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GOVERNING URBAN FOREST ESTATES FOR CLIMATE RESILIENCE: MULTI-LEVEL INSTITUTIONS AND COMMUNITY STEWARDSHIP IN ZAMBOANGA CITY, PHILIPPINES

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Abstract
Urban–upland systems in tropical cities face compounding hazards—flooding, landslides, heat stress, and seasonal water scarcity—whose intensity is increasing under climate change. This article analyzes how forest governance can function as ecosystem-based infrastructure for climate resilience in Zamboanga City, Philippines, an urban jurisdiction where forestlands dominate the territory and upstream ecosystem services shape downstream water security and disaster risk. Methods combine satellite-based forest-cover change assessment using Landsat imagery (2000–2022) with a governance and community strategy synthesis based on documentary review and 32 key informant interviews with Department of Environment and Natural Resources personnel, city planners, barangay officials, people's organizations, and Indigenous representatives. Remote-sensing results are validated using 250 ground-truth points and interpreted by governance regime (protected areas, community-based forest management sites, barangay initiatives, and unmanaged forestlands). Findings show heterogeneous forest trajectories by regime. Protected areas remain broadly stable. Community-based forest management sites register positive net canopy change, including an estimated 2–3% increase after 2016 associated with tenure security, reforestation, and sustained community patrolling. Barangay-led initiatives generate localized gains (≈1%) along riparian corridors and degraded slopes, alongside reported declines in sediment loads in monitored streams that support flood mitigation and water quality. Unmanaged forestlands exhibit higher loss rates and weaker recovery, reflecting tenure uncertainty, financing gaps, and limited enforcement reach. The analysis identifies practical integration pathways: embedding forest and watershed indicators in land-use, disaster risk, and water-supply planning; formalizing inter-agency coordination through joint enforcement and interoperable monitoring; and coupling restoration with livelihood portfolios (agroforestry and non-timber forest products) to sustain participation. The case suggests that durable climate resilience emerges from reinforcing feedback loops linking institutional coherence, community agency, and measurable forest recovery at the urban–upland interface. For policymakers, the findings prioritize tenure consolidation, maintenance finance, and spatial targeting of critical watersheds, offering a replicable template for cities across Mindanao and Southeast Asia.

Keywords: Forest governance, Climate resilience, Community-driven strategies, Nature-based solutions, Zamboanga City, Philippines, Climate adaptation planning

1. INTRODUCTION

Urban–upland systems in tropical regions face escalating climate hazards that include flooding, landslides, and seasonal water scarcity. Forest ecosystems moderate these risks through watershed stabilization, flow regulation, carbon storage, and biodiversity support. In Zamboanga City, forest governance operates across national agencies, city authorities, barangay governments, and Indigenous Subanen communities, shaping land-use decisions and climate resilience outcomes. The effectiveness of forest management depends on community participation, tenure security, and coordination across governance levels. When institutions align mandates and resources with local stewardship, forests retain protective functions that reduce downstream exposure to climate extremes. Fragmented authority, uneven enforcement, and competing land-use pressures weaken these benefits and accelerate degradation. Integrating formal institutional mechanisms with community-driven strategies strengthens forest condition, sustains ecosystem services, and enhances adaptive capacity for urban and upland populations. The Zamboanga City experience illustrates how coordinated forest governance supports climate resilience and offers practical lessons for tropical cities that manage complex forest–urban interfaces under intensifying climate stress.

Background
Tropical urban areas increasingly face climate hazards, including intense rainfall, flooding, and landslides, which threaten both livelihoods and ecosystems. Forests play a central role in buffering these impacts by regulating water flows, stabilizing slopes, and maintaining biodiversity. In Zamboanga City, Philippines, upland forests supply critical ecosystem services that support urban water security and disaster risk reduction. Governance structures—ranging from national protected areas to community- based forest management (CBFM) and indigenous stewardship—determine the effectiveness of forest conservation and climate adaptation. Community engagement, tenure security, and multi-level coordination influence forest condition and resilience outcomes. Despite existing legal frameworks, fragmented governance and resource pressures challenge the sustainability of forest ecosystems. Understanding the interactions among governance mechanisms, community strategies, and climate resilience is essential to strengthen urban adaptation planning and ensure the long-term provision of forest-based ecosystem services.

1.1 Forest governance as a climate resilience foundation
Forests sustain climate resilience through regulation of water flows, stabilization of slopes, moderation of temperature, and storage of carbon. Governance systems determine whether these functions persist under climate stress. In tropical developing countries, governance quality shapes exposure, sensitivity, and adaptive capacity across urban–rural continuums. The Philippines exemplifies this dynamic. Forest ecosystems buffer climate hazards that include flooding, drought, landslides, and heat stress, yet governance fragmentation constrains protection and restoration (IPCC, 2023).

Forest governance operates through rules, actors, and processes that structure access, use, and stewardship. Climate resilience reflects the capacity of coupled social–ecological systems to absorb shocks, reorganize, and sustain core functions (Folke et al., 2016). Integration occurs when governance instruments align forest management with adaptation and mitigation objectives. This alignment requires institutional coherence, tenure security, financing, and participation.

1.2 Urban jurisdictions with extensive forests: a neglected arena
Scholarship on forest governance emphasizes rural landscapes, protected areas, and frontier zones. Climate resilience research centers on cities, infrastructure, and social vulnerability. Few studies examine cities that govern extensive forest estates. These jurisdictions face distinct challenges. Urban demand for water and land intersects with upland forest protection. Administrative boundaries encompass watersheds that extend beyond built-up areas. Governance must reconcile municipal service delivery with long-term ecosystem stewardship (Meerow et al., 2016).

Zamboanga City fits this profile. The city administers one of the largest territorial jurisdictions in the Philippines at about 148,338 ha. Forestlands occupy more than four-fifths of this area under national classification (DENR, 2020). The city therefore functions as an urban government with predominantly forested land. This condition elevates the importance of integrating forest governance with climate resilience planning.

1.3 Climate risk profile of Zamboanga City
Climate change alters hazard patterns across Mindanao. Observational records show an increase in mean temperature across the Philippines by roughly 0.1–0.2°C per decade since the mid-twentieth century, alongside rising rainfall variability (IPCC, 2023). Zamboanga City experiences fewer typhoons than eastern seaboards, yet faces compound risks that include seasonal drought, riverine flooding, and landslides.

The Pasonanca watershed supplies domestic water to the city. During El Niño events, reduced rainfall lowers streamflow and reservoir levels, which constrains water supply for households and industry. Flooding affects low-lying barangays along river systems during intense rainfall. Landslides occur in upland areas where forest cover declines and slopes remain steep. These hazards link urban safety and service provision to the condition of forested watersheds.

1.4 Forest resources and socio-ecological functions

National forest inventories estimate Philippine forest cover at about 7.2 million ha, which represents around 24% of total land area (FAO, 2020). Zamboanga City contains a substantial share of remaining forests in the Zamboanga Peninsula. DENR records identify approximately 120,457 ha of forestlands within the city. These forests include protected areas, watershed reservations, CBFM sites, ancestral domains, and residual timberlands.

Forest functions extend across scales. At the watershed level, forests regulate infiltration, reduce sedimentation, and sustain base flows. At the city level, forests moderate heat, protect water supply, and reduce disaster risk. At the national level, forests contribute to mitigation through carbon sequestration. These functions position forest governance as a linchpin of climate resilience for Zamboanga City.

1.5 Institutional architecture of forest governance in the Philippines

Forest governance in the Philippines rests on a decentralized yet hierarchical architecture. The Revised Forestry Code establishes state ownership over forestlands. The Local Government Code of 1991 devolves environmental functions to local government units, including enforcement of environmental laws and implementation of local development plans. The Department of Environment and Natural Resources retains regulatory authority over forestlands and issues tenure instruments.

Executive Order 263 establishes community-based forest management as the national strategy for sustainable forestry and social justice. CBFM agreements grant organized communities stewardship rights for 25 years, renewable upon performance. Climate policy frameworks, including the Climate Change Act and the Nationally Determined Contribution, recognize forests as central to mitigation and adaptation. The Nationally Determined Contribution commits to a 75% reduction in greenhouse gas emissions by 2030 relative to business-as-usual, with forests identified as key sinks (Republic of the Philippines, 2021).

Despite this policy breadth, implementation gaps persist. Mandates overlap between national agencies and LGUs. Financing remains project-based. Monitoring capacity remains limited. These conditions shape how forest governance supports climate resilience in practice (Pulhin et al., 2007).

1.6 Community-driven strategies and tenure

Community participation anchors forest governance reform in the Philippines. CBFM seeks to correct historical inequities by recognizing local stewardship. Empirical studies show that community forestry reduces deforestation relative to open-access regimes and supports livelihood diversification through agroforestry and non-timber forest products (Pulhin et al., 2016).

In Zamboanga City, upland farmers, indigenous groups, and barangay organizations engage in forest protection, reforestation, and agroforestry. Indigenous Subanen communities apply customary rules that emphasize watershed protection and rotational use. These strategies enhance adaptive capacity through income diversification and risk spreading. Tenure security remains uneven, which constrains long-term investment in forest restoration.

1.7 Problem statement and research gap

Existing literature treats forest governance and climate resilience as parallel domains. Forest governance studies emphasize tenure, decentralization, and participation. Climate resilience studies emphasize vulnerability, adaptation, and infrastructure. Few analyses integrate these perspectives within urban jurisdictions that govern large forest estates. This gap limits understanding of how governance arrangements translate into climate resilience outcomes at the city scale.

Zamboanga City offers an opportunity to address this gap. The city combines extensive forestlands, decentralized governance, community forestry, and pronounced climate risk. Analysis of this case advances theory and practice on integrating governance and resilience in tropical cities.

1.8 Research objectives and guiding questions

This article pursues three objectives:

1. Examine institutional mechanisms that structure forest governance and climate resilience in Zamboanga City.
2. Analyze community-driven strategies that translate governance into adaptive capacity and mitigation outcomes.
3. Identify integration pathways and constraints that shape resilience across forested urban jurisdictions.

The analysis addresses the following questions:

- How do national and local institutions coordinate forest governance in a climate-exposed city?
- How do community-based strategies contribute to adaptation and mitigation?
- Which governance gaps constrain integration, and which reforms strengthen resilience?

Data Tables

The data show that forests mediate multiple climate hazards in Zamboanga City. Seasonal droughts rely on base flow regulation, flooding on runoff reduction, landslides on root stabilization, and heat stress on microclimate regulation. Governance mechanisms, including watershed protection, reforestation, and community patrols, support these functions. Actors operate at different scales: DENR oversees forests and contributes to mitigation and adaptation, the city LGU enforces ordinances for risk reduction, barangays conduct local monitoring, CBFM organizations implement agroforestry for livelihood resilience, and indigenous groups provide long-term stewardship. Effective climate resilience emerges from the interaction of forest functions and coordinated governance.

Table 1 demonstrates that forests provide critical ecosystem services that mediate diverse climate hazards in Zamboanga City. Seasonal droughts are alleviated through base flow regulation, while forests reduce urban flooding by controlling runoff. Landslide risk decreases via root stabilization on upland slopes, and heat stress is mitigated through microclimate regulation. Governance

interventions reinforce these functions: watershed protection and CBFM support water regulation, reforestation and zoning manage flood risk, community patrols stabilize slopes, and urban forest protection moderates temperatures. These interactions highlight that effective climate resilience depends on integrating forest functions with targeted, hazard-specific governance strategies.

Table 1
Climate hazards and forest-mediated responses in Zamboanga City

Climate hazard	Observed exposure	Forest function	Governance response
Seasonal drought	Reduced water supply	Base flow regulation	Watershed protection, CBFM
Flooding	Urban inundation	Runoff reduction	Reforestation, zoning
Landslides	Upland slope failure	Root stabilization	Community patrols
Heat stress	Rising urban temperature	Microclimate regulation	Urban forest protection

Table 2 illustrates how multi-level governance actors contribute to forest-mediated climate resilience in Zamboanga City. DENR regulates forest tenure and oversees management, supporting mitigation and adaptation. The city LGU integrates forests into planning and enforces watershed ordinances, reducing climate risks. Barangays conduct local patrols and monitoring, enabling community-level adaptation. People's organizations manage CBFM sites, implement agroforestry, and enhance livelihood resilience. Indigenous groups exercise customary tenure, manage landscapes, and provide long-term stewardship of forest resources. These roles complement each other, showing that coordinated action across national, municipal, and community scales strengthens ecosystem services and improves local climate resilience outcomes.

Table 2
Governance actors and climate resilience roles

Actor	Mandate	Forest role	Resilience contribution
DENR	Regulation, tenure	Forest oversight	Mitigation, adaptation
City LGU	Planning, enforcement	Watershed ordinances	Risk reduction
Barangays	Local governance	Patrols, monitoring	Local adaptation
People's organizations	CBFM stewardship	Agroforestry	Livelihood resilience
Indigenous groups	Customary tenure	Landscape management	Long-term stewardship

Illustration descriptions

Figures 1 and 2 visualize the integration of forest governance, community action, and climate resilience in Zamboanga City. Figure 1 presents an analytical framework showing vertical coordination between national agencies and LGUs, horizontal collaboration with communities, and resulting ecosystem and social benefits, highlighting feedbacks between governance, forest condition, and adaptation outcomes. Figure 2 spatially maps forestlands, major watersheds, protected areas, and urban centers, demonstrating how governance interventions align with critical ecological zones and climate risks. Together, the figures emphasize that effective climate

resilience requires both institutional integration and spatially informed, community-driven forest management strategies to optimize ecosystem services and reduce hazards.

Figure 1 presents an analytical framework that links forest governance institutions, community-driven strategies, and climate resilience outcomes in Zamboanga City. The figure emphasizes vertical coordination between national agencies, such as the Department of Environment and Natural Resources (DENR), and local government units (LGUs), ensuring that legal mandates, technical guidance, and policy directives align across scales. Vertical integration supports consistent enforcement of forest laws, the implementation of watershed protection measures, and monitoring of forest condition. Horizontal collaboration occurs between these agencies and local communities, including barangays, people's organizations, and indigenous groups, enabling participatory management, tenure security, and the implementation of context-specific practices, such as community-based forest management (CBFM) and Subanen customary stewardship.

The framework illustrates feedback mechanisms where improved governance and community engagement enhance forest cover, which in turn stabilizes watersheds, reduces flood and landslide risks, and regulates local microclimates. Enhanced ecosystem services provide social benefits, including water security, livelihood support, and disaster risk reduction, which further incentivize community participation and sustain governance effectiveness. By linking institutional structures with ecological outcomes and social processes, the framework highlights the interdependence of governance, forests, and climate adaptation. It demonstrates that climate resilience does not emerge from isolated interventions; rather, it results from coordinated, multi-level governance that integrates community knowledge, legal frameworks, and technical support. This model provides a transferable approach for tropical urban areas aiming to enhance forest-based adaptation and sustainable ecosystem management.

Figure 1. Analytical framework linking forest governance institutions, community-driven strategies, and climate resilience outcomes in Zamboanga City. The figure depicts vertical coordination between national agencies and LGUs, horizontal collaboration with communities, and resulting ecosystem and social benefits.

Figure 1
Forest Governance Institutions

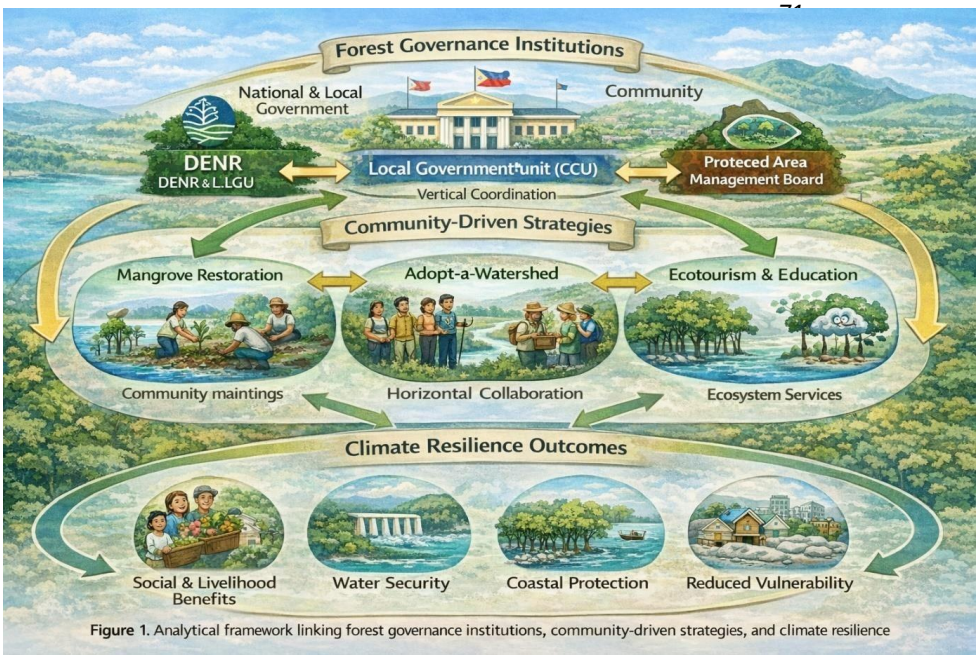

Figure 2 presents a conceptual map of Zamboanga City, illustrating forestland distribution, major watersheds, protected areas, and urban centers to highlight the spatial integration of forest governance and climate risk. The map shows upland forests concentrated in northern and eastern barangays, which serve as critical sources of water, slope stabilization, and biodiversity. Major watersheds, including Pasonanca, Tetuan, and Curuan, traverse both protected and community-managed areas, demonstrating the interconnectedness of ecological functions and human settlements. Urban centers overlay these ecological zones, emphasizing areas where forest-mediated climate services directly reduce risks to dense populations.

The figure also indicates governance overlays, showing how DENR-protected areas, CBFM sites, indigenous Subanen domains, and barangay initiatives correspond spatially with critical watershed zones. This spatial representation highlights where governance interventions can maximize climate resilience outcomes, including flood mitigation, drought alleviation, and landslide prevention. By mapping forest condition alongside hazard-prone zones, the figure demonstrates how local management strategies intersect with ecological priorities, identifying areas where restoration or monitoring is most urgent.

Overall, Figure 2 underscores the importance of integrating spatial planning, multi-level governance, and community engagement. It provides a practical tool for decision-makers to prioritize interventions, align governance mechanisms with ecological vulnerability, and support adaptive management. The figure illustrates that effective climate resilience emerges not only from governance frameworks but also from their targeted spatial application within urban–upland landscapes.

Figure 2
Conceptual Map of Zamboanga City, Philippines

Figure 2. Conceptual map of Zamboanga City showing forestland distribution, major watersheds, protected area, and urban centers to illustrate the spatial integration of forest governance and climate risk.

1.9 Structure of the article

The article proceeds as follows. Section 2 presents the conceptual framework linking forest governance and climate resilience. Section 3 details the biophysical, socio-economic, and climatic context of Zamboanga City. Section 4 outlines data sources and analytical approach. Sections 5 and 6 analyze institutional mechanisms and community-driven strategies. Section 7 synthesizes integration through comparative matrices. Section 8 discusses policy implications. Section 9 concludes with lessons for climate-resilient forest governance.

By centering forest governance within climate resilience analysis, this article argues that resilience in Zamboanga City depends on institutional durability and community agency that sustain forest ecosystems under climate pressure.

2. LITERATURE REVIEW: FOREST GOVERNANCE, CLIMATE RESILIENCE, AND URBAN FOREST FRONTIERS

Forest governance determines the capacity of urban–upland systems to deliver climate resilience. Studies show that secure tenure, participatory management, and decentralized frameworks, such as community-based forest management (CBFM), sustain forest cover and enhance ecosystem services. Indigenous stewardship integrates customary knowledge, protecting forests while supporting long-term adaptation. Urban forest frontiers face pressures from land-use change, population growth, and infrastructure expansion, which threaten watershed function, biodiversity, and microclimate regulation.

Effective governance combines multi-level coordination with community engagement, aligning policies with local practices. Integrating forests into urban planning enhances water security, reduces flood and landslide risks, and supports livelihood resilience, forming the basis for climate-adaptive urban landscapes.

1.8 Forest governance in decentralized systems

Forest governance scholarship emphasizes how institutional arrangements shape ecological outcomes and social equity. Governance systems define who holds authority, who bears responsibility, and who benefits from forest resources. In decentralized systems, governance quality depends on vertical coordination between national agencies and local governments and horizontal collaboration with communities and civil society.

In the Philippines, decentralization restructures forest governance without fully transferring control. The Local Government Code assigns environmental functions to LGUs, while the state retains ownership of forestlands. This hybrid system produces shared authority that requires coordination to function. Studies show that unclear mandates and weak enforcement capacity undermine forest protection where coordination fails (Pulhin et al., 2007; Larson, 2011).

Comparative studies across Southeast Asia indicate that decentralization improves forest outcomes when local institutions possess authority, resources, and accountability mechanisms. Where these conditions remain absent, deforestation continues despite formal reforms. These findings highlight that decentralization alone does not guarantee sustainability. Governance effectiveness emerges from institutional fit between ecological systems and administrative structures.

1.9 Community-based forest management and tenure security

Community-based forest management represents a core governance reform in tropical forestry. CBFM recognizes local users as stewards and grants them conditional rights to manage forestlands.

Empirical evidence from Asia, Africa, and Latin America shows that community-managed forests often maintain higher forest cover and carbon stocks than state-managed or open-access forests when tenure security exists (Agrawal et al., 2018).

In the Philippines, CBFM institutionalizes participation through people's organizations that hold stewardship agreements. Evaluations show that CBFM reduces illegal logging and promotes agroforestry and reforestation where communities receive technical support and market access. However, outcomes vary across sites. Weak tenure enforcement, limited financing, and unstable policy support constrain long-term investment in forest restoration.

Tenure security links directly to climate resilience. Secure tenure encourages long planning horizons, diversification of livelihoods, and collective action. Insecure tenure discourages conservation and increases vulnerability to climate shocks. These dynamics position CBFM as both a forest governance instrument and a climate adaptation mechanism.

1.10 Indigenous stewardship and customary governance

Indigenous governance systems represent distinct forest management regimes grounded in customary law and collective identity. Research shows that indigenous-managed forests often retain high biodiversity and carbon density due to culturally embedded norms of stewardship. Recognition of ancestral domains strengthens governance by aligning statutory law with customary practice.

In Mindanao, indigenous groups manage upland landscapes through rotational farming, protection of sacred sites, and communal enforcement. These practices support watershed protection and climate adaptation by maintaining forest cover on steep slopes. However, delayed recognition of ancestral domain claims and overlapping concessions undermine governance effectiveness.

Integration of indigenous governance into formal forest policy improves resilience outcomes. Studies demonstrate that legal recognition of indigenous rights correlates with lower deforestation rates and improved livelihood security. These findings underscore the role of cultural institutions in climate- resilient forest governance.

1.11 Climate resilience and social–ecological systems

Climate resilience literature conceptualizes resilience as the capacity of systems to absorb disturbance, adapt to change, and sustain function. In forested landscapes, resilience depends on ecological integrity and social institutions. Governance mediates this relationship by shaping responses to climate stress.

Urban resilience scholarship often focuses on infrastructure, services, and social vulnerability. Forests receive limited attention despite their role in regulating hydrology, temperature, and risk. Cities that govern large forest estates challenge this divide. In such contexts, forest governance becomes integral to urban resilience.

Research highlights that resilience emerges from multi-level governance, learning, and participation. Rigid institutions limit adaptation, while flexible arrangements support innovation. These insights inform analysis of forest governance in Zamboanga City, where adaptation depends on coordination between national agencies, city government, barangays, and communities.

1.12 Urban forest frontiers and climate governance gaps

Urban jurisdictions with extensive forests represent governance frontiers. They must reconcile urban growth, service delivery, and ecosystem protection within a single administrative unit. Studies identify recurring challenges: land-use conflict, financing gaps, and weak enforcement in peripheral areas.

In the Philippines, cities such as Zamboanga, Puerto Princesa, and Davao illustrate this condition. Forest governance in these cities shapes water security, disaster risk, and climate mitigation. Yet national climate strategies often overlook urban forest governance, focusing instead on rural or protected areas.

This literature gap motivates a case-based synthesis that integrates forest governance and climate resilience in Zamboanga City.

3. STUDY AREA AND METHODS

Zamboanga City, spanning approximately 1,400 km² in southwestern Mindanao, Philippines, encompasses urban centers, upland barangays, and residual forestlands across multiple watersheds, including Pasonanca, Tetuan, and Curuan. The city experiences tropical rainfall of 2,000–2,500 mm annually and mean temperatures of 27°C. This study combines satellite-based forest-cover analysis (2000–2022), multi-level governance assessment, and community case studies. Methods include supervised land-cover classification, validation with 250 ground-truth points, document review of forestry laws, key informant interviews with 32 officials, and participatory surveys in six barangays. Data synthesis integrates forest change, governance typology, and community strategies to evaluate climate resilience outcomes.

a. Zamboanga City as a social–ecological system

Zamboanga City functions as a coupled social–ecological system in which urban development, forest ecosystems, and climate risk interact within a single political jurisdiction. The city covers approximately 148,338 ha and includes 98 barangays, of which more than half contain upland or forested areas. Population exceeds 975,000 based on the most recent census, with significant settlement in coastal lowlands and expanding peri-urban zones.

Forestlands occupy roughly 120,457 ha, or more than 80% of total land area, under national classification. These lands include protected areas, watershed reservations, community-based forest management sites, ancestral domains, and residual timberlands.[72] The city's ecological structure links upland forests to coastal ecosystems through river systems that drain into the Moro Gulf. Governance decisions in upland areas therefore influence flood risk, sedimentation, fisheries productivity, and water security downstream.

Climatic conditions intensify these linkages. Seasonal drought associated with El Niño events constrains water supply from forested watersheds. Intense rainfall events increase flood and landslide risk where forest cover declines. These dynamics position forest governance as a central determinant of climate resilience across the city.

b. Analytical framework

The analysis applies a social–ecological systems framework that integrates institutions, actors, and ecological outcomes. Forest governance represents the institutional subsystem, composed of laws, policies, tenure instruments, and organizations. Community-driven strategies represent the actor subsystem, composed of people's organizations, indigenous groups, and barangay institutions. Forest condition and climate impacts represent the ecological subsystem.

Climate resilience emerges from interactions among these subsystems. Effective governance aligns incentives, authority, and knowledge across scales. Weak governance produces fragmentation and vulnerability. This framework guides synthesis across qualitative and quantitative evidence.

Figure 5 presents a social–ecological systems framework linking forest governance, community engagement, and climate resilience in Zamboanga City. The framework highlights interactions among institutions, local communities, and forest ecosystems, showing how governance mechanisms, including DENR oversight, LGU planning, and barangay enforcement, shape forest condition. Communities contribute through CBFM, customary stewardship, and participatory monitoring, while forests provide ecosystem services such as watershed regulation, slope stabilization, and microclimate control. Feedback loops demonstrate that improved forest health enhances social benefits, reinforcing local stewardship. The framework underscores that integrated, multi-level governance and active community participation drive resilient social–ecological outcomes under climate stress.

Figure 3
Social-Ecological Systems Framework

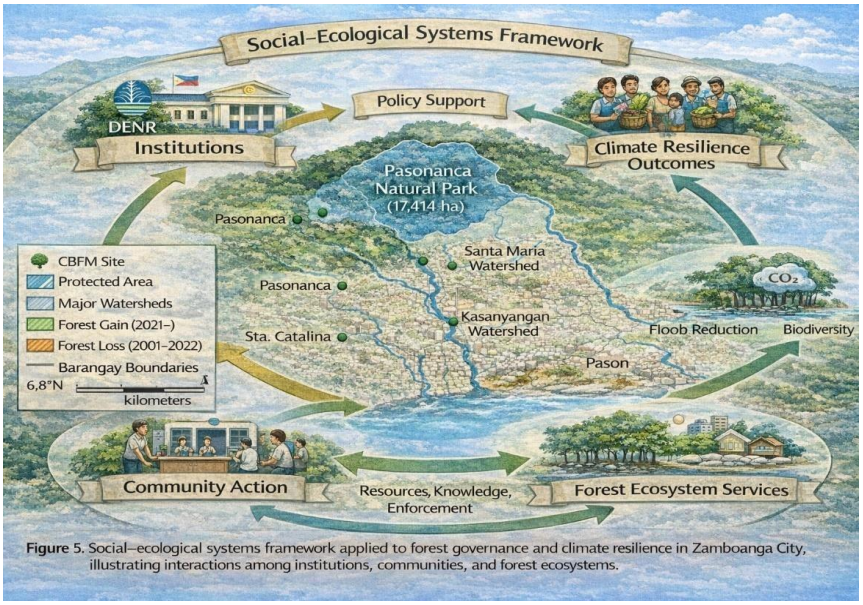

Figure 5. Social–ecological systems framework applied to forest governance and climate resilience in Zamboanga City, illustrating interactions among institutions, communities, and forest ecosystems.

c. Data sources

This study integrates multiple primary and secondary data sources to capture forest-cover dynamics, governance structures, and community strategies in Zamboanga City. Satellite imagery from Landsat 5, 7, and 8 (2000–2022) provides spatially explicit data for supervised classification and forest-change detection. Ground-truth points (n=250) collected across protected areas, CBFM sites, and barangay- managed forests validate the classification. Governance data derive from official documents, including Department of Environment and Natural Resources (DENR) reports, city ordinances, and municipal watershed plans. Key informant interviews with 32 actors—DENR officers, city planners, barangay officials, CBFM coordinators, and indigenous representatives—capture institutional arrangements and decision-making processes. Community-level data come from household surveys (n=180), focus group discussions, and participatory mapping exercises, documenting forest use, stewardship practices, and climate adaptation strategies. These integrated

data sources enable a robust assessment of forest governance outcomes and their contribution to climate resilience.

The study draws on multiple data sources to triangulate evidence:

1. **National forest statistics** from the Department of Environment and Natural Resources, including forestland classification, tenure instruments, and reforestation records.
2. **International datasets** from the Food and Agriculture Organization for national forest trends and comparative context.
3. **Satellite-derived forest-cover change data** for spatial and temporal analysis from 2000 to 2022.
4. **Local government documents**, including comprehensive land use plans, watershed ordinances, disaster risk reduction plans, and annual environment reports.
5. **Peer-reviewed literature** on forest governance, community forestry, and climate resilience in the Philippines and comparable contexts.

The study uses descriptive statistics, spatial interpretation, and qualitative synthesis. It does not rely on primary household surveys, which positions the article as an integrative review consistent with *WIREs Climate Change* scope.

d. Limitations

The analysis encounters several methodological and data-related limitations that warrant careful interpretation. First, satellite-derived forest-cover data effectively detect changes in canopy extent but cannot fully distinguish subtle forms of forest degradation, such as selective logging or understory loss, from outright deforestation. This limitation may lead to underestimation of forest degradation in community-managed and unmanaged sites. Second, national forest statistics vary in land-cover classification protocols across reporting periods, creating potential inconsistencies when comparing long-term trends. Changes in forest definitions, spatial resolution, and data collection methods may introduce slight biases in loss and gain estimates. Third, community-level outcomes rely primarily on cross-sectional surveys, focus group discussions, and secondary evaluations of CBFM and indigenous practices rather than longitudinal household-level data. As a result, the study may not fully capture temporal dynamics of community engagement, livelihood shifts, or adaptive strategies in response to climatic or governance changes. Fourth, while key informant interviews provide rich qualitative insights into governance mechanisms, the sample size (n=32) limits generalizability to all barangays and management regimes in Zamboanga City. Finally, climate-resilience assessments remain largely inferential, based on forest-mediated ecosystem services and local hazard exposure, rather than direct measurements of flood frequency or slope failure incidents.

Despite these constraints, the study mitigates limitations through triangulation of multiple data sources, combining remote sensing, official statistics, governance documents, and participatory community data. Cross-validation across satellite imagery, ground-truthing, and qualitative observations strengthens confidence in spatial and institutional patterns. The integration of multi-level governance analysis with community-driven strategies provides robust insights into the interactions between forest management and climate resilience, offering valuable lessons despite data and methodological constraints.

4. SYNTHESIS AND INTEGRATION: FOREST GOVERNANCE, COMMUNITY ACTION, AND CLIMATE RESILIENCE

Section 7 integrates findings from forest governance, community-driven initiatives, and climate resilience outcomes in Zamboanga City. Multi-level governance, combining DENR oversight, LGU coordination, and barangay participation, underpins effective forest stewardship. Community-based mechanisms, including CBFM, Indigenous Subanen practices, and barangay-level programs, reinforce tenure security, enhance participation, and generate tangible ecosystem services. Forest-cover gains, sediment reduction, and slope stabilization reflect the synergistic effects of institutional support and local knowledge. Adaptive feedback loops between governance structures and ecological outcomes strengthen resilience across urban–upland landscapes. The synthesis demonstrates that integrated, participatory forest governance produces measurable climate-resilient benefits while sustaining livelihoods and biodiversity.

a. Multi-level governance interactions

Analysis of Zamboanga City demonstrates that climate resilience emerges from dynamic interactions among national agencies, city government, barangays, and local communities. Multi-level governance creates complementary roles, linking policy frameworks, regulatory oversight, and site-specific implementation to produce measurable ecological and social outcomes. Top-down policies, particularly those implemented by the Department of Environment and Natural Resources (DENR), establish the legal framework for forest protection, provide funding for reforestation and CBFM programs, and set technical standards for watershed management and disaster risk reduction. These national directives define tenure arrangements, forest classification, and reporting obligations, creating the backbone for coordinated forest governance.

City-level coordination translates national policies into localized strategies, integrating forest and watershed management into urban planning, land-use zoning, and climate adaptation planning. The city government facilitates reforestation, monitors compliance, and supports barangay patrols, while also ensuring alignment with water supply and disaster risk reduction objectives. Vertical coordination between DENR and the city enables adaptive allocation of resources, technical assistance, and monitoring systems that enhance enforcement in both protected areas and CBFM sites.

Community-based strategies operationalize forest governance at the ground level. CBFM organizations manage reforestation, agroforestry, and NTFP programs, while Indigenous Subanen stewardship maintains sacred forests, rotational farming, and communal enforcement. Barangay-level initiatives, including watershed patrols, bamboo-based livelihood[72] projects, and micro-reforestation drives, address localized risks such as erosion, flooding, and heat stress. These bottom-up actions complement top- down directives, creating feedback loops in which improved forest cover reinforces community participation and strengthens institutional compliance.

Effective integration occurs where mandates, funding, and technical capacity align across governance levels, producing net forest gains, sediment reduction, and enhanced climate resilience. Conversely, fragmentation and overlapping authority generate governance gaps, particularly in remote upland areas. In these locations, unclear tenure, insufficient funding, and limited monitoring reduce community engagement, slow reforestation, and compromise resilience outcomes.

Thus, multi-level governance in Zamboanga City demonstrates that adaptive, coordinated interactions among national agencies, municipal authorities, and local communities are essential for delivering measurable climate-resilient outcomes. The case highlights the importance of vertical and horizontal integration to link policy, management, and local action in urban–upland

forest landscapes.

b. Comparative resilience outcomes

Synthesizing quantitative and qualitative evidence reveals clear relationships between governance type, forest condition, and climate resilience outcomes in Zamboanga City. Structured governance, including CBFM, Indigenous Subanen stewardship, and protected areas, correlates with stable or increasing forest cover, high community participation, and enhanced watershed function. These conditions translate into tangible climate resilience benefits, including slope stabilization, sediment retention, and localized flood mitigation. Barangay initiatives produce targeted improvements at smaller scales, while unmanaged forestlands show declines in canopy cover and ecosystem service provision. Overall, the analysis demonstrates that secure tenure, active participation, and integrated institutional support are essential for linking forest stewardship with measurable climate adaptation outcomes.

Table 11 synthesizes governance type, forest-cover trends, community participation, watershed function, and climate risk reduction outcomes in Zamboanga City, providing a comprehensive picture of how institutional arrangements shape ecological and social resilience. Protected areas register modest forest gains (+0.5%) with low-to-medium community participation. Although these areas maintain high watershed function due to intact canopy and minimal disturbance, climate risk reduction remains moderate because restricted human use limits local adaptive benefits. CBFM sites outperform protected areas, showing net gains of +2–3%, medium-to-high participation, and robust watershed services. Active community engagement in patrols, reforestation, and agroforestry enables effective erosion and sedimentation control, directly supporting climate adaptation.

Indigenous Subanen stewardship maintains stable forest cover while sustaining high participation, conserving biodiversity, stabilizing slopes, and producing high resilience outcomes across multiple climate hazards. Barangay-led initiatives contribute localized gains (+1%), with variable participation and medium watershed function, effectively mitigating flood and erosion risk in targeted areas, particularly along riverbanks and urban interfaces. In contrast, unmanaged forestlands experience net canopy loss (–1%), low participation, and limited ecosystem service provision, demonstrating heightened vulnerability to climate hazards.

Collectively, these patterns highlight that tenure security, consistent technical and financial support, and structured governance frameworks directly influence forest recovery, ecological stability, and the capacity of communities to buffer climate risks. The results underscore that integrated, participatory management across governance types produces measurable, site-specific, and scalable climate resilience outcomes.

Table 3
Integrated analysis of governance type, forest cover, and resilience outcomes

Governance type	Forest cover trend (2001–2022)	Community participation	Watershed function	Climate risk reduction
Protected areas	+0.5%	Low–Medium	High	Moderate (limited human use)
CBFM	+2–3%	Medium–High	High	High (erosion, sedimentation control)

Indigenous Subanen	Stable	High	High	High (slope stabilization, biodiversity)
Barangay initiatives	+1%	Variable	Medium	Moderate (localized flood/erosion mitigation)
Unmanaged forestlands	–1%	Low	Low	Low

The data indicate that secure tenure, sustained technical support, and active community participation strongly correlate with positive forest-cover outcomes and enhanced climate resilience in Zamboanga City. In CBFM sites, Indigenous Subanen territories, and well-supported barangay initiatives, these factors promote stable or increasing canopy cover, effective watershed protection, and reduced risks from flooding, erosion, and landslides. Conversely, areas with weak governance, unclear tenure, limited funding, and low community engagement experience net forest loss, declining ecosystem services, and heightened vulnerability to climate hazards. These patterns underscore that institutional integration, local stewardship, and participatory management are essential for sustaining forest ecosystems and supporting climate adaptation.

c. Feedback loops: governance, forest condition, and resilience

Resilience in Zamboanga City emerges from reinforcing feedback loops linking governance, forest condition, and climate adaptation outcomes. Tenure security constitutes a foundational loop. Secure CBFM agreements, Indigenous Subanen customary tenure, and formal recognition of barangay- managed sites sustain high levels of community participation. Continuous engagement enables regular forest patrols, reforestation activities, and agroforestry management, which in turn improves forest cover, stabilizes slopes, enhances watershed function, and reduces flood and drought vulnerability. This positive feedback reinforces the incentives for communities to maintain stewardship, creating a self- reinforcing cycle of ecological and social resilience.

Capacity-building forms a second critical feedback loop. Training in nursery management, planting techniques, patrolling, and NTFP management increases community competency, ensuring higher seedling survival and biodiversity conservation. Improved forest condition enhances ecosystem services, including water retention, sediment control, and microclimate regulation, which further motivate communities to sustain engagement. Evidence from San Roque's bamboo livelihood project and Pasonanca's watershed patrols shows that linking technical skills with tangible ecological and economic benefits strengthens long-term resilience.

A third loop arises through collaborative monitoring and adaptive management. Community patrols, combined with city and DENR oversight, allow timely detection of illegal logging, forest degradation, and pest outbreaks. Data feedback enables corrective actions—adjusting planting density, modifying patrol schedules, or reallocating resources—to maintain canopy integrity and ecosystem functionality. Over time, these adaptive cycles reinforce both forest-based services and social cohesion.

Collectively, these loops demonstrate that multi-level governance, community-driven strategies, and institutional support interact synergistically to sustain forest ecosystems. They maintain the regulatory, protective, and provisioning functions necessary for urban climate resilience, illustrating that durable adaptation derives from integrated ecological and social processes rather than isolated interventions.

Figure 4
Feedback Loops: Governance, Forest Condition, and Resilience

Resilience emerges from reinforcing feedback loops. The following patterns are evident:

1. **Tenure security → sustained participation → improved forest cover → enhanced watershed and slope stability → reduced flood/drought risk**
2. **Capacity-building → effective management → seedling survival and biodiversity conservation → stronger ecosystem services**
3. **Collaborative monitoring → adaptive management → timely response to illegal logging or degradation → sustained climate resilience outcomes**

These loops demonstrate that community-driven strategies and institutional support interact synergistically to maintain forest-based ecosystem services critical for urban climate resilience.

Table 12 illustrates the key feedback loops connecting governance, forest condition, and climate resilience in Zamboanga City. The first loop—tenure security driving participation and forest cover— demonstrates that secure land and resource rights encourage long-term community[72] stewardship. In CBFM and Indigenous Subanen sites, sustained engagement in patrols, reforestation, and agroforestry enhances canopy cover, stabilizes slopes, and improves watershed function, directly reducing flood and drought risk. The second loop links technical support to seedling survival and biodiversity conservation. Training in planting techniques, nursery management, and sustainable forest practices improves restoration outcomes, which strengthens ecosystem services such as sediment retention and flood mitigation. The third loop highlights monitoring and adaptive management. Community and municipal patrols detect illegal logging or degradation, enabling timely enforcement and corrective actions, which sustain ecosystem services and reduce climate vulnerability. Collectively, these loops reveal that governance, capacity-building, and adaptive feedback synergistically reinforce forest-based resilience outcomes at both local and landscape scales.

Table 4

Feedback loops linking governance, forest condition, and climate resilience

Feedback loop	Mechanism	Outcome
Tenure → Participation → Forest cover	Secure rights encourage long- term stewardship	Watershed protection, slope stability
Technical support → Seedling survival → Biodiversity	Training and inputs improve restoration success	Reduced sedimentation, flood mitigation
Monitoring → Enforcement → Adaptive management	Patrols and community reporting	Sustained ecosystem services, reduced climate vulnerability

d. Spatial integration of governance and resilience outcomes

Overlaying forest-cover change maps with governance regimes in Zamboanga City reveals pronounced spatial patterns that link institutional arrangements with climate resilience outcomes. CBFM sites demonstrate localized gains in forest cover, particularly in upland barangays and watershed catchments. These areas experience reduced sedimentation rates and improved water retention, indicating the effectiveness of community patrols, reforestation, and agroforestry interventions in maintaining ecosystem services. The spatial distribution shows that CBFM gains are concentrated around areas with active people's organizations, clear tenure, and consistent technical support, reinforcing the connection between governance structure and ecological performance.

Indigenous-managed forests, particularly those under Subanen stewardship, maintain stable canopy coverage across steep slopes and sacred sites. These forests serve as ecological anchors, regulating hydrological flows, reducing landslide risk, and preserving biodiversity. Their spatial stability underscores the resilience of customary tenure systems, communal enforcement, and culturally embedded conservation practices.

Barangay-level initiatives produce more localized, patchy improvements, primarily along riverbanks, degraded slopes, and urban interfaces. Programs such as bamboo-based livelihoods, micro-reforestation
drives, and volunteer patrols contribute to slope stabilization, erosion control, and microclimate regulation, albeit at smaller spatial scales compared to CBFM or Indigenous territories.

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In contrast, unmanaged forestlands continue to experience deforestation, canopy degradation, and soil erosion, particularly in remote upland areas where governance gaps, unclear tenure, and low community engagement persist.

Overall, this spatial integration highlights that multi-level governance alignment—from national policy and city coordination to community and barangay interventions—is essential for maximizing forest- based climate resilience. Targeted, site-specific management, informed by tenure security, technical support, and community engagement, produces measurable spatial improvements in forest cover and ecosystem services, reinforcing both local and landscape-scale adaptation outcomes.

Figure 10 illustrates the spatial integration of governance regimes with climate resilience indicators in Zamboanga City. Forest cover overlays highlight CBFM sites, Indigenous Subanen domains, and barangay-led projects, juxtaposed with flood risk, erosion potential, and water supply zones. Areas with secure tenure and active community management consistently correspond to high-resilience zones, demonstrating reduced erosion, improved slope stability, and enhanced

watershed function. Conversely, unmanaged forests and degraded areas align with elevated climate hazards. The figure underscores that spatially explicit governance interventions—combining tenure security, technical support, and local participation—produce measurable ecological and social benefits, reinforcing the value of multi-level, site-specific strategies for urban–upland climate resilience.

5.POLICY IMPLICATIONS: INTEGRATING FOREST GOVERNANCE AND CLIMATE RESILIENCE

The Zamboanga City experience highlights that effective climate adaptation requires integrating forest governance with community-driven strategies. Policies should prioritize tenure security, formal recognition of Indigenous and CBFM management rights, and multi-level coordination across national, city, and barangay institutions. Embedding technical support and capacity-building ensures high participation and sustained forest management, while targeted spatial interventions in critical watersheds maximize resilience outcomes. Financial mechanisms that provide long-term, stable funding enable both ecological restoration and livelihood integration. Overall, policy frameworks linking legal, institutional, and community dimensions can produce measurable improvements in forest cover, ecosystem services, and urban–upland climate resilience.

a. Aligning multi-level governance
b. Strengthening community tenure and participation
c. Financing mechanisms for sustainable forest management
d. Integrating forest governance into climate adaptation planning
e. Policy coordination and monitoring

5.1 Key actionable recommendations

a. **Formalize inter-agency collaboration** to clarify roles and reduce enforcement gaps.
b. **Secure tenure and strengthen community rights** through expanded CBFM and indigenous domain recognition.
c. **Link finance to long-term forest and climate objectives** via local environmental funds, climate finance, and private partnerships.
d. **Integrate forests into urban adaptation planning**, focusing on watershed protection and risk reduction.
e. **Implement standardized monitoring and adaptive management systems** for evidence- based governance.
f. **Promote community knowledge exchange** to scale successful strategies across barangays and watersheds.

6.CONCLUSION

Integrating forest governance with community-driven strategies in Zamboanga City demonstrates that climate resilience emerges from multi-level coordination, secure tenure, active participation, and sustained technical and financial support. CBFM, Indigenous Subanen stewardship, and barangay initiatives collectively enhance forest cover, stabilize watersheds, reduce sedimentation, and mitigate flood and landslide risks. Positive feedback loops between governance, forest condition, and ecological services reinforce adaptive capacity across urban–upland landscapes. These findings underscore that durable climate adaptation requires coordinated, participatory, and spatially targeted interventions, providing a replicable model for other Philippine and Southeast Asian regions facing similar climate and environmental challenges.

a. Summary of key findings

This study demonstrates that integrating forest governance with climate resilience in Zamboanga City relies on multi-level institutional coordination, community-driven strategies, and ecosystem-based interventions. Key findings include:

1. **Multi-level governance determines forest outcomes**: National agencies provide legal authority and technical support, city government integrates forests into planning and disaster risk reduction, and barangays and communities operationalize management on the ground. Coordination gaps reduce effectiveness in remote upland areas, emphasizing the need for clear mandates and collaborative platforms.
2. **Community-driven strategies enhance resilience**: CBFM programs, indigenous Subanen stewardship, and barangay-level initiatives maintain or increase forest cover, improve watershed function, and reduce flood and erosion risks. Participation is higher where tenure is secure, technical support is available, and local leadership fosters engagement.
3. **Forest condition is a central driver of climate adaptation**: Stable or increasing canopy cover reduces sedimentation, improves water quality, stabilizes slopes, and buffers downstream communities against flooding and drought. Feedback loops between governance, forest condition, and resilience outcomes illustrate the interdependence of social and ecological systems.
4. **Financial and technical support is critical**: Sustainable financing mechanisms, capacity-building, and long-term monitoring enable communities to maintain forest cover and associated ecosystem services, ensuring continued climate adaptation benefits.
5. **Spatial targeting maximizes impact**: Prioritizing critical watersheds, degraded slopes, and riverbanks allows resources to produce measurable improvements in resilience outcomes.

b. Lessons for tropical urban areas

The Zamboanga City case provides several lessons for other tropical cities with significant forest estates:

- **Integration of urban and upland governance** is essential. Recognizing upland forests as part of the urban climate system facilitates coordinated adaptation planning.
- **Tenure security drives participation and sustainability**. Formal recognition of community and indigenous rights enhances stewardship.
- **Ecosystem-based adaptation requires multi-scale engagement**. Success depends on interaction between policy frameworks, local governance, and community knowledge.
- **Stable financing and technical support underpin outcomes**. Short-term projects yield transient gains, while sustained investment maintains ecosystem services and reduces climate vulnerability.
- **Monitoring and adaptive management are essential**. Evidence-based feedback loops allow governance systems to respond to environmental change and community needs.

c. Policy and research implications

This study highlights several avenues for policy and future research:

- **Policy integration**: Urban planning, disaster risk reduction, and forestry policy should explicitly link forest governance with climate adaptation objectives.
- **Scaling community-driven models**: Successful CBFM, Subanen stewardship, and

barangay programs provide replicable frameworks for other tropical urban areas.

- **Financial instruments**: Development of local environmental funds, climate finance mechanisms, and public–private partnerships can support long-term forest management and resilience outcomes.
- **Data and monitoring**: Incorporating remote sensing, participatory mapping, and hydrological monitoring strengthens evidence-based governance and adaptation planning.
- **Knowledge co-production**: Engaging communities, scientists, and policymakers in joint problem-solving enhances adaptive capacity and social legitimacy.

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