

Adaptive Environmental Governance and Local Community Resilience in Addressing Tidal Flood Risks in the Peat-Coastal Lowlands of Indragiri Hilir Regency

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Abstract

Tidal flooding in Indragiri Hilir Regency, Indonesia, is expanding amid lowland geographical conditions and environmental degradation, while disaster management remains reactive and community adaptation is insufficiently integrated into environmental governance. This study examines the ecological and anthropogenic drivers of tidal flooding, environmental policies, disaster budgeting, and community adaptation strategies to inform sustainable coastal environmental policy. A qualitative explanatory-critical case study was conducted in Indragiri Hilir Regency, Riau Province. Data were collected through semi-structured in-depth interviews, field observations, and document analysis and analyzed through data condensation, thematic categorization, data display, and conclusion drawing and verification. The findings indicate that the number of subdistricts affected by tidal flooding increased from three in 2019 to six in 2021. Identified drivers included land conversion in water infiltration areas, mangrove degradation, riverbank settlements, and sedimentation and waste accumulation in canals. Environmental governance was constrained by the absence of specific regulations and the Regional Disaster Management Agency's (BPBD) annual budget of IDR 1 billion for managing multiple disaster types. Community adaptation strategies included maintaining seed reserves, adjusting planting calendars, undertaking independent evacuations, and collectively cleaning canals. These findings highlight the importance of integrating local adaptation strategies into environmental governance. The

study recommends strengthening regulations, adopting risk-based budgeting, rehabilitating ecosystems, and enhancing government–community collaboration to support a transition from reactive disaster management toward sustainable coastal environmental governance.

Keywords: Adaptive Environmental Governance; Tidal Flooding; Community Resilience; Coastal Peatlands; Local Adaptation

INTRODUCTION

Global climate change and the degradation of coastal ecosystems are increasing the risks faced by low-lying coastal regions, particularly through sea-level rise, extreme sea-level events, and changes in precipitation patterns (Hapsari et al., 2022; Intergovernmental Panel on Climate Change [IPCC], 2022). In Indonesia, flooding in vulnerable watersheds cannot be explained solely as a seasonal natural event, as its occurrence may also be influenced by interactions between hydrometeorological conditions and human-induced environmental changes. Evidence from the Teunom watershed in Aceh Jaya and the Barito watershed in South Kalimantan demonstrates the relevance of land-use and land-cover changes to flood occurrence, runoff dynamics, and watershed vulnerability (Adi & Savitri, 2022; Sugianto et al., 2022). In tropical coastal peatlands, sea-level rise and changing precipitation regimes further complicate environmental management and adaptation planning (Hapsari et al., 2022). From an environmental governance perspective, addressing these interconnected risks requires coordination among decision-making institutions, alignment between governance arrangements and ecological processes, and mechanisms for collaboration and accountability (Carlisle & Gruby, 2019). At the policy level, these findings underscore the importance of integrating climate adaptation, watershed management, land-use planning, and ecosystem protection to reduce flood risks in vulnerable coastal regions (Carlisle & Gruby, 2019; IPCC, 2022).

Indragiri Hilir Regency, located on the eastern coast of Riau Province, represents a tangible example of an ecological landscape that is highly vulnerable to such hydroclimatological dynamics. Geographically, this area, covering 12,614.78 km² and inhabited by 658,025 people across 20 subdistricts, 197 villages, and 39 urban villages, is dominated by lowland landscapes, which account for 93.31% of the region's total area, while the remaining 6.69% consists of low hills with elevations ranging from 6 to 35 meters above

sea level (BPS Kabupaten Indragiri Hilir, 2021). The soil characteristics, consisting of swamp deposits and extensive peatlands along the coast of the Berhala Strait and the estuary of the Indragiri River, have earned this region the nickname “Land of a Thousand Canals.” The network of main rivers, tributaries, and artificial canals constructed by local communities initially functioned as a natural water management system and as waterways for transportation. However, when maximum sea tides (spring tides) coincide with high-intensity rainfall and drainage flows toward the sea become obstructed, this area experiences the tidal backwater effect, which triggers prolonged tidal inundation or tidal flooding.

Ecologically, flood vulnerability in Indragiri Hilir Regency has escalated due to anthropogenic pressures on environmental carrying capacity. Based on empirical records from the Regional Disaster Management Agency (BPBD) of Indragiri Hilir Regency for the 2019–2021 period, the distribution of flood-affected subdistricts doubled from three subdistricts in 2019 (Tembilahan, Tembilahan Hulu, and Tempuling Subdistricts) to six subdistricts in 2021 (expanding to Gaung, Kemuning, Keritang, and Batang Tuaka Subdistricts), with damage affecting more than 1,130 residential units, damaging vital healthcare facilities such as the Regional General Hospital (RSUD) in Tembilahan Kota in 2020, and disrupting connecting bridges and interregional transportation routes. The primary drivers of the expansion of these inundated areas stem not only from weather anomalies but are also exacerbated by mangrove deforestation in coastal zones, the conversion of water-absorbing land that is inconsistent with designated spatial uses, the expansion of densely populated settlements encroaching upon river channels, and the shallowing of canals caused by mud sedimentation and the accumulation of domestic waste.

Although this coastal environmental crisis recurs annually, public policy responses at the regional level often remain focused on reactive emergency management rather than integrated, long-term risk reduction. Previous research by Rahmayanti and Meiwanda (2022) examined the disaster management capacity of the Indragiri Hilir Regency Government and highlighted limitations in local administrative capacity. From a theoretical perspective, effective local disaster management requires adequate institutional capacity, human resources, financial resources, technical capabilities, leadership, and policy implementation mechanisms. Similarly, research in Kampar Regency has examined flood-related problems and disaster mitigation strategies, highlighting the importance of strengthening regional approaches to flood risk reduction (Daryanes et al., 2026). However, important research gaps remain concerning environmental governance in Indragiri Hilir Regency, particularly the

relationship between coastal and peatland spatial planning, multi-risk budget allocation, and local ecological vulnerability. Further investigation is also needed to understand how communities and farmers in flood-prone areas develop autonomous adaptation strategies when formal government interventions are limited. These issues provide a basis for examining the integration of regional environmental policy, institutional capacity, and community-based adaptation in managing recurrent coastal flooding.

Building on this research gap, this article advances a novel analytical perspective by shifting the focus from measuring internal bureaucratic capacity toward an integrated framework of adaptive environmental governance and community social-ecological resilience. Adaptive governance emphasizes institutional flexibility, cross-scale coordination, learning, and the capacity to respond to environmental uncertainty (Chaffin et al., 2016; Herizal et al., 2024). Meanwhile, the social-ecological resilience perspective highlights the interdependence between community well-being, ecological dynamics, and the capacity to adapt to or transform in response to environmental change (Clement et al., 2024). Recent developments in adaptive and transformative governance further emphasize the importance of institutional arrangements that enable collaboration between government and communities and strengthen collective capacity for self-governance (DeCaro et al., 2025). The objectives of this study are to: (1) construct the ecological and anthropogenic driving factors that exacerbate tidal flood risks in the peatland coastal landscape of Indragiri Hilir Regency; (2) critically examine the paradoxes of environmental policy and regional disaster budgeting structures in addressing multiple ecological risks; and (3) analyze adaptation strategies based on local communities and formulate a model for sustainable coastal environmental policy transformation.

METHODS

This study employed a qualitative method using an explanatory-critical case study approach to examine the interrelationships among coastal environmental degradation, regional public policy design, and community adaptation practices in Indragiri Hilir Regency, Riau Province. A qualitative case study is appropriate for investigating complex contemporary phenomena within their real-life contexts and for examining interactions among institutional, social, and environmental factors (Ellinger & McWhorter, 2016). The selection of Indragiri Hilir Regency was based on its ecological characteristics, including

extensive low-lying peatlands, river and canal networks, and recurring flood risks. The reported figure that 93.31% of the regency's territory consists of swampy peatlands, as well as information regarding population density and inundation frequency in Tembilahan and Tembilahan Hulu, should be verified against official regional statistical publications and disaster records (Badan Pusat Statistik Kabupaten Indragiri Hilir, 2022, 2023).

Data collection combined primary and secondary sources gathered during 2021–2022. Informants were selected through purposive sampling to ensure that participants possessed relevant knowledge and direct experience of regional disaster management, environmental governance, emergency response, and community adaptation. Purposive sampling enables researchers to select information-rich participants whose experience is directly relevant to the research questions (Campbell et al., 2020). The informants comprised (1) the Head of the Emergency and Logistics Division of the Regional Disaster Management Agency (BPBD) of Indragiri Hilir Regency; (2) the relevant social affairs official responsible for social assistance and post-disaster logistics; (3) the Coordinator of the Search and Rescue (SAR) Post; (4) the Tembilahan Hulu subdistrict head and staff; and (5) flood-affected residents and farmers in Tembilahan Hulu and Sungai Sembilan.

Three complementary data collection techniques were employed to strengthen methodological triangulation. First, semi-structured in-depth interviews were conducted in July 2022 to explore regulatory implementation, budget allocation, spatial planning constraints, and community adaptation initiatives. The use of semi-structured interviews was informed by methodological guidance emphasizing systematic interview-guide development and alignment between research objectives and interview questions (Kallio et al., 2016). Second, direct field observations were conducted during the tidal flooding event on January 1, 2022, in Tembilahan and Tembilahan Hulu. The reported inundation depth of 30–35 cm and duration of two consecutive days should be supported by contemporaneous field notes, photographs, or official incident records. These observations were used to compare reported government standard operating procedures (SOPs) with the availability of emergency facilities and the implementation of response measures at the affected sites. Third, documentary analysis examined relevant regional regulations, national disaster management legislation, BPBD incident records for 2019–2021, and demographic publications issued by the Central Statistics Agency (BPS) of Indragiri Hilir Regency. Combining interviews, observations, and documentary evidence supports the comparison of different perspectives and strengthens the credibility of qualitative interpretations (Nowell et al., 2017).

Data analysis followed an iterative process involving data collection, data condensation and thematic categorization, analytical display through matrices, and the development and verification of conclusions. The analysis focused on environmental policy implementation, institutional capacity, ecological vulnerability, and community adaptation. A systematic and transparent analytical process, supported by documentation of coding decisions and the interpretation of themes, helps strengthen the trustworthiness of qualitative findings (Miles et al., 2019; Nowell et al., 2017).

RESULTS

Degradation of Ecological Carrying Capacity and the Escalation of Tidal Flooding in the “Land of a Thousand Canals” Landscape

Empirical findings indicate that flood vulnerability in Indragiri Hilir Regency results from the interaction between the geomorphological structure of low-lying coastal areas and human interventions that exceed the environment’s carrying capacity thresholds. Geographically located between 0°36' N – 1°07' S and 104°10' – 102°32' E, and directly bordering the Riau Islands Province to the east, almost all settlements and economic centers are situated within the estuarine zone of the Indragiri River and its thousands of connecting canals. When rising sea tides advance inland (tidal flooding) simultaneously with the rainy season, the extremely gentle land slope prevents river and canal water from flowing out to the sea, causing it instead to overflow and inundate the surrounding land.

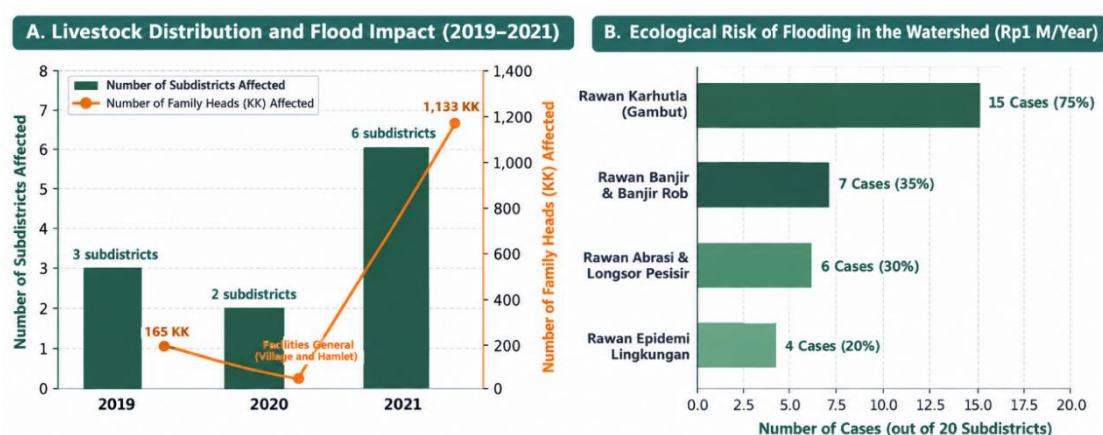


Figure 1. (A) Escalation in the number of subdistricts and affected households (KK) due to flooding in Indragiri Hilir Regency, 2019–2021; (B) Proportion of subdistricts vulnerable to multiple ecological risks that depend on the regional disaster management

budget ceiling of IDR 1 billion per year (Processed by the authors based on data from the Regional Disaster Management Agency (BPBD) and the Central Statistics Agency).

As illustrated in Figure 1A, the historical trend in flood incidents demonstrates spatial expansion and a sharp increase in the socioeconomic vulnerability burden. In 2019, flooding was recorded in three subdistricts: Tembilahan Subdistrict (Tembilahan Urban Village), Tembilahan Hulu Subdistrict (the Parit 6 area), and Tempuling Subdistrict (Mumpa Village, Cabang Galah Hamlet, affecting 85 households, and Karya Tunas Jaya Village, Sumber Jaya Hamlet, affecting 80 households). In 2020, although the recorded locations covered two subdistricts (Tembilahan Kota and the Parit 6 main road in Tembilahan Hulu), flooding inundated critical public service infrastructure, namely the Regional General Hospital (RSUD), and disrupted access to the main interregional road. Subsequently, in 2021, the scale of flooding increased dramatically, simultaneously affecting six subdistricts, impacting 1,133 households and damaging more than 1,130 residential houses. The affected areas included Gaung Subdistrict (Lahang Hulu Village, 167 households/167 houses); Kemuning Subdistrict (nine villages/urban villages, including Keritang Hulu, Kemuning Muda, Talang Jangkang, Lubuk Besar, Limau Manis, Sekara, Selensen Urban Village, Kemuning Tua, and Air Balui, with a total of 474 households/474 houses); Keritang Subdistrict (Harapan Village, Meranti Hamlet, Berkat Hamlet, and Sungai Intan Hamlet, affecting 489 households/489 houses); Batang Tuaka Subdistrict (Sungai Piring Urban Village, affecting three households and involving damage to a connecting bridge); as well as recurrent inundation in Tembilahan Subdistrict and along the Rengat main road at Parit 6 in Tembilahan Hulu Subdistrict.

In-depth interviews with regional disaster management authorities confirmed that the expansion of flood-prone zones into areas that had previously been relatively safe was closely associated with changes in land use and the degradation of water absorption areas:

“From the BPBD’s perspective, regional management in Indragiri Hilir Regency has not been sufficiently effective, as land-use changes have reduced water absorption areas, resulting in flooding during rainfall. In addition, the geographical conditions of Indragiri Hilir Regency cause damage to road access leading to affected locations, which also creates obstacles to disaster management.” (Interview with the Head of the Emergency and Logistics Division of the Regional Disaster Management Agency of Indragiri Hilir Regency, July 29, 2022).

Field findings identified four interlocking ecological and anthropogenic drivers in Indragiri Hilir Regency: (1) deforestation of mangrove belts along the coastline and river estuaries, which eliminates natural buffers against tidal energy while triggering coastal abrasion in six subdistricts along the Indragiri River (Kuala Indragiri, Enok, Tanah Merah, Tembilahan, Tembilahan Hulu, and Kateman); (2) the conversion of swamp and peatland areas into monoculture plantations and settlements without consideration of runoff coefficients; (3) the construction of residential buildings that directly encroach upon river channels and waterways; and (4) the disposal of domestic waste into canals, which accelerates the shallowing of urban and rural drainage channels.

Table 1. Matrix of Ecological Characteristics and the Distribution of Multiple Environmental Disaster Risks in Indragiri Hilir Regency

Ecological Risk Typology	Distribution of Vulnerable Areas (Subdistricts)	Environmental and Anthropogenic Triggering Factors	Major Socio-Ecological Impacts
Tidal Flooding (Rob) and River Overflow Flooding	7 subdistricts: Tembilahan, Tembilahan Hulu, Keritang, Kemuning, Batang Tuaka, Tempuling, and Gaung	Basin-shaped/lowland topography (93.31% of the total area), tidal backwater effects, conversion of water absorption areas, mangrove deforestation, sedimentation, and waste accumulation in canals	1,133 households (more than 1,130 houses) inundated in 2021; disruption of RSUD facilities and main roads; crop failures affecting plantations and rice fields; psychological distress among residents
Forest and Land Fires (Peatland Fires)	15 subdistricts: Tembilahan, Tembilahan Hulu, Batang Tuaka, Keritang, Kemuning, Kempas, Tempuling, Gaung, Enok, Kateman, Gaung Anak Serka, Pelangiran, Concong, Reteh, and Tanah Merah	Peat soils drying during the dry season and agricultural/plantation land clearing through burning	Degradation of peatland hydrology (land subsidence that exacerbates flooding during the rainy season), haze, increased incidence of acute respiratory infections (ARI), and school closures
Coastal Abrasion and Riverbank Landslides	6 subdistricts: Kuala Indragiri, Enok, Tanah Merah, Tembilahan, Tembilahan Hulu, and Kateman	Loss of coastal mangrove protection belts, exposure to tidal waves and tidal currents in the Indragiri River, and densely populated settlements along the coastline	Coastal land erosion, loss of residents' plantation land, collapse of connecting bridges, and the displacement of houses along riverbanks and coastlines
Tornadoes and Environmental Epidemics	Transitional seasons throughout the coastal region; epidemic-prone	Extreme atmospheric pressure anomalies during seasonal transitions and inadequate	Physical damage to residential buildings and infrastructure, and

Ecological Risk Typology	Distribution of Vulnerable Areas (Subdistricts)	Environmental and Anthropogenic Triggering Factors	Major Socio-Ecological Impacts
	areas in Kuala Indragiri, Tanah Merah, Concong, and Kateman	sanitation of stagnant water following tidal flooding in densely populated areas	the risk of transmission of waterborne diseases

The Paradox of Regional Environmental Policy and the Politics of Multi-Risk Budgeting

From an environmental policy perspective, the high level of biophysical vulnerability summarized in Table 1 necessitates risk-based environmental regulation instruments and adequate fiscal support. However, the policy analysis reveals a structural paradox in disaster and environmental governance in Indragiri Hilir Regency. Legally, disaster management in this region continues to rely on overarching regulations, namely Law No. 24 of 2007 concerning Disaster Management, Riau Province Regional Regulation No. 17 of 2013 in conjunction with No. 9 of 2017 concerning Natural Disaster Management, and Indragiri Hilir Regency Regional Regulation No. 09 of 2010, subsequently amended by Regional Regulation No. 14 of 2014 concerning the Organization and Working Procedures of the Regional Disaster Management Agency. At the time this study was conducted, the Indragiri Hilir Regency Government had not enacted a specific Regional Regulation or Regent Regulation governing coastal flood risk management, the protection of water absorption areas, or spatial planning controls specifically designed for tidal zones:

“There is currently no specific flood policy within the BPBD; the existing policies only regulate the duties of each division within the BPBD. However, we are now planning to update the disaster-prone area map of Indragiri Hilir Regency to anticipate future disasters.” (Interview with the Head of the Emergency and Logistics Division of the Regional Disaster Management Agency of Indragiri Hilir Regency, July 29, 2022)

The absence of sector-specific legal instruments for flood control directly weakens the enforcement capacity of the regional government in controlling the conversion of water absorption areas and regulating buildings along riverbanks and canals. The revision of the disaster-prone area map undertaken by the BPBD remains at the informative mapping stage and has not yet been integrated into legally binding instruments for controlling spatial utilization permits.

This regulatory weakness is further exacerbated by regional budgetary politics that have not prioritized ecological mitigation in fiscal allocation. Based on primary interview data, the budget allocated to the Regional Disaster Management Agency of Indragiri Hilir Regency through the Regional Revenue and Expenditure Budget (APBD) amounts to only IDR 1 billion per year, and this ceiling already includes contingency expenditures for managing all types of natural and non-natural disasters across 20 subdistricts:

“The government has provided a budget for addressing disasters in Indragiri Hilir Regency. However, there is no budget specifically allocated for flooding. The government provides the BPBD with IDR 1 billion annually, and this amount already includes contingency expenditures.” (Interview with the Head of the Emergency and Logistics Division of the Regional Disaster Management Agency of Indragiri Hilir Regency, July 29, 2022).

When critically examined through a risk-based budgeting approach, the annual budget ceiling of IDR 1 billion for a region covering 12,614.78 km², with 15 subdistricts vulnerable to peatland forest and land fires, six subdistricts vulnerable to coastal abrasion, and seven subdistricts vulnerable to flooding (Figure 1B), creates an acute fiscal capacity deficit. The absence of a dedicated budget allocation category for flood mitigation means that limited funds are diverted toward forest and land fire suppression during the dry season or incidental emergency responses. Furthermore, the budgetary structures of collaborating agencies are fragmented: the Indragiri Hilir Regency Social Affairs Office, the SAR Post, and the Tembilahan Hulu Subdistrict Government have no dedicated budget allocations for flood management. The Social Affairs Office functions only as a passive distributor of logistical assistance, including rice, basic food supplies, and bedding, sourced from the Riau Province Social Affairs Office or the regency government. Consequently, in 2019, assistance was distributed only to Tempuling Subdistrict; in 2020, no logistical assistance was provided; and in 2021, assistance reached only Keritang, Gaung, and Kemuning subdistricts. Meanwhile, affected residents in Batang Tuaka Subdistrict and those experiencing recurrent inundation in Tembilahan and Tembilahan Hulu received no assistance interventions.

The tangible consequences of budgetary constraints and institutional fragmentation were confirmed through the author's field observations during the flooding that occurred in Tembilahan and Tembilahan Hulu subdistricts on January 1, 2022. Although floodwater reached a depth of 30–35 cm for two days and disrupted residents' activities, no public

kitchens operated by the Social Affairs Office or field emergency posts complying with disaster management standards were found at the affected locations. Meanwhile, the Indragiri Hilir SAR Post was staffed by only seven personnel, without a specific division of responsibilities due to limited human resources, and conducted evacuations only when the disaster status was upgraded from “alert” to “emergency response.” Consequently, because annual tidal flooding and river overflows in Indragiri Hilir are frequently classified only under “alert” status, affected communities experience an absence of rapid government response in the field.

Local Community Resilience and Autonomous Ecological Adaptation as a Policy Buffer

One of the most critical findings of this study which is often overlooked in conventional bureaucratic evaluations is the emergence of autonomous ecological adaptation capacity among local communities as a direct response to the limitations of regional government intervention.

In Indragiri Hilir Regency, particularly in the agricultural areas and tidal swamp settlements of Tembilahan Hulu Subdistrict, communities no longer remain passive while waiting for government logistical assistance. Given that most residents work in agriculture, plantations, and fisheries, all of which depend heavily on water management stability, local farmers have independently developed four ecological and social adaptation mechanisms:

1. **Innovations in Seed Management and Adaptive Rice Varieties:** In response to the risk of rice fields being inundated during the peak months of the rainy season and high tides, farmers in Tembilahan Hulu deliberately sow additional rice seedlings during the planting period as a buffer stock for replanting if some rice field plots are damaged by flooding, while also selecting rice varieties with greater tolerance to water inundation.
2. **Institutionalization of Pre-Planting Village Deliberations:** Before beginning the planting cycle, farming communities hold village deliberations to agree on a shared planting calendar based on observations of rainy-season indicators and river tidal cycles, thereby collectively minimizing the risk of simultaneous crop failures.
3. **Kinship-Based Independent Evacuation Networks:** For households located around low-lying agricultural areas and canal banks, residents establish self-evacuation mechanisms by

moving vulnerable family members and essential belongings to the homes of relatives or neighbors with elevated stilt-house structures, without waiting for SAR teams to arrive.

4. Collective Maintenance of Communal Canal Networks: Through coordination among subdistrict governments, urban village/village administrations, and neighborhood associations (RT), residents periodically engage in mutual cooperation to remove mud deposits, weeds, and accumulated waste from canals and culverts to maintain the smooth circulation of tidal water.

The active participation of local communities and subdistrict-level authorities is reinforced by statements from community informants and the Head of Tembilahan Hulu Subdistrict:

“As members of the local community, every few months we work together to clean the environment and remove waste and mud from the canals so that they do not become shallow or blocked, which could cause flooding.” (Interview with a resident of Indragiri Hilir Regency, July 25, 2022)

Table 2. Evaluation of the Gap Between Formal Environmental Policy and Local Community Adaptation Practices in Indragiri Hilir Regency

Governance Dimension	Existing Regional Government Policy Conditions	Local Community Resilience and Adaptation Practices	Implications for Environmental Sustainability
Regulation and Spatial Planning	No specific Regional Regulation on tidal flooding/coastal water management; existing measures are limited to Regional Regulation No. 14/2014 on BPBD organizational structure and disaster-prone area map updates	Local agreements through village deliberations to regulate rice field land-use patterns and seasonal planting schedules	Without formal spatial planning enforcement, the conversion of water absorption areas and mangroves in upstream and coastal areas remains uncontrolled
Funding and Economic Resources	BPBD budget ceiling of only IDR 1 billion annually for all disasters; no dedicated flood mitigation budgets at the Social Affairs Office, SAR Post, or subdistrict level	Farmers independently provide additional rice seed reserves and bear the costs of post-flood land recovery	The ecological and economic burden shifts to farming households, increasing their structural vulnerability to poverty due to recurrent crop failures
Infrastructure and Drainage Management	Urban drainage construction is not yet integrated with tidal systems and is constrained by road damage affecting access to disaster locations	Periodic communal efforts to remove mud sedimentation and domestic waste from canal networks and culverts	Manual community maintenance is effective at the micro level but cannot withstand sea-level rise and large-scale tidal flooding

Governance Dimension	Existing Regional Government Policy Conditions	Local Community Resilience and Adaptation Practices	Implications for Environmental Sustainability
Emergency Response and Early Warning	Irregular, incidental awareness activities; the SAR Post, staffed by seven personnel, responds only when the status reaches “emergency response”; public kitchens are frequently absent	Self-evacuation to relatives’ or neighbors’ homes and adaptation of residential structures to inundation depths of 30–35 cm	Reduces fatalities in the short term but causes psychological exhaustion and public distrust of the government

Designing Policy Transformation Toward Adaptive Coastal Environmental Governance

The comparison presented in Table 2 demonstrates that although local community resilience has successfully served as a socioeconomic safety valve at the local level, autonomous community adaptation has ecological thresholds beyond which it becomes ineffective (adaptation limits). Community efforts to clean canals and farmers’ strategies of maintaining additional seed reserves cannot withstand rising sea levels, saltwater intrusion, and major flood runoff if the degradation of water absorption areas and the conversion of mangrove forests continue across the regency's landscape. Furthermore, the imbalance between the adaptive burden borne by residents and the limited government presence has generated public dissatisfaction, as residents have expressed that regional government policies have been unable to address annual flooding that disrupts their economic activities.

The Indragiri Hilir Regency Government needs to transform its policies from a centralized and reactive disaster management model toward proactive co-management of coastal peatland ecosystems. Four environmental policy reform agendas need to be institutionalized:

Table 3. Synthesis of Coastal Environmental Policy Transformation Strategies in Indragiri Hilir Regency

Policy Reform Pillar	Existing Conditions (Reactive-Sectoral Paradigm)	Recommended New Policy (Adaptive Environmental Governance)	Implementing Actors and Policy Instruments
1. Spatial Planning Regulations Based on Peatland Hydrological Carrying Capacity	Absence of a specific Regional Regulation on flood control; uncontrolled conversion of water absorption areas and riverbanks	Enactment of a Regional Regulation on Integrated Coastal and Canal Management; designation of strictly protected mangrove belts and swamp-peatland water	Regent, Regional House of Representatives (DPRD), Regional Development Planning Agency (Bappeda), Environmental Agency, Public Works and Spatial

Policy Reform Pillar	Existing Conditions (Reactive-Sectoral Paradigm)	Recommended New Policy (Adaptive Environmental Governance)	Implementing Actors and Policy Instruments
		absorption areas in the Regional Spatial Plan (RTRW)	Planning Agency (PUPR), and BPBD (Regional Regulation and Risk-Based RTRW Revision)
2. Risk-Based Ecological Budgeting	Centralized BPBD budget of IDR 1 billion annually for all disasters; no mitigation funds allocated to subdistricts and villages	Reallocation of the APBD based on flood risk indices, including dedicated tidal flood mitigation funds; decentralization of contingency funds to vulnerable subdistricts and use of Village Funds for canal maintenance	Regional Government Budget Team (TAPD), DPRD, BPBD, subdistrict governments, and village governments (APBD and Green Village Fund Allocations)
3. Green-Gray Infrastructure (Hybrid Engineering) and Revitalization of the Thousand Canals	Conventional drainage construction and incidental manual waste removal	Integration of coastal mangrove rehabilitation (green belts) with automatic tidal flap gates and integrated normalization of the “Thousand Canals” network	Public Works and Spatial Planning Agency, Environmental Agency, BPBD, and River Basin Organization (Coastal Hydrological Restoration Program)
4. Community Co-Management and Hydrometeorological Early Warning Systems	Unscheduled awareness activities; farmers adapt independently without climate advisory services or improved seeds	Institutionalization of Coastal Disaster-Resilient Villages; subsidies for flood- and salinity-tolerant rice seeds; integration of real-time tidal schedules at the village level	BPBD, Agriculture Agency, Social Affairs Office, SAR Post, subdistrict heads, and village farmer groups (Cross-Sectoral Joint Decrees)

As formulated in Table 3, the first pillar requires strengthening legal instruments through the establishment of a Regional Regulation on Integrated Coastal Area and Canal Network Management, which integrates the BPBD flood risk map into the control of spatial utilization permits. Any conversion of swamp water absorption areas or mangrove deforestation should be subject to administrative sanctions and ecological restoration obligations (Law No. 32 of 2009 and Law No. 26 of 2007). The second pillar requires regional fiscal restructuring: the Indragiri Hilir Regency Government needs to separate coastal flood mitigation funding from general contingency expenditure, increase the budget ceiling beyond IDR 1 billion in accordance with the vulnerability profile of the seven flood-prone subdistricts, and create fiscal space for subdistrict and village governments to independently finance the maintenance of micro-scale water management infrastructure.

Furthermore, the third pillar combines technical and ecological engineering (hybrid engineering) by integrating the rehabilitation of mangrove green belts along the eastern coast of Indragiri Hilir to reduce tidal wave energy and coastal abrasion with the modernization of the “Thousand Canals” management system through the construction of tidal flap gates and periodic sediment dredging. Finally, the fourth pillar integrates social capital and local farmers’ adaptation practices into formal co-management arrangements. The initiatives of farmers in Tembilahan Hulu to develop planting calendars and maintain seed reserves should be supported by the Agriculture Agency and BPBD through the provision of improved rice varieties that are tolerant to inundation (submergence-tolerant varieties) and salinity, accompanied by a scheduled and transparent tidal early warning system extending to the neighborhood association level.

DISCUSSION

Ecological Degradation as an Intensifier of Tidal Flood Risk

The research findings indicate that flooding in Indragiri Hilir Regency cannot be understood solely as a consequence of rainfall or high tides; rather, it needs to be analyzed as the result of interactions between landscape characteristics and human activities. The predominance of low-lying areas, the presence of swamps and peatlands, and the network of rivers and canals make the efficient flow of water a critical factor. When waterways become shallower due to sediment accumulation, water infiltration areas shrink, and mangrove cover declines, the environment's capacity to retain and channel water becomes increasingly limited.

This interpretation is consistent with discussions of peatland conversion and the decline in hydrological functions presented by (Wijedasa et al., 2020; Alfian et al., 2023). In the context of Indragiri Hilir, field findings concerning land-use conversion, sedimentation, and waste disposal indicate that ecological pressures are associated with spatial utilization practices and everyday environmental management. Therefore, flood management requires a combination of measures to reduce exposure to hazards, restore ecosystem functions, and control activities that increase surface runoff.

Flood distribution data for 2019–2021 also indicate the need for caution when interpreting changes in the number of affected subdistricts. Although the 2021 records indicate a wider geographical spread of flooding, the figures and lists of locations need to be

interpreted in accordance with the disaster administration data sources used. These findings support the need for a consistent disaster recording system so that mitigation planning can be based on comparable spatial and temporal information.

Regulatory Gaps and Budgetary Fragmentation

The research findings indicate that the regulatory framework available during the research period did not specifically govern coastal flood risk management or the protection of water infiltration areas. The absence of more specific instruments may limit the local government's ability to connect disaster-prone area maps with spatial-use controls, riverbank protection, and mangrove restoration. Updated risk maps would be more beneficial if followed by clear regulations, a division of responsibilities, monitoring mechanisms, and implementation resources.

This issue is related to the study by Rahmayanti and Meiwanda (2022) on the capacity of the Indragiri Hilir Regency Government to manage flooding. Research on disaster governance in other regions, such as (Ramanda & Meiwanda, 2021), also highlights limitations in government capacity to address flooding. The present study adds an environmental policy dimension, indicating that limited response capacity is associated not only with administrative capabilities but also with the lack of integration among spatial planning controls, ecosystem damage prevention, and mitigation financing.

The BPBD's annual budget allocation of approximately IDR 1 billion, which is used to address various types of disasters, illustrates the challenges involved in determining fiscal priorities. When limited funding must meet the needs of forest and land fires, coastal abrasion, flooding, and other unforeseen events, preventive activities risk receiving lower priority than emergency response. This condition highlights the importance of risk-based budgeting that considers geographical coverage, exposure levels, event frequency, the number of affected residents, and potential losses. Mitigation financing also needs to be coordinated with technical agencies, subdistrict governments, and village governments to ensure that responsibility is not concentrated solely within the BPBD.

From an environmental governance perspective, Carlisle and Gruby (2019) explain the relevance of polycentric governance systems, while Ostrom emphasizes the importance of arrangements involving multiple centers of decision-making. This framework is relevant to promoting a division of roles across levels of government and among institutions.

However, coordination cannot be established through administrative arrangements alone; it must be supported by clear mandates, accessible funding, data exchange, and accountability mechanisms.

Community Resilience and the Limits of Autonomous Adaptation

Community strategies, including rice seed reserves, adjustments to planting calendars, independent evacuation, and canal maintenance, demonstrate that residents have the capacity to respond to recurring disruptions through local knowledge and collective action. These practices constitute forms of adaptation closely aligned with local conditions because they have developed through experience in dealing with inundation patterns and tidal fluctuations. These findings emphasize that communities are not merely recipients of assistance but also actors who contribute to reducing flood impacts at the household and environmental levels.

These findings can be interpreted through recent developments in adaptive governance and community resilience. Adaptive governance emphasizes the importance of institutional flexibility, social learning, and coordination among actors in responding to environmental change (Herizal et al., 2024; Yulianto et al., 2025). Community resilience is also shaped by social networks and the capacity of local communities to organize collective responses before, during, and after disruptive events. Furthermore, research on adaptive governance and community resilience in coastal Bangladesh highlights the importance of social learning and institutional collaboration in strengthening responses to environmental hazards. In this study, pre-planting deliberations and collective canal-cleaning activities can be understood as forms of collective action that create opportunities for knowledge exchange, coordination, and community engagement. These practices may provide a foundation for strengthening community preparedness, although their actual contribution depends on whether collective action is sustained and translated into effective adaptation measures.

Nevertheless, autonomous adaptation has its limits. Seed reserves and adjustments to planting schedules can help farmers reduce losses on particular plots of land, while canal cleaning can maintain the flow of local waterways. These practices cannot replace land-use change controls, coastal ecosystem rehabilitation, or the infrastructure required to address large-scale flooding. If the entire burden of adaptation is placed on communities, particularly

households whose livelihoods depend on agriculture and fisheries, ecological risks may become a recurring economic burden.

Therefore, community resilience should be positioned as a partner to formal policy rather than as a justification for the government to reduce its responsibilities. The government can support local practices through agricultural extension services, the provision of suitable seeds, tidal information and early warning systems, evacuation support, and mechanisms for involving residents in program planning and evaluation.

Directions for Transformation Toward Adaptive Coastal Environmental Governance

Based on the research findings and the adaptive governance framework, policy transformation in Indragiri Hilir Regency can be directed toward four interconnected agendas. First, spatial planning regulations need to be strengthened by incorporating the hydrological carrying capacity of peatlands, the protection of water infiltration areas, and mangrove belts into spatial planning and land-use control instruments. Risk maps need to be linked to licensing decisions, monitoring, and restoration obligations when environmental damage occurs.

Second, risk-based ecological budgeting needs to distinguish more clearly between mitigation and preparedness requirements and emergency response expenditure. Allocation decisions should be based on risk levels and location-specific needs, accompanied by coordination among the BPBD, technical agencies, subdistrict governments, and villages. Third, infrastructure management needs to combine ecological and technical approaches, including mangrove rehabilitation, canal network maintenance, sedimentation control, and feasibility assessments of sluice gates or tidal control infrastructure in accordance with local hydrological conditions.

Fourth, community adaptation practices need to be institutionalized through co-management. Local planting calendars, seed reserves, collective action activities, and evacuation networks can be integrated into village preparedness plans and cross-sectoral programs. Early warning systems should also communicate information that communities can understand and act upon. This direction is consistent with the discussion of coastal disaster risk governance by (Lyu et al., 2023; Carlisle & Gruby, 2019).

Thus, the required policy model is not merely an improvement in response when flooding occurs, but an integrated approach to risk management before, during, and after an

event. The success of this transformation needs to be assessed through measurable indicators, such as the consistency of flood event data, the restoration of water infiltration areas and mangroves, the accessibility of preparedness services, the availability of mitigation budgets, and community participation in water management decisions.

Consistency Issues Requiring Verification

1. The abstract states that flooding expanded from three to six subdistricts, whereas several sections of the manuscript refer to seven subdistricts classified as flood-prone or affected. Clarify whether these figures refer to subdistricts that experienced flooding in a particular year or to subdistricts classified as disaster-prone areas.
2. The figures of 1,133 households and more than 1,130 affected houses need to be cross-checked against the breakdown by subdistrict, as the totals calculated from the details presented in the manuscript should be verified against BPBD data.
3. Table 1 presents several risk and impact categories that need to be linked to clearly identified data sources. Ensure that all figures, lists of subdistricts, and reference periods are consistent.
4. Ensure that all sources cited in the discussion are fully listed in the references, and revalidate the bibliographic metadata and DOI information before submitting the manuscript to the journal.

Research Implications, this study highlights the importance of shifting from reactive tidal flood management toward preventive, adaptive, and sustainable environmental governance. Local governments need to strengthen regulations, allocate risk-based budgets, protect coastal ecosystems, and involve communities in environmental management.

Research Limitations, this study focuses on Indragiri Hilir Regency using a qualitative case study approach. The findings are based on interviews, observations, and document analysis; therefore, they may not fully represent the conditions of other coastal areas. Furthermore, this study does not quantitatively measure the effectiveness of policies or community adaptation strategies.

CONCLUSION

The annual tidal flooding and river overflow crisis in Indragiri Hilir Regency is not merely a technical and operational disaster management issue, but rather a reflection of the

structural vulnerability of environmental policy in low-lying coastal peatland areas. The research findings lead to three main conclusions. First, the escalation in flood distribution from 3 subdistricts (2019) to 6 subdistricts, inundating more than 1,130 residential houses (2021), was triggered by the interaction between lowland topography (93.31% of the total regional area) and anthropogenic environmental degradation, including the conversion of water absorption areas, coastal mangrove deforestation, the narrowing of riverbanks due to settlements, and sedimentation and waste blockages within the “Thousand Canals” network. Second, regional environmental policies remain reactive and fragmented due to the absence of specific regional regulations governing coastal flood control and the limited BPBD budget of IDR 1 billion per year, which must cover multiple ecological risks (forest and land fires in 15 subdistricts, coastal abrasion in 6 subdistricts, and flooding in 7 subdistricts), without being supported by mitigation budget allocations at the subdistrict level or within relevant agencies. Third, amid the limited reach of these formal policies, local communities and farmers have been able to develop autonomous social-ecological resilience through innovations involving rice seed reserves, the selection of adaptive varieties, pre-planting village deliberations, kinship-based independent evacuation, and the communal maintenance of canals. To prevent the community’s adaptive capacity from collapsing as ecological thresholds are exceeded, the Indragiri Hilir Regency Government is recommended to promptly enact regulations protecting water absorption areas and coastal mangroves, implement risk-based ecological budgeting, and institutionalize co-management partnerships for water governance with local communities.

This study contributes to the development of adaptive environmental governance by linking ecological factors, government policies, disaster budgeting, and community resilience in addressing tidal flooding. The findings strengthen the understanding of the importance of government–community collaboration in building coastal resilience.

Future researchers are encouraged to conduct comparative studies across several coastal areas, employ quantitative or mixed-methods approaches to measure the effectiveness of policies and community adaptation strategies, and examine the long-term impacts of land-use changes and ecosystem degradation on the increasing risk of tidal flooding.

REFERENCES

- Adi, R. N., & Savitri, E. (2022). The effect of land cover changes on the 2021 flood in the Barito watershed, South Kalimantan. *IOP Conference Series: Earth and Environmental Science*, 1109(1), Article 012017. <https://doi.org/10.1088/1755-1315/1109/1/012017>
- Alfian, D., Meilianda, E., Achmad, A., & Syukri, M. (2026). Integrating hydrodynamic modeling and multi-criteria decision support for flood risk management in coastal systems. *Global Journal of Environmental Science and Management*, 12(3), 1287–1310. <https://doi.org/10.22034/gjesm.2026.03.13>
- Badan Pusat Statistik Kabupaten Indragiri Hilir. (2021). *Kabupaten Indragiri Hilir dalam Angka 2021*. <https://inhilkab.bps.go.id/id/publication/2021/02/26/718579f7e7006a1ac73ddc0e/kabupaten-indragiri-hilir-dalam-angka-2021.html>
- Badan Pusat Statistik Kabupaten Indragiri Hilir. (2022). *Kabupaten Indragiri Hilir dalam Angka 2022*. <https://inhilkab.bps.go.id/id/publication/2022/02/25/8dac18317b85ae263259c743/kabupaten-indragiri-hilir-dalam-angka-2022.html>
- Badan Pusat Statistik Kabupaten Indragiri Hilir. (2023). *Kabupaten Indragiri Hilir dalam Angka 2023*. <https://inhilkab.bps.go.id/id/publication/2023/02/28/d2719bc17ad60b48fe644549/kabupaten-indragiri-hilir-dalam-angka-2023.html>
- Campbell, S., Greenwood, M., Prior, S., Shearer, T., Walkem, K., Young, S., Bywaters, D., & Walker, K. (2020). Purposive sampling: Complex or simple? Research case examples. *Journal of Research in Nursing*, 25(8), 652–661. <https://doi.org/10.1177/1744987120927206>
- Carlisle, K., & Gruby, R. L. (2019). Polycentric systems of governance: A theoretical model for the commons. *Policy Studies Journal*, 47(4), 927–952. <https://doi.org/10.1111/psj.12212>
- Chaffin, B. C., Garmestani, A. S., Gunderson, L. H., Benson, M. H., Angeler, D. G., Arnold, C. A., Cosens, B., Craig, R. K., Ruhl, J. B., & Allen, C. R. (2016). Transformative environmental governance. *Annual Review of Environment and Resources*, 41(1), 399–423. <https://doi.org/10.1146/annurev-environ-110615-085817>
- Clement, S., Jozaci, J., Mitchell, M., Allen, C. R., & Garmestani, A. S. (2024). How resilience is framed matters for governance of coastal social-ecological systems. *Environmental Policy and Governance*, 34(1), 65–76. <https://doi.org/10.1002/eet.2056>
- Daryanes, F., Sayuti, I., & Fikri, K. (2026). Analisis Permasalahan Banjir dan Strategi Mitigasi Bencana Banjir di Kabupaten Kampar Provinsi Riau. *Indonesian Journal of Environment and Disaster*, 5(1), 194–208. <https://doi.org/10.20961/ijed.v5i1.3157>
- DeCaro, D. A., Schlager, E. C., & Frimpong Boamah, E. (2025). The state-reinforced self-governance framework: Conceptualizing and diagnosing legal and other institutional foundations of adaptive and transformative environmental governance. *Ecology and Society*, 30(2), Article 1. <https://doi.org/10.5751/ES-15567-300201>
- Ellinger, A. D., & McWhorter, R. (2016). Qualitative case study research as empirical inquiry. *International Journal of Adult Vocational Education and Technology*, 7(3), 1–13. <https://doi.org/10.4018/IJAVET.2016070101>

- Hapsari, K. A., Jennerjahn, T., Nugroho, S. H., Yulianto, E., & Behling, H. (2022). Sea level rise and climate change acting as interactive stressors on development and dynamics of tropical peatlands in coastal Sumatra and South Borneo since the Last Glacial Maximum. *Global Change Biology*, 28(10), 3459–3479. <https://doi.org/10.1111/gcb.16131>
- Herizal, Rasanjani, S., Afrijal, Muhkrijal, & Wance, M. (2024). Systematic literature review: The evolution of adaptive governance and practice in the context of the environmental crisis. *Jurnal Ilmu Lingkungan*, 22(5), 1326–1337. <https://doi.org/10.14710/jil.22.5.1326-1337>
- Intergovernmental Panel on Climate Change. (2022). *Climate change 2022: Impacts, adaptation and vulnerability*. Cambridge University Press. <https://doi.org/10.1017/9781009325844>
- Kallio, H., Pietilä, A.-M., Johnson, M., & Kangasniemi, M. (2016). Systematic methodological review: Developing a framework for a qualitative semi-structured interview guide. *Journal of Advanced Nursing*, 72(12), 2954–2965. <https://doi.org/10.1111/jan.13031>
- Miles, M. B., Huberman, A. M., & Saldaña, J. (2019). *Qualitative data analysis: A methods sourcebook* (4th ed.). SAGE Publications.
- Nowell, L. S., Norris, J. M., White, D. E., & Moules, N. J. (2017). Thematic analysis: Striving to meet the trustworthiness criteria. *International Journal of Qualitative Methods*, 16(1), 1–13. <https://doi.org/10.1177/1609406917733847>
- Rahmayanti, Y., & Meiwanda, G. (2022). Kapabilitas Pemerintah Kabupaten Indragiri Hilir dalam Penanggulangan Bencana Banjir. *Journal of Research and Development on Public Policy*, 1(3), 21–34. <https://doi.org/10.58684/jarvic.v1i3.22>
- Ramanda, M. S., & Meiwanda, G. (2021). Kapabilitas Pemerintah Kota Dumai dalam Penanggulangan Bencana Banjir. *Jurnal Administrasi Publik*, 8(2), 45–58.
- Sugianto, Deli, A., Miswar, E., Rusdi, M., & Irham, M. (2022). The effect of land use and land cover changes on flood occurrence in Teunom watershed, Aceh Jaya. *Land*, 11(8), Article 1271. <https://doi.org/10.3390/land11081271>
- Wijedasa, L. S., Sloan, S., Page, S. E., Clements, G. R., Lupascu, M., & Evans, T. A. (2018). Carbon emissions from South-East Asian peatlands will increase despite emission-reduction schemes. *Global Change Biology*, 24(10), 4598–4613. <https://doi.org/10.1111/gcb.14340>
- Yulianto, Rosalia, F., & Hutagalung, S. S. (2025). Adaptive governance in environmental issue: Systematic literature review. *International Journal of Environmental Impacts*, 8(3), 615–625. <https://doi.org/10.18280/ijei.080319>