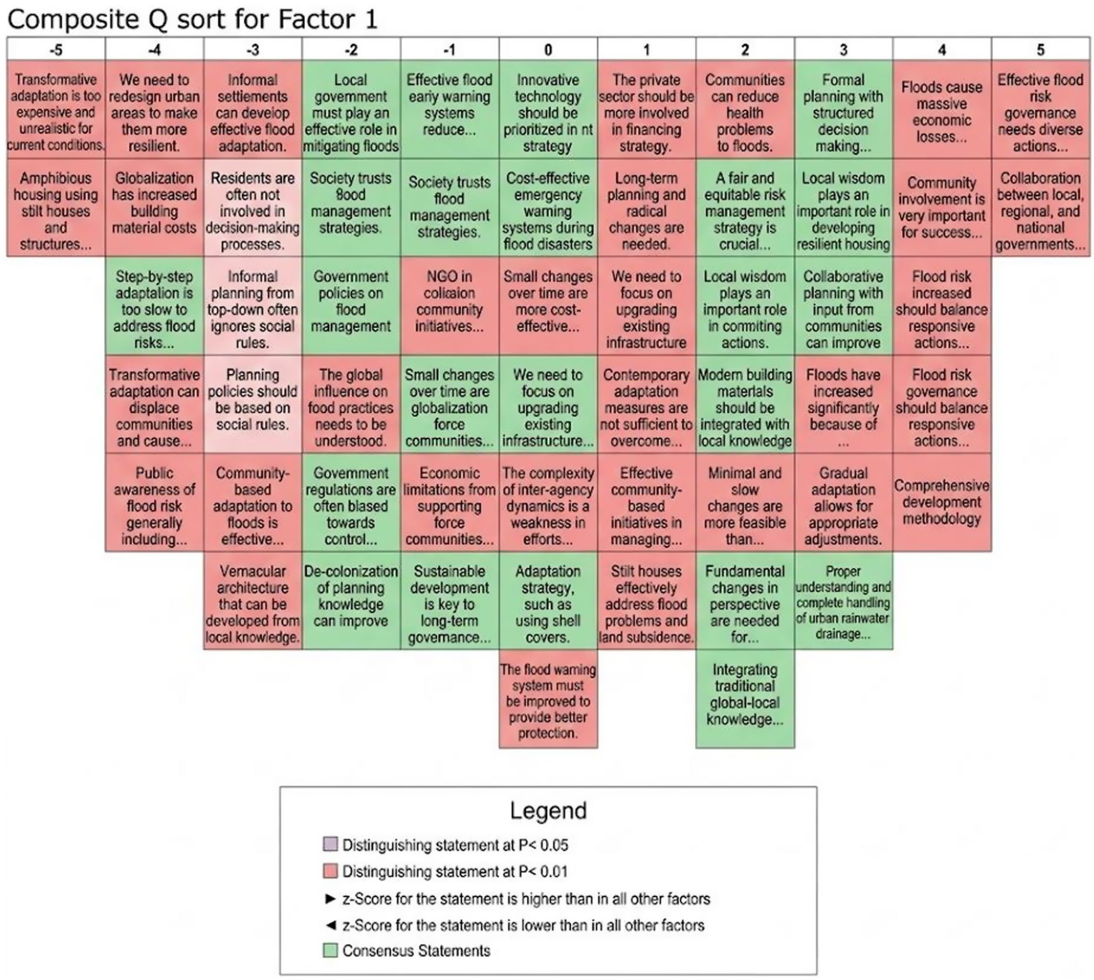


FIGURE 2
Composite Q sort for Factor 1, city-level analysis (Kota Semarang).

The quantitative stage in the middle of the Q methodology presents unexpected challenges. It provides a quick evaluation of the primary qualitative information and challenges of assumptions about stakeholder categories. After the ranking, a follow-up interview was conducted during which stakeholders expanded their opinions regarding each statement. Special emphasis was placed on statements at the extremes of the ranking grid to gain a more comprehensive understanding of their viewpoints.

Once participants completed a Q-sort, they are ranked-ordering the 25 and 57 statements on a quasi-normal distribution grid (e.g., from −5 "Most Disagree" to +5 "Most Agree"). The resulting correlation matrix of individual sorts was subjected to factor analysis using KADE software. We employed Principal Component Analysis (PCA) for factor extraction, retaining factors with eigenvalues greater than 1.0, and used Varimax rotation to achieve simple structure and maximize the distinctiveness of the factors. The extracted factors, which represent statistically significant shared viewpoints, were then interpreted to define the unique positions and underlying rationales (the *institutional friction*) that contribute to policy inconsistency and the resultant paralysis of PCG.

3.2.2 Land use and land cover (LULC) change analysis

The Cellular Automata (CA)-Markov chain model was used to project future LULC change, specifically quantifying the expansion of impervious surfaces as the measurable physical consequence of governance failure (Policy Inconsistency). This study used the Cellular Automata-Markov Chain (CA-MC) method to predict land-use changes, following the methodology of Hakim et al. (2025). Land-use data from 2009 and 2014 are used to predict land use in 2019, which is then validated against actual 2019 land-use data. If the validation value reaches 80%, the model built can be used to predict land use until 2024, 2029, 2034, and 2039. This future land-use prediction, focusing on urban land-use type, is overlaid with flood-prone data to assess urban land expansion in the flood-prone area. In this study, two scenarios were built: Business-as-Usual (BAU) and Distance from Road.

The Cellular Automata (CA) model, widely used in the literature to study complex systems, updates each cell's state based on its neighbors, according to transition rules. CA can predict recurring spatial patterns over time, integrated with the Markov Chain (MC) framework. The state vector p(t), representing the cell distribution, evolves according to $p(t + 1) = T \cdot p(t)$, where T is the transition matrix that defines the probability of state changes. This iterative process helps understand long-term dynamics, identify trends, and simulate spatial dependencies.

Land use data were sourced from the GLC_FCS30D dataset, a global land cover dataset with a 30-meter resolution spanning 1985 to 2022, organized into a classification system with 35 classes. The validated accuracy for the primary classification system is 80.88% (±0.27%), while its accuracy in the LCCS level-1 validation system reaches 73.24% (±0.30%) (Bastos et al., 2022; Zhang et al., 2024) [2]. Road data was sourced from Indonesia's basic maps (Rupa Bumi Indonesia, RBI) at a scale of 1:25,000. This projection serves as the objective, environmental evidence, quantifying the long-term acceleration of flood vulnerability resulting from persistent policy inconsistency and underlying institutional frictions identified via the Q-methodology.

4 Results

4.1 Q methodology results on institutional friction and vulnerability acceleration

The Q-Methodology analysis successfully identified two distinct, statistically significant factors (Viewpoints 1 and 2) that collectively explained 58.7% of the total variance (N = 58). These factors represent core ideological friction points—or tensions—in flood governance among city-level officials, sub-district authorities, and community representatives, confirming a functional fracture within the Polycentric Governance (PCG) model along two primary dilemmas: the Adaptation Tempo Dilemma and the Collaboration vs. Skepticism (Trust Deficit). The results of activity at the city level are shown in Table 2, and the results from the subdistrict level are shown in Table 3.

At the city level, Factor 1 (The Transformative Planning Advocate) emphasizes the necessity for immediate, large-scale structural change, registering a strong disagreement (Q-SV: −4, Z-score: −1.294) with the statement that "Incremental adaptation is too slow to address urgent flood risks," indicating a belief that the current gradual pace is critically inadequate. This viewpoint simultaneously supports the need for formal planning (Statement 32) and collaborative planning (Statement 36), alongside valuing local wisdom (Statement 41) and community cooperation (Statement 28). In contrast, Factor 2 (The Adaptive Incrementalist) favors flexible, gradual adaptation (Statement 14, Q-SV: 3, Z-score: 1.11), which "allows for continuous improvement based on evolving conditions and information," thus engaging the Adaptation Tempo Dilemma. This incremental perspective is coupled with a profound Trust Deficit, evidenced by negative scores regarding the need for local governments to assume primary responsibility (Statement 2, Q-SV-3, Z-score −0.956) and the inconsistency of government policies (Statement 6, Q-SV-1, Z-score −0.306) (Figure 3).

The respondents at the subdistrict level revealed two distinct and compelling viewpoints, labeled Factor 1 (The Transformative Governance Advocate) and Factor 2 (The Pragmatic Systems Incrementalist). Both factors agreed on the fundamental importance of multi-level collaboration and recognized that flooding causes significant economic losses, suggesting a consensus on the severity and complexity of the challenge (see Table 3).

Factor 1, the *Transformative Governance Advocate*, holds the view that only profound, systemic governance reform can adequately address escalating flood risks. Stakeholders loading on this factor

TABLE 2 Factor Q sort values at City Level, starting with the statements on which there is the most agreement between factors (–5: strongly disagree with +5: strongly agree with statement).

No.	Statement	F1 Q-SV	F1 z	F2 Q-SV	F2 z	Sig.
2	Local government should act as the primary party responsible for flood adaptation.	-2	−0.778	−3	−0.956	*
3	NGOs play an important role in supporting community-based flood-management initiatives.	0	0.152	−1	−0.294	*
6	Government flood-management policies are often inconsistent and weakly enforced.	−2	−0.806	−1	−0.306	*
11	Innovative technology should be prioritised in flood-management strategies.	0	0.181	0	−0.037	*
14	Incremental adaptation allows adjustments based on the latest information and changing conditions.	2	0.669	3	1.110	*
18	Incremental adaptation is too slow to address urgent flood risks.	−4	−1.294	−2	−0.727	*
19	Floods have increased significantly because of climate change.	2	0.746	0	0.287	*
21	Flood-disaster emergency response is well coordinated.	−1	−0.504	−1	−0.153	*
24	Flood early-warning systems are effective in reducing impacts.	−1	−0.058	1	0.288	*
28	There is a strong sense of community cooperation in responding to floods.	2	0.578	3	1.148	*
29	The public trusts the government's flood-management strategies.	−2	−0.794	−2	−0.746	*
32	Formal planning with structured decision-making is needed for comprehensive flood management.	3	1.143	4	1.435	*
33	Government regulation favours flood-control approaches but is insufficient to reduce flood damage.	−2	−0.889	−1	−0.650	*
36	Collaborative planning with community input can improve flood-adaptation strategies.	3	1.071	3	1.282	*
41	Local wisdom plays an important role in developing flood-adaptive settlements.	2	0.850	5	1.600	—
43	Integrating global and local knowledge can optimise flood-adaptation methods.	3	0.948	2	0.791	*
45	Economic constraints from globalisation force communities to use modern rather than traditional materials.	−1	−0.572	−2	−0.938	*
46	Decolonising planning policy can improve flood adaptation in informal settlements.	−2	−0.890	−5	−1.610	—
47	Flood-risk governance must balance immediate response with long-term risk reduction.	3	1.051	4	1.435	*
49	Community-led development is key to successful flood-risk governance.	−1	−0.769	−1	−0.453	*
52	Adaptive strategies, such as using shells and bamboo, are cost-effective for informal residents.	0	0.143	0	0.077	*

Q-SV = rounded factor-array value; z = normalised factor score. "*" = distinguishing statement; "—" = non-distinguishing/consensus. Grid range −5 to +5.

TABLE 3 Factor Q sort values at sub district level, starting with the statements on which there is the most agreement between factors (−4: strongly disagree with +4: strongly agree with statement).

No.	Statement	F1 Q-SV	F1 z	F2 Q-SV	F2 z	Sig.
1	Collaboration among local, regional, and national government is essential for effective flood management.	4	1.640	4	2.350	—
2	Local government should act as the primary party responsible for flood adaptation.	−1	−0.479	−1	−0.484	*
5	The private sector should be more involved in funding flood-adaptation projects.	−1	−0.444	0	0.011	*
6	Government flood-management policies are often inconsistent and weakly enforced.	1	0.319	0	−0.060	*
7	Major infrastructure change is not needed to address flooding in Semarang City.	−4	−1.655	−3	−1.373	*
8	Long-term planning and radical change are needed to manage flood risk effectively.	0	0.280	2	0.900	—
9	We need to redesign urban areas to be more flood-resilient.	0	−0.165	−1	−0.401	*
10	Transformative adaptation can displace communities and cause social disruption.	−1	−0.790	−1	−0.702	*
12	Incremental adaptation measures are insufficient to address the severity of flooding.	−1	−0.625	−1	−0.457	*
14	Floods have not increased significantly because of climate change.	−3	−1.577	−2	−1.300	*
17	Floods cause major economic losses in Semarang.	2	0.986	3	1.552	*
20	Community involvement is essential for successful flood adaptation.	1	0.543	0	0.117	*

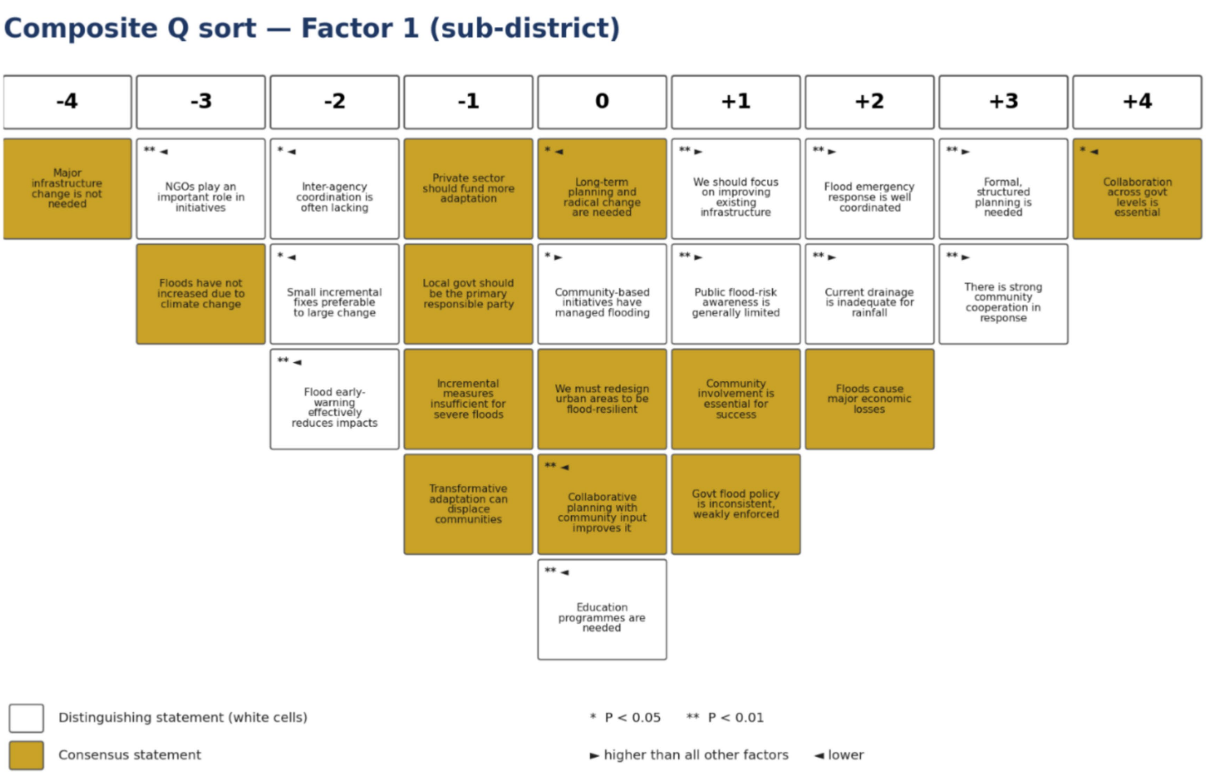


FIGURE 3
Composite Q sort for Factor 1, sub-district analysis (Pedurungan, Gayamsari, Genuk, Semarang Timur).

place the highest importance on strong multi-level collaboration between local, regional, and national authorities (Nm 1, Q-SV = 4). Nevertheless, they express deep dissatisfaction with current approaches, most notably rejecting the notion that adaptive strategies can rely on easily modifiable, information-based adjustments (Nm 7, Q-SV = −4). Their strong disagreement with claims minimizing climate-driven increases in flooding (Nm 14, Q-SV = −3) underscores an acute awareness of climate-related threats and a belief that incremental measures are dangerously insufficient. In contrast, Factor 2, the *Pragmatic Systems Incrementalist*, shares several priorities with Factor 1—such as the central role of multi-level collaboration (Nm 1, Q-SV = 4), recognition of significant economic losses from flooding (Nm 17, Q-SV = 3), and rejection of climate skepticism (Nm 14, Q-SV = −2)—yet approaches adaptation from a more measured standpoint. While supportive of long-term planning and substantial policy shifts (Nm 8, Q-SV = 2), this group favors strengthening and optimizing existing governance and emergency-response systems rather than pursuing the sweeping, immediate overhaul advocated by

Factor 1. Together, these factors illustrate a spectrum of adaptation preferences—from radical transformation to pragmatic systemic refinement—within stakeholders' perspectives on flood governance (Figure 4).

Despite their different levels of urgency, both factors reached consensus (non-significant difference in Z-scores) on several critical points, highlighting institutional and policy deficiencies. Both groups agreed that government policies regarding flood management are often inconsistent and poorly enforced (Nm 6) and that emergency response systems to disasters are poorly coordinated (Nm 10). They also shared the view that effective flood control systems are less effective in reducing impact (Nm 12) and that the private sector should be more involved in funding flood adaptation projects (Nm 5). This broad consensus underscores a shared diagnosis across subdistrict stakeholders: the current governance structure is fragmented, inconsistent, and under-resourced, irrespective of whether they prefer a radical or a pragmatic path forward.

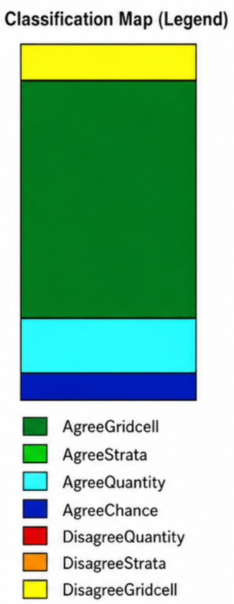
Across both city and sub-district levels, the Collaboration vs. Skepticism tension is pervasive. While there is a strong consensus on the formal necessity of coordinated, multi-actor collaboration (Sub-district Q-SV: 4, Z-score: 1.64), this is undermined by consistent skepticism toward institutional roles, manifesting as a negative perception toward the local government acting as the primary entity responsible for flood adaptation (City Q-SV: −2 to −3; Sub-District Q-SV: −1). This collective low score signifies a fragmentation of authority. This skepticism is structurally linked to the finding that government policies are often inconsistent and weakly enforced (City Q-SV: −1 to −2), an operational failure that is the qualitative root cause of uncoordinated spatial planning, community displacement during large-scale projects (river normalization), and a general perception of reactive management. Finally, the Adaptation Tempo Dilemma is reinforced at the sub-district level by a strong negative perception regarding the necessity of significant infrastructure changes (Q-SV: −4), suggesting a community-level resistance to the social disruption associated with transformative projects, thereby capturing the key policy dilemma: Policy-makers are caught between the urgent need for structural change demanded by city-level advocates and the social resistance favoring flexible, community-driven, but ultimately slower, incrementalism.

4.2 Physical consequences of friction: LULC change and vulnerability acceleration

Before generating the forward projections, the calibrated model was validated by using the 2009 and 2014 maps to predict land use in 2019 and comparing the prediction against the observed 2019 map with the TerrSet VALIDATE procedure (Pontius, 2000). The validation returned a standard Kappa (K_standard) of 0.865, a Kappa for no information (K_no) of 0.888, and a Kappa for location (K_location, equal to K_locationStrata) of 0.878, with an overall agreement of 0.887 and disagreement components of 0.011 (quantity) and 0.094 (location) (Figure 4). Because all Kappa statistics exceed the 0.80 threshold adopted in this study, the model reproduces both the quantity and the spatial allocation of observed change with substantial agreement and is therefore considered reliable for the 2024–2039 projections. It should nonetheless be emphasised that the model is intentionally parsimonious: the quantity of change is estimated solely from the

Model Validation: Classification Accuracy Metrics

Multiples of Base Resolution (MBR) = 1×1



Information of Location — Information of Quantity

Metric	No [–]	Medium [m]	Perfect [–]
Perfect [P(x)]	0.3660	0.9886	1.0000
PerfectStratum [K(x)]	0.3660	0.9886	1.0000
MediumGrid [M(x)]	0.3206	0.8947	0.8906
MediumStratum [H(x)]	0.0588	0.2181	0.2191
No [N(x)]	0.0588	0.2181	0.2191

AgreeGridcell	= 0.6766	DisagreeQuantity	= 0.0114	Kstandard	= 0.8653
AgreeStrata	= 0.0000	DisagreeStrata	= 0.0000	Kno	= 0.8881
AgreeQuantity	= 0.1593	DisagreeGridcell	= 0.0939	Klocation	= 0.8781
AgreeChance	= 0.0588			KlocationStrata	= 0.8781

Note: *MBR = Multiples of Base Resolution; P(x) = Probability of correct quantity; K(x) = Probability of correct stratum; M(x) = Probability of medium accuracy in grid; H(x) = Probability of medium accuracy in stratum; N(x) = Probability of no accuracy.*

FIGURE 4
Model validation: classification accuracy of the 2019 prediction against the observed 2019 map (TerrSet VALIDATE). K_standard = 0.865, K_no = 0.888, K_location = 0.878; overall agreement = 0.887.

empirically observed 2009–2014 transition probabilities, and its spatial allocation is governed only by cell-neighbourhood rules and, in the Distance-from-Road scenario, proximity to the road network. The model does not incorporate demographic drivers (e.g., population density or growth) or statutory spatial-planning instruments (e.g., RTRW/RDTR zoning); its projections should accordingly be read as a continuation of historically embedded spatial behavior rather than as a fully process-based forecast of urban growth.

Across the projection period, Semarang shows a consistent expansion of impervious surfaces, increasing from approximately 39% in 2009 to more than 51% by 2039. This growth is accompanied by a marked reduction in vegetated and agricultural Land, including declines in rainfed cropland, sparse vegetation, and open evergreen forest. These trajectories reflect rapid urbanization, especially in low-lying northern districts that already face significant fluvial and tidal flooding.

Under both scenarios, impervious surfaces increasingly encroach into designated flood-prone zones. By 2039, between 5,147 ha (BAU) and 5,226 ha (Distance-from-Road) of impervious area is projected to lie within official flood hazard zones. The slightly higher encroachment in the Distance-from-Road scenario suggests that road-oriented development patterns are amplifying spatial exposure to flood risk by directing growth toward easily accessible but hazard-prone areas (Figures 5, 6). Relative to the fixed 8,631 ha flood-prone zone, these figures mean that the proportion of hazardous land already sealed by impervious cover rises from 54.0% in 2024 to 59.6% in 2039 under BAU, and from 56.9 to 60.5% under the Distance-from-Road scenario. In other words, by the end of the projection period close to three-fifths of Semarang's officially designated flood-prone land is built over under both trajectories. Figure 6 makes this encroachment spatially explicit: the additional impervious cells (486 ha under BAU and 318 ha under Distance-from-Road between 2024 and 2039) are concentrated along existing road corridors in the low-lying northern districts, precisely where fluvial and tidal flooding is already most severe. This overlay therefore translates the abstract governance failure into a measurable, mapped quantity of new development placed directly within the hazard zone, and provides the spatial

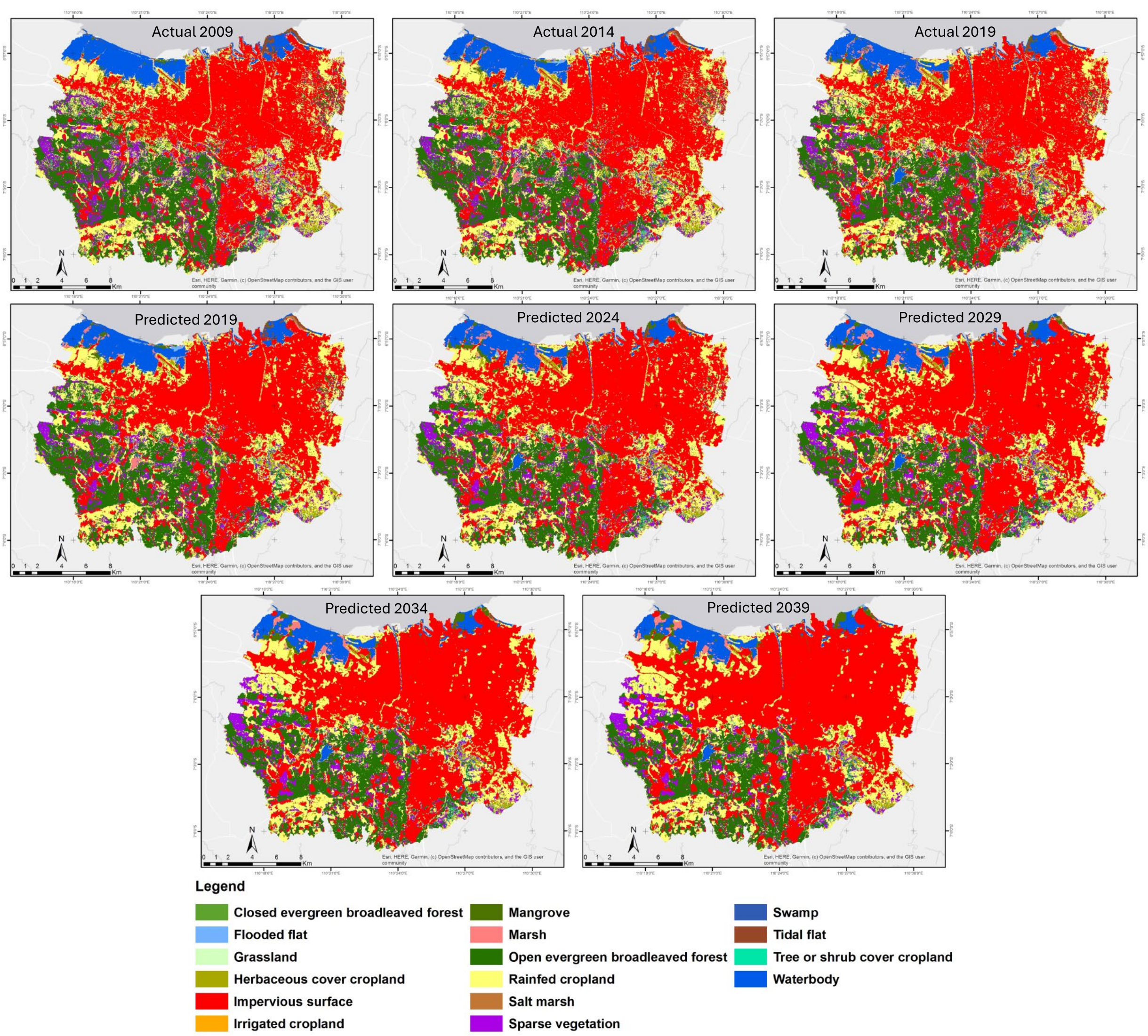


FIGURE 5
Land use maps for the years 2009–2039 based on the BAU scenario. Source: Hakim et al. (2025).

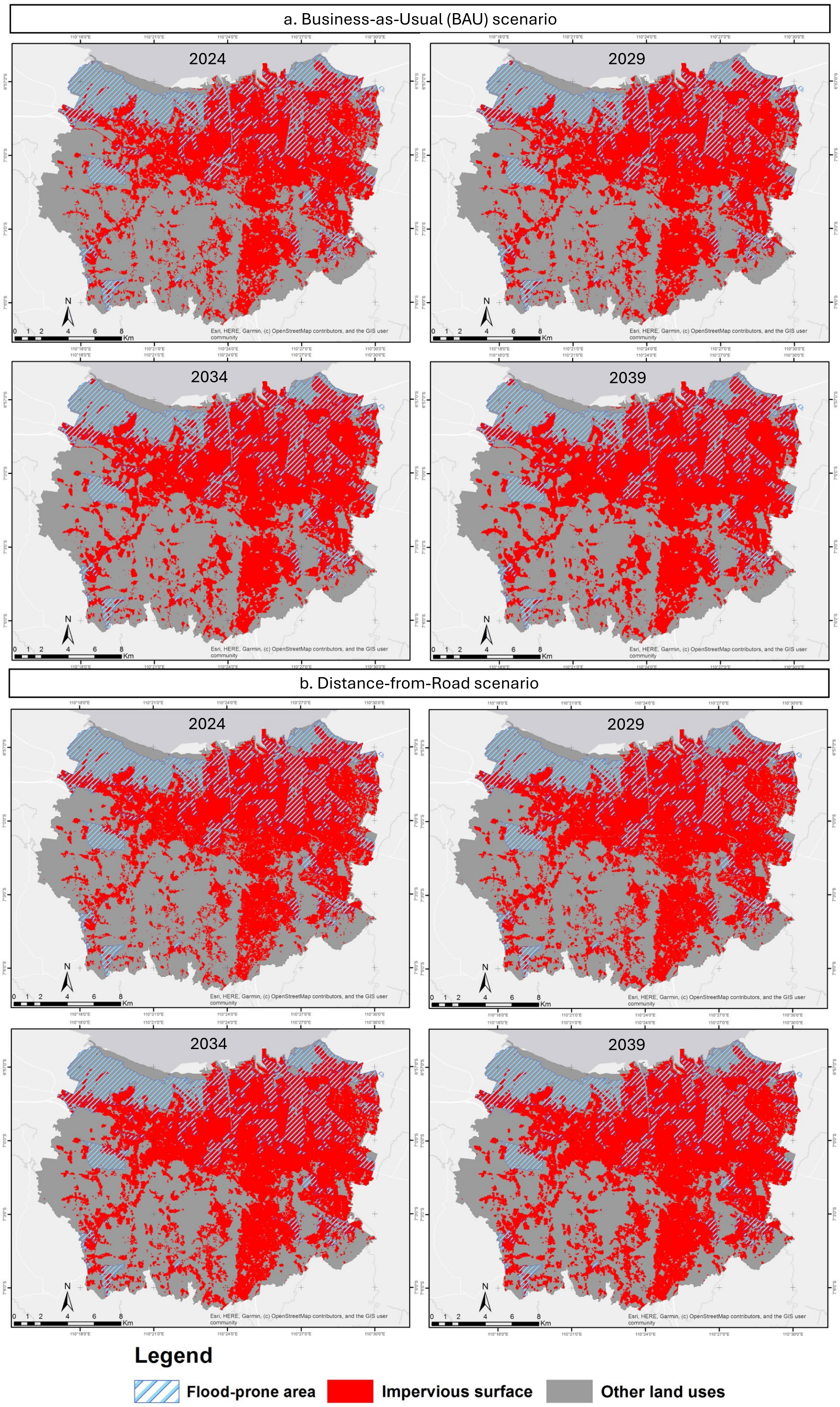


FIGURE 6
Maps of impervious surfaces within flood-prone area for the years 2024–2039: **(a)** BAU scenario and **(b)** Distance-from-road scenario.

evidence requested for the impervious-versus-flood-zone analysis.

5 Discussion

5.1 Resolving the paradox: institutional frictions as the primary barrier to transformative adaptation

The global imperative for climate resilience has widely championed polycentric governance (PCG) as the optimal structural model for managing complex challenges such as urban flooding, particularly in rapidly developing coastal cities of the Global South. Proponents of PCG argue that its distributed, multi-level nature inherently offers flexibility and robustness by engaging a wide array of actors, thus overcoming the limitations of centralized, top-down approaches (Akther and Evans, 2024; Shukla et al., 2023). However, this structuralist perspective is challenged by our empirical findings. Widespread failure of PCG to deliver transformative adaptation outcomes, an observed phenomenon in many vulnerable cities, suggests a fundamental breakdown in implementation mechanisms that remain poorly identified. We contend that the debate should shift from the structure of PCG to its institutional preconditions.

Here, we offer a fundamental correction: we demonstrate that the operational friction within PCG is driven by two critical, interlinked institutional factors, a pervasive public Trust Deficit and entrenched Policy Inconsistency, which constrain successful outcomes. Our analysis provides empirical evidence to associate these socio-political frictions with the sustained, measurable physical expansion of flood vulnerability in the city of Semarang. This finding resolves the long-standing paradox by identifying a plausible institutional mechanism that qualifies the structural determinism often implied in PCG models and establishes that institutional friction has a concrete, spatialized cost.

5.2 The trust deficit and policy inconsistency: generalizable drivers of adaptation lock-in

The results of the Q-methodology reveal a profound institutional rift among governance actors. This finding directly contributes to the ongoing debate over the most effective modes of domestic climate governance. While models often prioritize technical solutions (e.g., the market failure model) or the optimization of actor roles (e.g., the socio-technological transition model), our data forces the insertion of a critical political-economy layer: the quality of institutional interaction.

The widespread Trust Deficit, manifesting as consistent public skepticism and low confidence in local government efficacy, acts as a powerful negative feedback loop on collaboration (Kim, 2020; Sapiains et al., 2021; Zelli, 2011). This counters the optimistic assumption in many PCG theories that multiple nodes of authority will spontaneously coordinate. We argue that effective PCG requires a high degree of horizontal and vertical trust to coordinate distributed action and share resources; when this trust is compromised, as our data shows, actors revert to siloed, low-risk, and short-term actions, effectively precluding engagement in transformative, high-cost adaptation pathways.

Furthermore, the finding of entrenched Policy Inconsistency is critical. This directly challenges the notion that governance complexity (multi-level, multi-actor) is simply a necessary feature of adaptation. Instead, we show that this incoherence is a direct consequence of structural friction: the conflicting mandates, often favoring national economic growth over local environmental protection, translate into an effective policy of unregulated urban expansion. This results in an adaptation lock-in, where the system's inertia defaults to managing symptoms rather than addressing underlying vulnerabilities. The institutional friction thus prevents the critical, cross-scalar policy alignment necessary for major adaptation projects, providing empirical support for the critique that multi-actor governance in contexts of deep inequality and asymmetric power is inherently unstable.

5.3 Physical manifestation of governance failure: the vicious cycle of urban expansion

The most significant contribution of this work lies in quantifying the physical consequences of this institutional failure. The Land Use/Land Cover (LULC) predictive modeling reveals that the Trust Deficit and Policy Inconsistency coincide with the physical expansion of urban vulnerability. Within the 8,631 ha designated as flood-prone, impervious cover is projected to expand from 4,661 ha in 2024 to 5,147 ha by 2039 under the BAU scenario (an increase of 486 ha), and from 4,908 ha to 5,226 ha under the Distance-from-Road scenario. In relative terms, the share of the flood-prone zone sealed by impervious surfaces rises from 54.0 to 59.6% under BAU, and from 56.9 to 60.5% under the Distance-from-Road scenario, so that by 2039 close to three-fifths of Semarang's flood-prone land is projected to be built over.

This progressive sealing of flood-prone land is the measurable cost of governance failure. It demonstrates that when institutional actors are fragmented and policies are incoherent, the *de facto* outcome is unregulated urban sprawl, pushing development into fragile ecosystems and compounding flood risk (Abdullah et al., 2019; De, 2025; Naboureh et al., 2021; Sarfo et al., 2025). This finding refutes the notion that PCG failure is an abstract organizational problem; it is a physical driver of environmental degradation and climate disaster risk, trapping the city in a vicious cycle where institutional friction exacerbates physical vulnerability, which in turn deepens public mistrust. This interdisciplinary link between institutional dysfunction and physical LULC change is a crucial empirical advance for the climate governance literature.

5.4 Re-framing the adaptation agenda: prioritizing institutional preconditions

Our results necessitate a fundamental re-orientation of the global adaptation agenda. The assumption that simply adopting a polycentric structure will inherently lead to better outcomes is flawed. We propose a new framework for climate governance that illustrates how Polycentric Governance (PCG) Failure can lead to a cycle of Governance Paralysis (see Figure 7). This failure, along with Incremental Adaptation (IA), drives Policy Inconsistency

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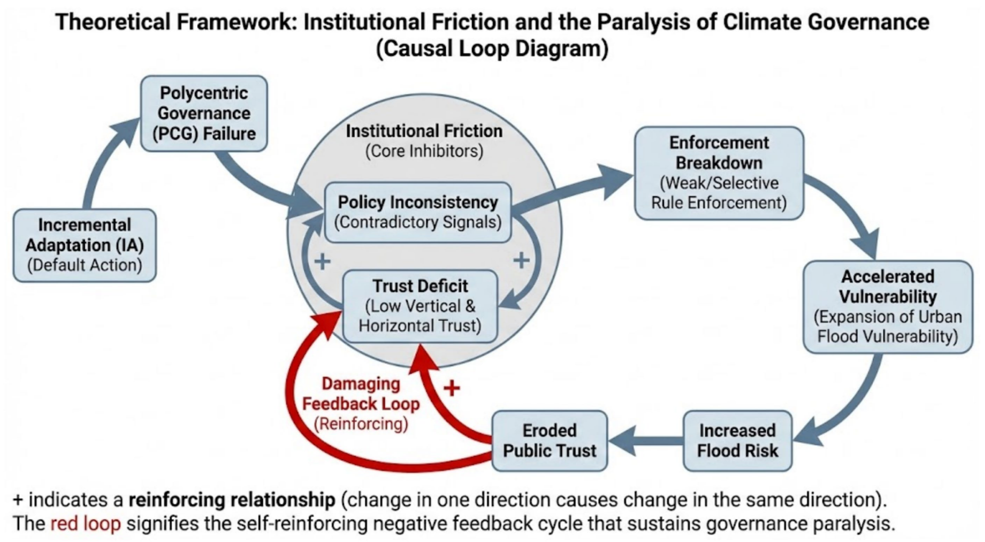

FIGURE 7
Framework illustrating the damaging feedback loop of institutional friction and urban flood risk (Developed by the authors).

(contradictory signals). Policy Inconsistency, along with a Trust Deficit (low vertical and horizontal trust), forms Institutional Friction (Core Inhibitors) that reinforce each other. This friction contributes to an Enforcement Breakdown, leading to Accelerated Vulnerability and, subsequently, Increased Flood Risk. This, in turn, leads to Eroded Public Trust, which creates a Damaging Feedback Loop (indicated by the red arrow) that further exacerbates the Trust Deficit and sustains governance paralysis.

For cities in the Global South, this means shifting the focus from optimizing decentralization to prioritizing institutional reform and capacity-building that directly address the root causes of the Trust Deficit and Policy (Böhmelt et al., 2016; Tosun et al., 2023). Unless institutional foundations are secured, attempts at structural collaboration will remain fragile and will consistently lead to the physical expansion of vulnerability, as demonstrated by the LULC changes in Semarang. This insight is generalizable: any PCG experiment operating under conditions of asymmetric power and low institutional capacity is likely to fail in its transformative goals.

6 Conclusion

We demonstrate that the prevalent failure of polycentric governance (PCG) in the Urban Global South to deliver transformative climate adaptation is not a simple problem of organizational design, but an outcome of two critical institutional failures: a pervasive Trust Deficit and entrenched Policy Inconsistency. Crucially, we quantify the ultimate cost of this friction by showing that it coincides with the physical expansion of flood-vulnerable urban areas, locking cities into a continuous cycle of risk expansion. Our findings challenge the conventional wisdom regarding PCG implementation and propose that institutional health must be prioritized as a necessary precondition for successful, transformative adaptation. This work provides a new, empirically grounded lens for climate governance, essential to securing the resilience of the world's most vulnerable coastal cities. While this study provides a crucial empirical contribution, it is limited by its primary focus on a single case study, Semarang. Future research should apply the "institutional precondition" framework to other urban contexts across the Global South to test the generalizability of our proposed model. Furthermore, quantitative research should focus on modeling the economic costs of policy inconsistency and on developing metrics to track the evolution of the Trust Deficit over time as a leading indicator of adaptation success or failure.

Data availability statement

The original contributions presented in the study are included in the article/Supplementary material, further inquiries can be directed to the corresponding author/s.

Ethics statement

The studies involving humans were approved by the Ethics Committe of Social Science and Humanities Research of BRIN. The studies were conducted in accordance with the local legislation and institutional requirements. The participants provided their written informed consent to participate in this study. Written informed consent was obtained from the individual(s) for the publication of any potentially identifiable images or data included in this article.

Author contributions

SD: Software, Investigation, Writing – review & editing, Funding acquisition, Methodology, Data curation, Writing – original draft, Formal analysis, Conceptualization. BS: Project administration, Validation, Conceptualization, Writing – review & editing, Supervision, Writing – original draft. GS: Writing – review & editing, Writing – original draft, Formal analysis, Investigation, Conceptualization. AH: Writing – review & editing, Investigation, Software, Writing – original draft. AR: Conceptualization, Writing – review & editing, Investigation, Writing – original draft. CZ: Writing – original draft. SP: Writing – review & editing, Validation, Writing – original draft. AA: Writing – original draft. LL: Writing – original draft. RP: Supervision, Funding acquisition, Writing – original draft.

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Conflict of interest

The author(s) declared that this work was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Supplementary material

The Supplementary material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frsc.2026.1857403/full#supplementary-material

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