BIODIVERSITAS
Volume 27, Number 4, April 2026
Pages: 10

ISSN: 1412-033X
E-ISSN: 2085-4722
https://doi.org/10.13057/biodiv/d270409

Institutional model for integrating Sasi and local wisdom into Indonesia's national mangrove conservation policy

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Manuscript received: 11 January 2026. Revision accepted: 7 April 2026.

Abstract. *Suwarno E, Effendi I, Matitaputty JK, Zainuri, RA DS. 2026. Institutional model for integrating Sasi and local wisdom into Indonesia's national mangrove conservation policy. Biodiversitas 27 (4): d270409. https://doi.org/10.13057/biodiv/d270409*. Indonesia's ambitious mangrove conservation targets face a persistent challenge in substantively integrating local governance systems like Sasi. This study employs a qualitative regulatory gap analysis of three document corpora: national legal instruments, ethnographic studies on Sasi, and supporting academic literature. We identify fundamental tensions between Maluku's temporally-based Sasi system and Indonesia's spatial zoning-based national mangrove policy, particularly regarding the non-recognition of traditional *kewang* authority and incompatibility between temporal moratoriums (Sasi *tutup*) and static spatial zoning. Complementary potential exists in monitoring and enforcement capacities. To bridge this gap, we propose the Temporal-Spatial Bridge (TSB) model, a hybrid institutional framework with four pillars: mutual legal recognition, nested temporal-spatial rules, tiered polycentric enforcement, and localized benefit-sharing. The model is presented as a conceptual hypothesis requiring empirical testing, not as a ready-to-implement policy framework. It offers potential to enhance biodiversity outcomes by embedding life-cycle protection into national planning and formalizing local ecological knowledge into adaptive management systems. We conclude that bridging legal pluralism in conservation requires deliberate institutional engineering, offering the TSB model as a conceptual template derived from the Maluku context for Indonesia and similar contexts.

Keywords: Coastal biodiversity, hybrid governance, legal pluralism, regulatory gap analysis, traditional ecological knowledge

INTRODUCTION

Indonesia's mangrove ecosystems, recognized as global blue carbon sinks and bastions of coastal biodiversity, face tremendous pressure from aquaculture conversion, infrastructure development, and climate change impacts such as sea level rise (Friess et al. 2016; Adame et al. 2021). In response, national governments are launching ambitious conservation and rehabilitation programs, often formulated within global climate commitments. However, implementation of these top-down policies frequently ignores pre-existing location-based governance systems—systems that have managed these resources sustainably for generations. These gaps are not simply operational inefficiencies but fundamental flaws in governance design, with potential to trigger community resistance, misaligned incentives, and ultimately ecological failure (Andradi-Brown et al. 2025).

The consequences of such misalignment between customary systems and state policy have been documented across Indonesia. Thorburn (2000) showed how the introduction of national fisheries legislation undermined Sasi laut in the Kei Islands, leading to erosion of customary authority and ultimately resource degradation. This illustrates that when top-down policies disregard local institutions, they can inadvertently dismantle the very governance systems that have sustained resources over generations—a dynamic that remains relevant for mangrove conservation today.

In coastal communities of Maluku, the Sasi system has for centuries orchestrated intricate harmony between human communities and their marine and coastal environments. More than just a sacred prohibition, Sasi is a sophisticated community-based natural resource management system. It serves as an institutionalized mechanism to prevent the "tragedy of shared ownership" by regulating harvest times and methods to ensure long-term sustainability (Prasetyo 2019). Operated through rituals of Sasi *tutup* (closing) and Sasi *buka* (opening) cycles, and managed by *kewang* customary institutions, Sasi upholds collective discipline that maintains resource abundance and ecosystem health (Harkes and Novaczek 2002; Salampessy et al. 2024).

While Sasi is often associated with marine resources such as *lola* snails and sea cucumbers, it also applies to mangrove ecosystems. In Buano Island, Sasi regulates the harvest of mangrove crabs (*Scylla serrata*) and the collection of mangrove timber, with *kewang* institutions monitoring compliance and enforcing seasonal closures (Salampessy et al. 2024). These examples illustrate that Sasi is not merely a marine fisheries institution but a broader resource governance framework relevant to mangrove conservation.

From an ethnobiological perspective, Sasi represents institutionalized traditional ecological knowledge (TEK), operating on principles of shared resource management including clear boundaries, tiered sanctions, and participatory monitoring. Its efficacy is demonstrated in maintaining mangrove forest health on Buano Island, where communities under Sasi governance show higher compliance with sustainable harvesting practices compared to areas without such customary rules (Salampessy et al. 2024). Sasi embodies a holistic sustainability framework that integrates five interdependent pillars—economic, social, ecological, cultural, and political—reflecting local practice with global relevance (Matitaputty et al. 2018).

Academic discourse on Sasi and national mangrove policy develops along separate paths. Socio-anthropological studies examine social complexities and cultural values, while applied policy research evaluates rehabilitation success (Arifanti et al. 2022). This separation yields superficial policy narratives advocating "local wisdom integration" without operational understanding of Sasi's interaction with national conservation law. On the ground, this manifests as community confusion about which rules to follow, reluctance to comply with illegitimate-seeming state regulations, and missed governance synergies (Satria and Mony 2019; Thorburn 2000).

This is the critical research gap that this study aims to address. In the midst of accelerating national mangrove rehabilitation through instruments such as Presidential Regulation No. 120 of 2020, the absence of a meaningful integration roadmap risks significant resource allocation errors. "Blind" programs to living local institutions such as Sasi can trigger local rejection, mistargeting, and ecological failure (Andradi-Brown et al. 2025). Therefore, it is no longer enough to simply document Sasi or criticize national policies separately. A deeper and more technical involvement is needed: a normative dissection that systematically compares the institutional substance of the Sasi system with the corpus of state regulations.

This article has two interrelated objectives. First, to conduct a systematic regulatory gap analysis by mapping concrete points where Sasi's management principles and national mangrove policy contradict, overlap, or complement each other. Second, based on this diagnosis, design a viable hybrid institutional model as an operational protocol for local implementation. The research questions guiding this investigation are: What specific normative dimensions create tension between Sasi and state law? What institutional architecture can transform these tensions into synergies for more effective mangrove conservation?

MATERIALS AND METHODS

Research design and conceptual framework

This research employs a descriptive-analytical qualitative design focused on regulatory and document analysis to uncover meanings, logics, and normative assumptions underlying both rule systems. The study bridges ethnobiology—understanding Sasi as institutionalized local ecological knowledge—with policy analysis examining the formal state framework. Sustainable resource management requires careful integration between institutional layers (Basupi et al. 2019), and a legal-normative approach helps identify space for recognizing multiple legal systems (Sutisna et al. 2025).

The primary analytical lens is "regulatory gap analysis," systematically comparing principles, norms, operational rules, and enforcement mechanisms in customary law with state law. This aligns with perspectives that inclusive environmental governance requires strengthening customary institutions' legal status and fostering cooperation between knowledge systems (Aldyan et al. 2025). Previous Indonesian studies confirm potential synergies and challenges in integrating customary systems into state policies, including soa-based collaborative management in Mount Sirimau Protected Forest (Parera et al. 2022), verification of Boti indigenous people's existence (Dako et al. 2024), and coexistence of customary tenure systems with state orders in Mutis Area (Budiman et al. 2020). Through gap analysis, this research aims to create an "institutional bridge" providing acceptability, legitimacy, and sustainability at the site level.

Types and sources of data

The data corpus consists of three distinct groups selected to enable systematic comparison between customary and state governance systems as detailed below.

National and regional policy corpus

The first group comprises seven main legal instruments selected based on legal hierarchy, substantive relevance, and jurisdictional coverage over mangrove ecosystems, coastal areas, indigenous peoples, and village governance. The core regulations include: Law No. 32 of 2009 concerning Environmental Protection and Management; Government Regulation No. 27 of 2025 concerning Protection and Management of Mangrove Ecosystems; Regulation of the Minister of Maritime Affairs and Fisheries No. 8 of 2018 concerning Procedures for Determining Customary Law Community Management Areas; Regulation of the Minister of Environment and Forestry No. P.17/MENLHK/SETJEN/KUM.1/8/2020 concerning Customary Forests and Forest Rights; Maluku Provincial Regulation No. 10 of 2013 concerning Management of Coastal Areas and Small Islands; Maluku Provincial Regional Regulation No. 16 of 2019 concerning Arrangement of Customary Villages; and Law No. 6 of 2014 concerning Villages. To ensure comprehensive coverage, we also reviewed an additional 13 supporting legal documents (e.g., ministerial decrees) that elaborate on the implementation of these core instruments.

Sasi customary law corpus

The second group contains 27 primary ethnographic and interdisciplinary studies identified through systematic searches in Scopus, Google Scholar, and university repositories. Searches employed keywords "Sasi Maluku," "Sasi mangrove," and "*kewang* institution" for publications from 1994 to 2025, with inclusion criteria requiring operational descriptions of temporal rules, enforcement mechanisms, institutional roles, or ecological outcomes.

Most studies were published between 2019 and 2024, reflecting recent scholarly interest in Sasi. Our understanding of Sasi's historical dynamics draws on three foundational studies: Harkes and Novaczek (2002), providing longitudinal data from 1997-98 across 63 villages in Central Maluku; Zerner (1994), tracing Sasi's discursive construction from the colonial era through the 1990s; and Bubandt (2005), analyzing Sasi as an "imagined tradition" reinvented since colonial times. While these offer valuable historical depth, we recognize that Sasi institutions have likely evolved in ways not fully captured, and that 1990s contexts differ from contemporary conditions.

Only one study—Salampessy et al. (2024)—directly examines Sasi in the mangrove forest management context. Wonley et al. (2021) address mangroves but in an educational context. Several others mention mangroves indirectly. The remaining studies address marine and fisheries Sasi, including reef fish, sea cucumbers, and trochus shells. While these marine-focused studies illuminate Sasi's institutional logic—authority structures, sanctioning systems, temporal rules—they are not direct evidence for mangrove ecosystems, which involve different ecological dynamics and tenure arrangements. We therefore treat marine Sasi literature as providing institutional analogies rather than direct evidence. Regarding ecological outcome data, only Purba et al. (2025) include a quantitative assessment; most studies describe rules and social functions without measuring ecological impacts. Consequently, claims about biodiversity outcomes of Sasi are theoretically grounded expectations rather than empirically demonstrated outcomes.

Supporting theoretical literature

The third group comprises foundational works on shared resource governance (Ostrom 1990), legal pluralism, adaptive governance, and hybrid governance models. This literature serves as the theoretical lens for regulatory gap analysis and Temporal-Spatial Bridge (TSB) model design, providing conceptual tools for diagnosing institutional tensions and designing bridging mechanisms between customary and state systems.

Data collection and analysis procedure

Data collection and analysis followed a structured phased process encompassing document identification, systematic coding, and iterative interpretation. The first stage involved the identification and selection of documents from both corpora. For the national policy corpus (20 documents comprising 7 core regulations and 13 supporting instruments), key regulations were identified based on legal hierarchy and substantive relevance to mangrove management, coastal governance, and customary recognition. For the Sasi customary law corpus, systematic searches were conducted in Scopus and Google Scholar using keywords "Sasi Maluku," "Sasi mangrove," and "*kewang*" with a 31-year publication window (1994-2025) to capture both contemporary practices and historical dynamics. Priority was given to empirical studies detailing Sasi's operational rules, enforcement mechanisms, and institutional roles.

The second stage employed Qualitative Content Analysis with Thematic Coding following established protocols (Hsieh and Shannon 2005; Elo and Kyngäs 2008). Coding was performed by the lead author and an independent coder using NVivo 12 software. After independently coding a subset of documents to develop a common understanding and resolve initial discrepancies, they proceeded to code the entire corpus. To ensure reliability, inter-coder agreement was assessed on randomly selected 20% of documents (9 of 45), showing 87% agreement (Cohen's $\kappa = 0.82$), with remaining differences resolved through consensus discussion. This rigorous approach minimized individual bias while maintaining interpretive richness.

Analysis proceeded through three iterative phases. In the Deductive Coding Phase, an initial framework was developed from research questions, generating four main categories: (C1) Sources of Legitimacy & Authority; (C2) Management and Rules Paradigm; (C3) Enforcement & Sanctions System; and (C4) Management Objectives & Benefit Streams. The coding process remained open to inductive emergence of sub-categories, allowing unexpected patterns to surface and mitigating confirmation bias. In the Organization Phase, entire texts were systematically encoded through open coding and matrix creation, with collected codes synthesized to identify core principles and norms in each system. These were organized into a "Comparative Analytical Matrix" (Table 1) with columns for Core Principles, Interaction Diagnosis, and Implications for Integration. In the Interpretation and Model Synthesis Phase, this matrix was analyzed to identify patterns of congruence, tension, and complementary potentials between the two governance systems. This diagnostic process provided the empirical foundation for designing the Temporal-Spatial Bridge Model through iterative linking of data findings with theoretical insights on adaptive governance, legal pluralism, and institutional design (Erlingsson and Brysiewicz 2017).

RESULTS AND DISCUSSION

Normative mapping: The philosophical and operational foundations of Sasi

Synthesis of ethnographic literature reveals Sasi as a holistic resource management framework resting on four interconnected pillars. While we present a synthesized framework, Sasi practices exhibit significant diversity across Maluku in ritualization, target species, sanction strength, gender roles, and erosion degrees.

First pillar: Temporal moratoriums based on local ecological knowledge. Sasi *tutup* implements species-specific harvest bans aligned with biological cycles and cultural calendars, serving as a preventive sustainability mechanism. For mangrove ecosystems, Sasi *tutup* regulates harvest of mangrove crabs (*S. serrata*) during spawning and molting periods in Buano Island, where closures align with peak reproductive cycles (Salampessy et al. 2024). Some villages also impose seasonal restrictions on mangrove timber collection, allowing regenerating stands to recover.

Second pillar: Socio-culturally legitimized authority (*kewang*). Customary *kewang* derive authority from ancestral mandate and community recognition, supported by high

social capital. Their surveillance areas have clear geographical boundaries. In mangrove contexts, *kewang* monitor compliance, patrol forests, and report violations. In Buano, they conduct regular patrols and confiscate illegally harvested crabs or timber (Salampessy et al. 2024)—a critical function given mangrove ecosystems' accessibility and vulnerability to encroachment.

Third pillar: Tiered, contextual sanction system. Violations face proportionate sanctions including fines, confiscation, or social exclusion, with decisions balancing enforcement and social cohesion. Mangrove-related sanctions include fines in kind, confiscation, and temporary social exclusion—designed not only to punish but to restore social harmony, distinguishing customary from state enforcement (Salampessy et al. 2024).

Fourth pillar: Sustainable livelihood security orientation. Sasi ensures sustainable harvesting, supporting local food security, economy, and culture, integrating conservation with livelihood imperatives. In mangrove communities, crabs, fish, and timber are essential for subsistence and markets. Communities report larger harvests during opening periods, supporting household consumption and income (Salampessy et al. 2024).

National policy architecture: Universal, spatial, and state-centric logic

Analysis of national regulations reveals four dominant characteristics.

Static spatial zoning dominance

Conservation management divides landscapes into fixed zones: core, utilization, and rehabilitation. This approach protects ecosystem services but lacks temporal dynamics. Mangrove zoning designates permanent protected areas without seasonal closures tied to species' life cycles.

State-centric authority

Regulatory authority resides with state actors—ministries, local governments, and implementing units. Legitimacy flows vertically from constitutions and laws, not community recognition, marginalizing local roles. Some laws (e.g., Village Law No. 6/2014) create limited space for community-based management, but these remain exceptions.

Standardized formal legal sanctions

Enforcement relies on uniform criminal/administrative sanctions with limited social context consideration. This rigidity triggers local resistance, manifesting as conflicts where communities view state sanctions as illegitimate compared to customary rules (Thorburn 2000; Satria and Mony 2019).

Global biodiversity protection narrative

Policies emphasize biodiversity, ecosystem functioning, and carbon stocks aligned with international commitments (Purnomo et al. 2020). Global benefits often do not directly reach communities bearing opportunity costs, though implementation varies across ministries.

Gap analysis: Diagnosing conflict, confluence, and complementarity

The comparative analysis in Table 1 reveals complex relationships characterized by structural legitimacy conflicts and operational complementarity.

The root tension lies in legitimacy sources: socio-cultural *kewang* versus legal-formal state. Without mutual recognition, interaction creates governance vacuums exploitable by external actors (Thorburn 2000; Angga et al. 2024).

Table 1. Normative gap analysis results: Sasi vs. national mangrove policy

Categories analysis	Core principles in Sasi system	Core principles in national policy	Diagnosis of interactions	Implications for integration
Sources of legitimacy & authority	Community-based authority (k*ewang*). Sources: ancestral customs, community recognition. Socio-cultural	State-centered (MoEF, Regional Government). Sources: constitutions and laws. Legal-rational	Structural conflict. No mutual recognition. *Kewang* considered "non-formal" in state framework	Legal interface recognizing k*ewang* as managing partners
Management paradigm & rules	Time-based, species-specific (Sasi *tutup*). Dynamic, biocyclically oriented	Space-based zoning, static, fixed rules	Operational complementarity. Static zoning lacks temporal closure mechanism	Hybridization: Embed Sasi *tutup* into utilization zone as "temporal management unit."
Enforcement & sanctions system	Tiered social sanctions. Customary fines, confiscation. Fast, maintains cohesion	Standardized formal legal sanctions. Slow, expensive, damages relationships	Conflict and complementarity. Customary system fills formal system's weaknesses	Hybrid enforcement: Minor violations by *kewang*, serious offenses escalated to state
Management objectives & benefit stream	Sustainable local livelihood security. Direct community benefits	Biodiversity protection, global benefits (carbon, coastal protection)	Congruence in sustainability goal, conflict in benefit flow	Localized benefit-sharing: Channel global benefits to communities

However, operational synergies exist. Sasi's temporal approach fills the spatial zoning's void. For mangrove crabs, Sasi *tutup* during spawning complements permanent spatial protection—a dimension absent from static zoning (Salampessy et al. 2024; Novato et al. 2025). Daily monitoring capacity can be combined with the state coercive authority. Effective integration requires careful institutional engineering that bridges different logics.

Discussion

Interpreting the gap and placing the TSB model in theoretical discourse

The gap analysis confirms that inconsistencies between Sasi and national policy reflect deeper governance logic clashes rather than simple formal/informal dichotomies (Cleaver and Whaley 2018). States operate on universalism, standardization, and centralized control—necessary for large-scale coherence but rigid regarding local variations. Sasi operates on particularism, contextualism, and local adaptation—allowing flexibility but lacking capacity for external pressures. This clash creates institutional voids where state rules seem distant, while customary rules lose "legal teeth" against external interests (Angga et al. 2024). Consequently, mangrove ecosystems exist in "limbo"—neither under effective state control nor fully protected by customs—increasing degradation vulnerability.

This diagnosis, grounded in gap analysis (Table 1), informs our institutional bridging strategy. The key insight is that the temporal logic of Sasi and the spatial logic of state policy address different sustainability dimensions. The challenge lies in designing an architecture allowing synergistic function. However, this requires understanding Sasi as a historically dynamic system. Zerner (1994) documents Sasi's continuous reinterpretation over a century, by Dutch colonial officials codifying *adatrecht*, post-independence state authorities, and NGOs framing it as "customary environmental law." This trajectory reveals that Sasi's resilience lies in absorbing changing contexts—a quality Bubandt (2005) conceptualizes as "imagined tradition" reinvented through interactions between communities, church, and state.

This historical perspective carries profound implications. First, integrating Sasi into national policy means engaging with a living, adaptive system shaped by external forces. Second, non-recognition of *kewang* authority reflects a deeper historical pattern: state ambivalence toward customary institutions. Third, hybrid arrangements are not unprecedented impositions but a continuation of Sasi's long adaptation history. The challenge is designing institutional interfaces allowing adaptive capacity within national policy—avoiding both colonial co-optation and post-independence marginalization.

While Sasi represents sophisticated governance, we acknowledge its limitations: elite capture, gender exclusion, erosion under modernization, and intra-community conflict. Zerner's (1994) cautionary note is salient: NGO "invention" of customary law sometimes imposed external expectations misaligned with local realities. Conversely, state law offers legal certainty and enforcement for large-scale threats but can be socially alienating. The Temporal-Spatial Bridge Model seeks complementarity through safeguards, including transparent benefit-sharing. Our stance is pro-hybrid, but integration must be critically aware of these risks—treating Sasi as a living institution whose evolution will be shaped by integration processes.

Responding to gaps: Introducing the Temporal-Spatial Bridge (TSB model)

Based on gap analysis identifying complementary spaces—particularly in temporal versus spatial paradigms and enforcement—this study formulates the "Temporal-Spatial Bridge model" (TSB). We present TSB as a conceptual hypothesis requiring empirical testing, not a ready-to-implement framework. It offers design principles that need contextual adaptation and legal feasibility assessment before implementation. The core logic embeds Sasi's time-based dynamics into national spatial frameworks, creating hybrid governance with dual legitimacy through four interrelated components forming an adaptive governance cycle.

The TSB Model assumes functional and socially legitimate *kewang* institutions. In contexts where these institutions have experienced erosion, revitalization of customary governance may need to precede integration—elaborated in Implementation Challenges. This conditional premise underscores that the model's viability depends on local institutional capacity, requiring careful diagnostic assessment before any pilot implementation. Without functioning customary authorities, the nested rules and tiered enforcement mechanisms cannot operate as designed. Conversely, where *kewang* institutions remain strong, the TSB model offers a pathway to amplify their effectiveness by connecting customary authority with state legal backing and broader resource flows.

First, Mutual Legal Recognition through Collaborative Instruments with Hierarchical Alignment. This initial step establishes a legal interface through Cooperation Agreements between local governments with village governments and *kewang* institutions. Alternatively, Joint Village Regulations or Special Regional Regulations formally recognize *kewang* as co-management partners. Crucially, these instruments must align with Indonesia's legal hierarchy—referencing National Spatial Plan, Provincial Spatial Plans, Government Regulation No. 27/2025 on Mangrove Ecosystem Management, and relevant technical guidelines. This vertical harmonization ensures formal legitimacy while avoiding conflicts with existing zoning.

Second, Integration of Nesting Rules: Creating Temporal Management Units with Spatial Harmony. In recognized cooperative areas, Sasi *tutup* provisions become legally binding local regulations. A national "Utilization Zone" transforms into a "Temporal Management Unit (TMU)" where national spatial rules remain, supplemented by Sasi temporal rules governing harvest timing. This embodies Ostrom's (1990) nested rules principle while ensuring TMUs align with broader Regional Spatial Planning and Coastal Zone Zoning Plans. For mangrove ecosystems, utilization zones could incorporate Sasi *tutup* periods for crab harvest, adding temporal protection—addressing static zoning's lack of life-cycle specificity identified in Table 1.

Third, Hybrid and Polycentric Law Enforcement. A tiered enforcement system is formed where *kewang* serve as frontline enforcers for everyday and minor offenses within the TMU, imposing agreed customary sanctions. For serious, organized, or criminal offenses involving outsiders, *kewang* have a formal channel to escalate cases to state authorities. This system combines customary enforcement's speed and contextuality with state law's coercive capacity. Customary sanctions effectively handle everyday violations but lack teeth against external commercial interests, while state enforcement is powerful but slow and socially alienating. The proposed escalation ladder combines their strengths.

Fourth, Adaptive Monitoring and Localized Benefit-Sharing. *Kewang* and the community conduct participatory monitoring of ecological indicators; this data is institutionalized as local ecological knowledge for adaptive management. Benefit-sharing mechanisms are proposed as illustrative examples requiring context-specific feasibility studies. Blue carbon revenue could allocate verified carbon credits to community-managed funds for conservation activities, as piloted in REDD+ and PES schemes globally (Bernard and Minang 2019; Hernández-Blanco et al. 2022). Sustainability certification for Sasi-managed fisheries could generate premium prices supporting community stewardship. Ecotourism revenue sharing and PES have documented analogs in co-management literature (Sahputra et al. 2021). We intentionally avoid specifying percentages—appropriate ratios depend on local context, resource values, and negotiation processes. All mechanisms require careful design to avoid elite capture, ensure transparency, and maintain community trust (Coolsaet et al. 2020). The four pillars of the TSB model are illustrated schematically in Figure 1.

Legal-institutional feasibility of the TSB model in Indonesia's governance context

TSB implementation requires navigating Indonesia's complex legal hierarchy: constitutional basis in Article 18 of 1945 Constitution recognizing customary law communities; spatial planning integration requiring TMU inclusion in Regional Spatial Plans through revisions or special provisions (Government Regulation No. 21/2021); ministry coordination so Environment and Forestry and KKP regulations accommodate TMUs through joint decisions or technical guidelines; and financial mechanism legality ensuring benefit-sharing schemes comply with relevant regulations (Government Regulation No. 46/2017).

We reiterate TSB as a conceptual hypothesis, not a fully vetted legal framework. Mentioned instruments are potential pathways requiring detailed legal analysis, stakeholder consultation, and pilot testing. Analysis of conflicts with budgeting rules, carbon-accounting frameworks, or inter-ministerial coordination is beyond this paper's scope—critical future research. Maluku pilot projects could provide an empirical basis for refining the model and assessing feasibility.

Implications of the TSB model for mangrove biodiversity conservation

Building directly on gap analysis findings and proposed TSB architecture, we explore potential implications as theoretical hypotheses requiring future research and pilot implementation.

First, Potential for Increasing Target Species Population Resilience through Life Cycle Protection. By legally securing Sasi *tutup* periods through TMUs, ecologically valuable species like mangrove crabs (*S. serrata*) could receive guaranteed protection during critical life phases such as spawning, molting, and juvenile rearing. Theoretically, this time-based protection could contribute to increasing population viability and preserving genetic structure from size or season-focused overexploitation—a dynamic well-documented in fisheries management where continuous harvest during reproductive windows leads to recruitment failure. This expectation is grounded in studies showing that traditional management supports demographic sustainability (Fraser et al. 2006; Novato et al. 2025). For mangrove ecosystems specifically, protecting gravid female crabs during spawning migrations could enhance larval export to adjacent areas, potentially benefiting fisheries beyond TMU boundaries. Empirical testing through before-after-control-impact designs would be needed to confirm outcomes across different mangrove sites and species.

Second, Potential for High-Resolution, Low-Cost Biodiversity Monitoring Systems. *Kewang* patrol networks represent dispersed, low-cost, responsive human ecological monitoring assets that government agencies could never replicate at similar scales. Operating daily across their customary territories, *kewang* detect subtle local changes—invasive species emergence, disease outbreaks, abnormal sedimentation, illegal encroachment—far faster than periodic government surveys. This capability aligns with calls for "smart" conservation infrastructure that combines local observation with technological tools. Integrating daily observations into formal reporting systems could create ecological early-warning networks enabling timely preventive conservation (Antonelli et al. 2022). Realizing this potential requires investment in training, standardized protocols, and institutional linkages that validate and transmit *kewang* observations to management authorities without undermining their customary authority.

Third, Ethnobiology Instrumentation in Policy Frameworks. This study demonstrates a concrete pathway for ethnobiology's shift from descriptive-academic role to functional policy instrumentation. Rather than treating Sasi as an object of exotic cultural study, the TSB framework positions it as a living operational system of ecological regulation and data collection—enriching conventional conservation toolkits with time-tested wisdom (Berkes et al. 2000; Picauly et al. 2022). This instrumentation has reciprocal benefits: national policy gains locally-adapted management rules and monitoring capacity, while customary institutions gain formal recognition and access to resources that support their continuity. The challenge lies in ensuring this instrumentation does not co-opt or distort customary practices, but rather creates space for their continued evolution.

Fourth, Towards a Scalable and Adaptable Framework—A Research Agenda. TSB principles could inform integration for other customary systems across Indonesia's archipelago, but this remains a hypothesis requiring systematic comparative research. Systems like *Awig-awig* in Lombok's coastal communities, *Tana' Ulen* in Kalimantan's forest territories, and *Panglima Laot* in Aceh's fisheries operate under different institutional logics, ecological contexts, and legal histories. Future comparative studies could explore which TSB components transfer readily, which require contextual adaptation, and what factors enable or constrain hybrid governance success. Such research would contribute not only to Indonesian policy but to global scholarship on legal pluralism and adaptive co-management.

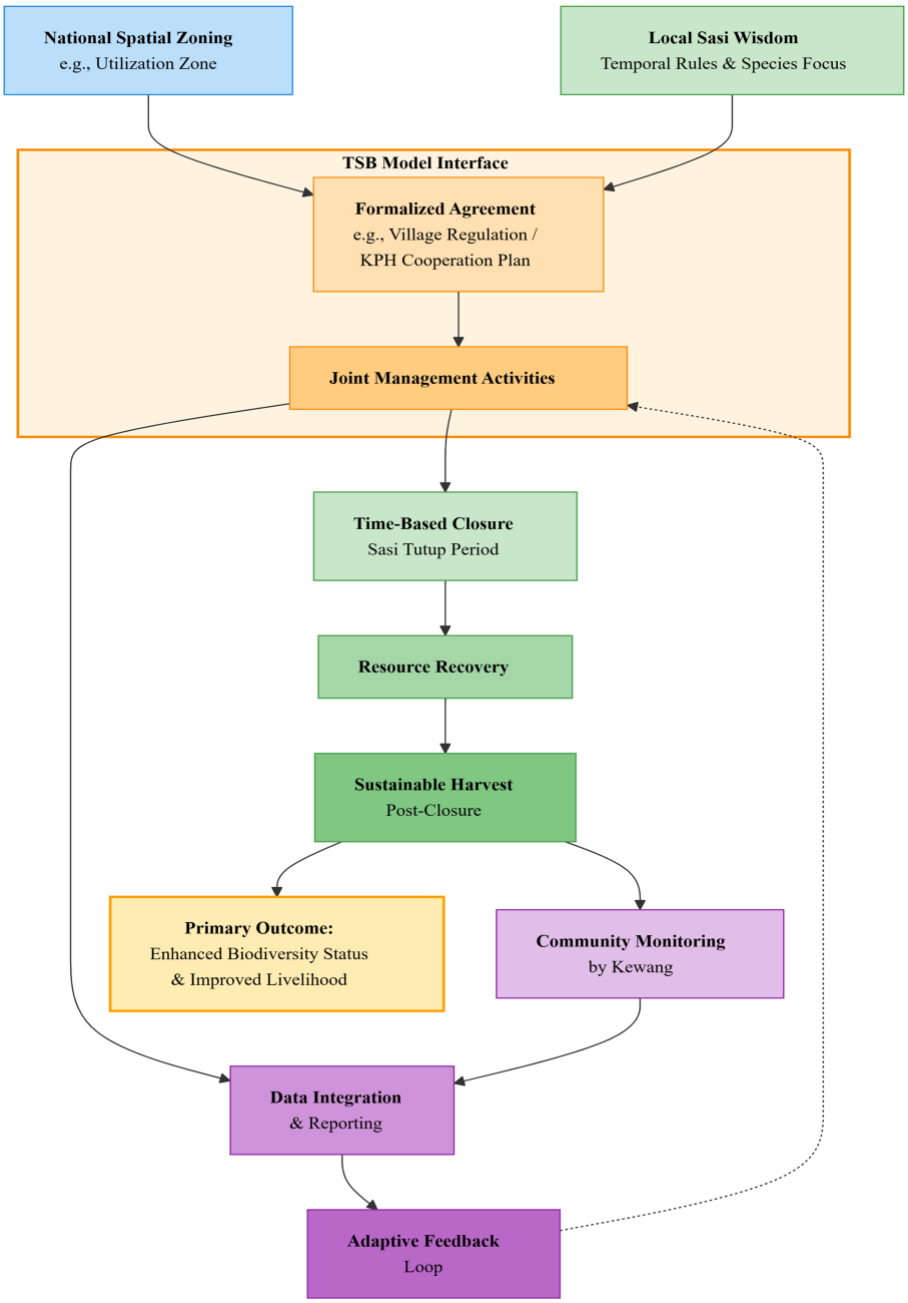

Figure 1. Temporal-Spatial Bridge (TSB) hybrid model of mangrove management. Four-pillar architecture: (i) Legal recognition establishes cooperation between state and customary institutions, (ii) Nested rules integrate temporal closures into spatial zoning as Temporal Management Units, (iii) Tiered enforcement creates an escalation ladder from customary to state sanctions, (iv) Adaptive monitoring and benefit-sharing channels global benefits to communities while incorporating LEK. Arrows indicate adaptive management feedback loops. The conceptual hypothesis requires empirical testing; assumptions—functional *kewang* and political will—are context-dependent

Implementation challenges and success prerequisites

Successful TSB implementation depends on critical prerequisites across multiple levels. These challenges must be addressed before moving from concept to practice, and failure at any level could undermine the entire enterprise.

At the government level, real political will and significant bureaucratic adaptation are needed. Local governments and management units (BKSDAs, FMUs) must share authority, adopt participatory planning processes, and recognize decision-makers outside formal administrative structures. This requires moving beyond rhetorical commitments to "community participation" toward genuine power-sharing arrangements that may feel threatening to agencies accustomed to centralized control. Without sustained commitment, the model languishes as a ceremonial Memorandum of Understanding with no operational impact (Segger and Khalfan 2004). Experience from Valentine Strait, West Seram, shows community participation becomes effective precisely when *kewang* receive formal roles in mangrove rehabilitation schemes (Aipassa et al. 2024). Conversely, where recognition remains absent, interactions between customary systems and state agencies create governance vacuums exploitable by external commercial interests (Massiri et al. 2025; Zulfiani et al. 2025).

At the community level, the model assumes functional, legitimate *kewang* institutions—a conditional premise that cannot be taken for granted. In communities where customary governance has experienced erosion due to modernization, out-migration, or past development interventions, revitalization programs may need to precede any integration effort. Even where institutions remain strong, transparency and fairness in benefit-sharing mechanisms are absolutely critical. If benefits flow disproportionately to village elites or are distributed through non-transparent processes, the model may trigger intra-community conflict and undermine the social cohesion that makes customary enforcement effective (Bernard and Minang 2019; Coolsaet et al. 2020). Studies from Jaring Halus Village, North Sumatra, confirm that mangrove management sustainability depends critically on integrating local regulations with government programs and, crucially, on providing equitable economic incentives that communities perceive as fair (Sahputra et al. 2021).

Broader context: Learning from other contexts reinforces these lessons. Maybrat District, West Papua, underscores that traditional knowledge provides the indispensable foundation for legitimate resource governance (Sagrim 2022). Limpopo Province, South Africa, demonstrates that local knowledge-based management achieves effectiveness precisely because it is embedded in community practices and social norms, not imposed through external regulations (Rasethe et al. 2022). The Swedish case of Nämdö Archipelago offers cautionary evidence: rigid National Park procedures fostered local mistrust and resistance, while flexible Biosphere Reserve governance that respected local knowledge strengthened both legitimacy and conservation outcomes (Westerberg et al. 2025). A systematic review of Riau's customary forest governance similarly concludes that formal legal recognition of customary territories must be accompanied by substantive integration of customary institutions into state planning and enforcement mechanisms, otherwise hybrid governance remains merely symbolic (Suwarno et al. 2026). Collectively, these lessons reinforce that local ecological knowledge should constitute the core of hybrid governance systems, not serve as an exotic complement (Fatharini et al. 2024; Haq et al. 2025; Purba et al. 2025). They also underscore that successful integration requires institutional designs capable of navigating tensions between state universality and community particularism—precisely the challenge the TSB Model seeks to address.

In conclusion, this study confirms that the gap between the Sasi system and national mangrove policy is fundamental, reflecting a clash between the logic of state universality and the logic of community contextuality. Systematic normative analysis successfully mapped the main sources of tension, particularly the non-recognition of *kewang* institutions' legitimacy and the temporal versus spatial management paradigm, while identifying opportunities for synergy in participatory monitoring and social sanction enforcement. In response, the study proposes the Temporal-Spatial Bridge (TSB) Model, an innovative hybrid governance blueprint that creates a legal interface to accommodate *kewang* authority and transforms Sasi's temporal logic into a legitimate Temporal Management Unit within the state's spatial framework. Three strategic actions are recommended: (i) initiating a collaborative pilot project in Maluku through a Cooperation Agreement recognizing *kewang* as management partners, (ii) preparing a supporting regulatory framework by the Ministry of Environment and Forestry governing recognition of the Temporal Management Unit and equitable benefit-sharing, and (iii) investing in long-term capacity building and periodic dialogue platforms. The TSB Model is presented as a conceptual hypothesis requiring empirical testing, not a ready-to-implement policy framework, with its value lying in framing the right questions and suggesting design principles for hybrid governance that can be empirically investigated and progressively improved through context-specific engagement.

ACKNOWLEDGEMENTS

We extend our sincere gratitude to the Faculty of Forestry and Science, Universitas Lancang Kuning, Indonesia, for the financial contribution provided to support this research. This contribution was formally granted through the legal basis of Decree Number 225.A/Fahutsains/Pen/V/2025.

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