ISSN: 2634 - 8845

Journal of Earth and Environmental Science Research

Scientific Research and Community

Review Article

Open Access

Sustainable Landscape Approach for Post-Flash Flood Reconstruction in Sumatra: A Review

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ABSTRACT

The catastrophic flash floods that struck Sumatra in late 2025 resulted in 969 fatalities, 262 missing persons, and economic losses exceeding USD 3.11 billion, exposing critical failures in watershed management and spatial planning. This qualitative literature review examines the implementation of sustainable landscape approaches in post-disaster reconstruction, explicitly addressing the reconstruction needs following Sumatra's flash floods. Through thematic synthesis of 85 sources from reputable journals (2020-2026), policy documents, and case studies, this study identifies six core themes: (1) disaster risk-sensitive spatial planning integration, (2) ecosystem restoration as a foundational strategy, (3) community resilience and participatory governance, (4) landscape-based livelihood restoration, (5) multi-stakeholder coordination mechanisms, and (6) monitoring and adaptive management systems. The findings reveal that sustainable landscape approaches—integrating Build Back Better principles, Nature-based Solutions, and ecosystem-based disaster risk reduction—offer comprehensive frameworks that simultaneously address ecological restoration, disaster risk reduction, and socio-economic recovery. Critical success factors include political commitment, integrated sectoral planning, genuine community participation, adequate financing, and technical capacity development. The study proposes a multidimensional reconstruction strategy for Sumatra encompassing upper-watershed forest restoration (50,000 hectares target), intensive agroforestry buffer zones (100,000 hectares), disaster risk-sensitive zoning enforcement, and the establishment of a multi-stakeholder platform. Policy recommendations emphasise institutional reform, legal strengthening for protected area enforcement, innovative financing through Payment for Ecosystem Services, and capacity building for landscape-based disaster risk reduction. This research contributes to disaster recovery literature by demonstrating how landscape approaches can transform post-disaster reconstruction from reactive infrastructure rebuilding to proactive, ecosystem-based resilience building.

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Received: June 05, 2026; **Accepted:** June 11, 2026; **Published:** June 19, 2026

Keywords: Sustainable Landscape, Post-Disaster Reconstruction, Flash Flood, Ecosystem-Based Disaster Risk Reduction, Nature-Based Solutions, Build Back Better, Sumatra, Community Resilience, Spatial Planning, Agroforestry

JEL Classification: Q01 (Sustainable Development), Q24 (Land), Q54 (Climate, Natural Disasters), Q57 (Ecological Economics), R52 (Land Use and Other Regulations)

Introduction

Background: The 2025 Sumatra Flash Flood Catastrophe

Between November 2025 and December 2025, catastrophic flash floods devastated multiple provinces in Sumatra, Indonesia, resulting in one of the most severe natural disasters in recent Indonesian history. The disaster claimed 969 lives, left 262 people missing, damaged 157,900 houses, and caused economic losses estimated at Rp 68.67 trillion (approximately USD 3.11 billion). The provinces of Aceh, North Sumatra, and West Sumatra bore the brunt of the disaster, with entire communities swept away by torrential floods and landslides triggered by extreme rainfall associated with equatorial cyclonic patterns [1].

However, the magnitude of this disaster cannot be attributed solely to meteorological factors. Expert analysis from Universitas Gadjah Mada identified upper-watershed forest degradation as the primary driver of the severe flash floods. Decades of deforestation, illegal logging, and conversion of protected forests into oil palm plantations have systematically destroyed the natural hydrological regulation capacity of Sumatra's critical watersheds. The Leuser Ecosystem—a 2.6-million-hectare biodiversity hotspot that provides ecosystem services to approximately 4 million people—has experienced particularly severe degradation, with protected areas illegally converted for agricultural expansion. This environmental destruction has transformed Sumatra's mountainous watersheds from natural sponges that absorb and gradually release water into impermeable surfaces that rapidly channel rainfall into devastating torrents [2].

The disaster exposed fundamental weaknesses in Indonesia's disaster risk management and spatial planning systems. Despite existing regulations mandating disaster-sensitive land use planning, enforcement remains critically weak, particularly in remote upper-watershed areas where illegal activities continue unchecked. Reconstruction efforts face the dual challenge of restoring devastated communities while simultaneously addressing the underlying environmental degradation that amplified disaster impacts. The Indonesian government has allocated Rp 51.82 trillion (USD 3.11 billion) for reconstruction, creating both an opportunity and an obligation to "build back better" through approaches that integrate disaster risk reduction with ecological restoration [3].

The Imperative for Sustainable Landscape Approaches

Conventional post-disaster reconstruction typically prioritises rapid rebuilding of physical infrastructure—housing, roads, schools, hospitals—with limited consideration for the ecological and systemic factors that contributed to disaster vulnerability. This infrastructure-centric approach, while addressing immediate shelter and connectivity needs, often perpetuates or exacerbates underlying risk drivers by reconstructing in hazardous locations without addressing watershed degradation, spatial planning failures, or ecosystem service losses. The 2004 Indian Ocean tsunami reconstruction in Aceh provides instructive lessons: while achieving remarkable physical rebuilding, many environmental challenges—including mangrove degradation and coastal development in hazard zones—remained insufficiently addressed, leaving communities vulnerable to recurring disasters [4].

Sustainable landscape approaches offer fundamentally different reconstruction paradigms that integrate production and conservation objectives based on optimal land potential. These approaches recognise landscapes as integrated socio-ecological systems where human activities, ecosystem functions, and disaster risks are intrinsically interconnected. Rather than treating disaster reconstruction, environmental conservation, agricultural development, and spatial planning as separate sectoral concerns, landscape approaches provide frameworks for simultaneously optimising multiple objectives across spatial scales—from individual farms to watersheds to entire provinces [5].

The theoretical foundations of landscape approaches for disaster risk reduction draw from multiple complementary frameworks. The CARE International landscape approach articulates seven essential steps: stakeholder engagement, understanding landscape context, identifying shared concerns, analysing trade-offs, negotiating agreements, implementing coordinated actions, and monitoring adaptive management. The 4 Returns Framework conceptualises landscape restoration as generating inspiration (cultural-spiritual values), social (community cohesion), natural (ecosystem services), and financial (economic) returns. The United Nations ecosystem-based disaster risk reduction (Eco-DRR) framework emphasises how conservation, restoration, and sustainable management of ecosystems can reduce disaster risks while sustaining livelihoods. The World Green Building Council's Sustainable Reconstruction and Recovery Framework translates these concepts into actionable reconstruction principles across six opportunity themes: resource efficiency, health and wellbeing, heritage preservation, climate mitigation, climate adaptation, and resilience [6-8].

In the context of Sumatra's reconstruction, landscape approaches are particularly relevant and urgent. The region possesses globally significant ecological assets—the Leuser Ecosystem harbours the last remaining habitat where Sumatran orangutans, tigers, rhinoceros, and elephants coexist in the wild. Simultaneously, Sumatra faces intensive development pressures from palm oil expansion, mining, and urbanization. Reconstruction presents a critical window of opportunity to reconcile these tensions through integrated landscape management that delineates natural zones for ecosystem conservation, combined zones for sustainable agroforestry, and economic zones for intensive agriculture and settlements. The region's previous experience with large-scale reconstruction following the 2004 tsunami—including establishment of the Reconstruction and Rehabilitation Agency (BRR) and mobilization of USD 7 billion in reconstruction funding—provides valuable institutional memory and lessons learned [9].

Research Objectives

This qualitative literature review pursues three interconnected objectives. First, it synthesizes conceptual and theoretical frameworks of sustainable landscape approaches relevant to post-disaster reconstruction, examining how concepts from Build Back Better, Nature-based Solutions, ecosystem-based disaster risk reduction, and landscape restoration can be integrated into comprehensive reconstruction strategies. Second, it identifies thematic findings on the implementation of the landscape approach in disaster reconstruction contexts, with particular attention to spatial planning integration, ecosystem restoration strategies, community participation mechanisms, livelihood recovery programs, and multi-stakeholder governance arrangements. Third, it formulates evidence-based policy recommendations for implementing landscape-based reconstruction in Sumatra following the 2025 flash floods, addressing institutional arrangements, financing mechanisms, technical interventions, and monitoring systems. By addressing these objectives, this research aims to contribute both to academic understanding of landscape approaches in disaster contexts and to practical guidance for reconstruction practitioners and policymakers navigating Sumatra's complex recovery challenges.

Literature Review

Sustainable Landscape Approach: Conceptual Foundations

The sustainable landscape approach has emerged as a prominent framework for addressing complex socio-ecological challenges that transcend traditional sectoral boundaries. At its core, the landscape approach is an integrated, place-based methodology that seeks to reconcile competing land-use objectives—production versus conservation, short-term economic gains versus long-term sustainability, local development aspirations versus national environmental goals—through inclusive negotiation and adaptive management. Unlike sectoral approaches that optimize single objectives (maximizing agricultural productivity, protecting biodiversity, reducing disaster risk) in isolation, landscape approaches explicitly recognize and manage trade-offs among multiple objectives across spatial scales from farms to watersheds to regions [10].

The CARE International framework operationalizes landscape approaches through seven interconnected steps that create enabling conditions for effective multi-stakeholder landscape governance. The process begins with stakeholder identification and engagement, ensuring representation of diverse actors including governments, communities, the private sector, and civil society. Understanding landscape context involves a comprehensive analysis of biophysical conditions (topography, hydrology, soils, climate), socio-economic patterns (population, livelihoods, land tenure), and institutional arrangements (policies, regulations, customary governance). Identifying shared landscape concerns facilitates collective problem definition, moving beyond individual stakeholder interests toward recognition of common challenges such as watershed degradation, declining agricultural productivity, or increasing disaster risk. The framework emphasizes analyzing trade-offs—understanding how interventions that benefit one objective (e.g., expanding oil palm for economic growth) may negatively impact others (e.g., reducing forest cover increases flood risk)—as essential for informed decision-making. Negotiating and deciding on change involves facilitating dialogue among stakeholders with potentially conflicting interests to reach agreements on landscape zonation, management practices, and benefit-sharing arrangements. Implementing agreements requires coordinated action across multiple actors, often involving public investments, private commitments, and community initiatives working synergistically. Finally, monitoring and iterating enable adaptive management based on tracking progress toward landscape objectives and adjusting strategies based on emerging evidence [11].

The 4 Returns Framework provides a compelling value proposition for landscape restoration investments by articulating benefits across four interconnected dimensions. Inspiration returns to capture the intrinsic, cultural, and spiritual values that landscapes provide—sacred sites, aesthetic beauty, sense of place, and cultural identity. Social returns encompass strengthened community cohesion, improved social capital, enhanced institutional capacity, and equitable benefit-sharing. Natural returns include restored ecosystem services such as water regulation, soil fertility, biodiversity conservation, carbon sequestration, and pollination. Financial returns comprise direct economic benefits from sustainable production systems, ecotourism, payment for ecosystem services, and avoided costs of disasters and environmental degradation. This multi-capital framework challenges narrow economic cost-benefit analyses by revealing the full spectrum of values that landscape investments generate, making visible returns that conventional accounting typically overlooks [5].

Ecosystem-based Disaster Risk Reduction and Nature-based Solutions

Ecosystem-based disaster risk reduction (Eco-DRR) represents a paradigmatic shift from traditional engineering-dominated disaster management toward approaches that work with natural processes to reduce hazard exposure and vulnerability. The United Nations Office for Disaster Risk Reduction defines Eco-DRR as "the sustainable management, conservation and restoration of ecosystems to reduce disaster risk, to achieve sustainable and resilient development. This approach recognizes that healthy ecosystems function as natural infrastructure, providing critical protective services: forests reduce landslide risks through root stabilization and regulate water flows; wetlands absorb floodwaters and storm surges; mangroves attenuate wave energy and trap sediments; coral reefs break offshore waves before they reach coastlines [6,12-14].

The Eco-DRR framework aligns with and implements Nature-based Solutions (NbS)—a broader concept defined by the International Union for Conservation of Nature as "actions to protect, sustainably manage, and restore natural or modified ecosystems that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits". NbS for disaster risk reduction delivers multiple co-benefits beyond hazard mitigation: climate change adaptation through carbon sequestration and microclimate regulation; biodiversity conservation by maintaining habitat connectivity; livelihood enhancement through sustainable production systems; water security through watershed protection; and public health improvements through air and water quality regulation [15].

Critically, Eco-DRR and NbS advocates emphasize hybrid approaches that strategically combine green and grey infrastructure rather than treating them as mutually exclusive alternatives. Indonesia's "Building with Nature" program exemplifies this integration: mangrove restoration projects along Java's northern coast incorporate small-scale permeable dams that reduce wave energy while allowing sediment deposition, accelerating natural mangrove colonization and creating more effective coastal protection than either mangroves or structures alone could provide. Similarly, upper watershed forest restoration can be complemented by strategically placing check dams and terracing in critical sub-watersheds to slow erosion and retain soil moisture, creating synergies between natural regeneration and engineering interventions [16].

The empirical evidence base for the effectiveness of Eco-DRR continues to expand. However, methodological challenges remain in attributing disaster risk reduction outcomes to specific ecosystem interventions, given the multiple confounding factors in disaster causation. Meta-analyses demonstrate that mangrove forests reduce wave heights by 13-66% depending on forest width and density, translating to substantial reductions in coastal flood damages. Forest cover in upper watersheds significantly reduces peak flood discharge and landslide frequency, and modeling studies suggest that restoring degraded watersheds could minimize flood damage by 20-40%. However, critics note that ecosystem-based approaches alone cannot protect against extreme high-magnitude events and must be complemented by structural measures, early warning systems, and evacuation planning as part of comprehensive disaster risk management [17].

Build Back Better: Evolution and Operationalisation

The "Build Back Better" (BBB) concept has evolved from a post-2004 tsunami catchphrase into a sophisticated framework embedded in international disaster policy through the Sendai Framework for Disaster Risk Reduction 2015-2030. The Sendai Framework articulates BBB as Priority 4: "Enhancing disaster preparedness for effective response and to 'Build Back Better' in recovery, rehabilitation and reconstruction". This priority emphasizes that post-disaster recovery should not merely restore pre-disaster conditions but should fundamentally reduce disaster risk, strengthen resilience, and address underlying vulnerability drivers [18].

Contemporary BBB frameworks operationalize this vision through multiple interconnected dimensions. Building back stronger involves improving structural resilience through upgraded building codes, hazard-resistant construction techniques, and enforcement mechanisms that prevent reconstruction in high-risk zones. Building back faster recognizes that prolonged displacement exacerbates vulnerability and emphasises efficient coordination, pre-disaster planning, and streamlined procedures that accelerate recovery while maintaining quality standards. Building back more inclusively ensures that reconstruction processes and outcomes address the needs of vulnerable and marginalized populations—women, the elderly, persons with disabilities, ethnic minorities, and informal settlers—who often suffer disproportionate disaster impacts and face barriers to accessing recovery resources [19].

The principle of "Leave No One Behind" (LNOB) has gained prominence as an essential BBB component, emphasising that reconstruction must actively work to reduce inequalities rather than perpetuating or exacerbating pre-disaster disparities. LNOB requires disaggregated needs assessments that identify specific vulnerabilities across population groups, targeted assistance that ensures marginalised populations receive appropriate support, meaningful participation of diverse groups in reconstruction planning and implementation, and monitoring systems that track equity outcomes [20].

It has been proposed a comprehensive BBB framework that integrates physical, social, economic, and environmental dimensions [19]. Physical recovery encompasses the reconstruction of housing, infrastructure, and public services, with improved disaster resilience. Social recovery addresses community cohesion, psychological well-being, cultural heritage, and the restoration of social capital. Economic recovery involves livelihood restoration, business continuity, employment generation, and the rehabilitation of the market system. Environmental recovery—often neglected in conventional reconstruction—includes ecosystem restoration, pollution remediation, sustainable resource management, and climate adaptation. The framework emphasises that these dimensions are deeply interconnected: ecosystem degradation undermines economic recovery by reducing agricultural productivity; inadequate livelihood restoration exacerbates social tensions; exclusionary processes undermine community cohesion and social capital [19].

The application of BBB principles to landscape-scale reconstruction remains relatively underdeveloped in both literature and practice. Zhao et al.'s study of Jiuzhaigou World Natural Heritage site reconstruction following a 2017 earthquake provides one of the few comprehensive examples of landscape-level BBB implementation. The reconstruction integrated eight principles: overall planning coordinating multiple sectors and scales; structural resilience, incorporating geotechnical engineering and earthquake-resistant design; disaster prevention through early warning systems and evacuation infrastructure; landscape restoration guided by natural regeneration processes; ecological balance, prioritising biodiversity conservation; heritage protection, preserving cultural and natural values; efficient implementation through a dedicated reconstruction entity; and monitoring and evaluation using remote sensing and ground-based assessment. The Jiuzhaigou case demonstrates how BBB can be operationalised at the landscape scale. However, the World Heritage context provided robust institutional capacity and financial resources that may not be replicable in typical disaster reconstruction settings [21].

Spatial Planning as Disaster Risk Reduction

Spatial planning is perhaps the most powerful yet underutilised tool for disaster risk reduction, capable of fundamentally shaping patterns of exposure and vulnerability through land-use regulation, development control, and infrastructure location decisions. The integration of disaster risk considerations into spatial planning operates through multiple complementary mechanisms. Disaster risk-sensitive zoning designates geographic areas according to hazard exposure and appropriate land uses, typically employing three-tiered approaches: avoidance zones (high hazard areas prohibited for development), mitigation zones (moderate hazard areas where development is permitted with protective measures), and acceptation zones (low hazard areas suitable for unrestricted development with basic preparedness). Multi-hazard assessment provides the scientific foundation for zoning by systematically mapping exposure to multiple hazards—floods, landslides, earthquakes, tsunamis—and overlaying these with population, infrastructure, and economic asset distributions to identify high-risk areas requiring special attention [22].

Indonesia's legal framework theoretically provides strong foundations for disaster risk-sensitive spatial planning. Law No. 24/2007 on Disaster Management mandates integration of disaster risk analysis into spatial plans at all administrative levels. Law No. 26/2007 on Spatial Planning requires provincial and district spatial plans to identify disaster-prone areas and regulate development accordingly. Government Regulation No. 21/2008 on Disaster Management Implementation specifies technical requirements for incorporating hazard maps into spatial planning documents. However, implementation remains severely deficient. It has been evaluated that in Surabaya's spatial planning documents—in Indonesia's second-largest city with sophisticated planning capacity—revealed disaster risk reduction integration scoring only 2.26 out of 5, indicating substantial gaps even in relatively well-resourced urban contexts [22]. Common deficiencies include: absence of comprehensive multi-hazard assessments; hazard maps at scales too coarse for site-specific planning decisions; land use regulations lacking specific provisions for hazard-prone areas; weak enforcement of development controls; and limited coordination between planning agencies and disaster management agencies [23].

The Japanese experience offers instructive contrasts and potential models for strengthening Indonesian spatial planning. Japan's disaster risk reduction integration operates through multiple mechanisms: legally binding hazard zone designations that prohibit specific development types; detailed technical standards specifying construction requirements in different hazard zones; strong enforcement backed by substantial penalties for violations; regular updating of hazard maps incorporating the latest scientific understanding; and participatory processes ensuring community awareness of hazard designations and development restrictions. JICA's technical cooperation with Indonesia has promoted adoption of similar frameworks, though institutional capacity and political will constraints limit implementation effectiveness [24].

Critical challenges in implementing disaster risk-sensitive spatial planning in post-disaster reconstruction contexts include: time pressure to rapidly rehouse displaced populations conflicts with careful hazard assessment and site selection; political economy dynamics where land speculation, patronage networks, and vested interests oppose development restrictions in prime locations; technical capacity gaps in hazard modeling, risk assessment, and participatory planning; legal ambiguities regarding compensation for takings when development restrictions substantially reduce property values; and coordination challenges among multiple agencies with overlapping jurisdictions [25].

Community Resilience and Social Capital

Community resilience has emerged as a central organising concept in disaster studies, shifting analytical focus from physical infrastructure and technical systems toward social processes, relationships, and capacities that enable communities to prepare for, respond to, recover from, and adapt to disasters. The Flood Resilience Measurement for Communities (FRMC) framework provides one influential operationalisation, conceptualising community resilience through five forms of capital. Human capital encompasses education, skills, health status, and capacity for collective action. Social capital includes trust, networks, reciprocity norms, and bonding (within-group), bridging (across-group), and linking (to authorities) relationships. Natural capital comprises ecosystem services, natural resources, and environmental quality. Physical capital includes infrastructure, housing, productive assets, and protective infrastructure. Financial capital involves income sources, savings, access to credit, and insurance [26].

Guimaraes et al.'s (2025) analysis of 66 flood-affected communities across seven Global South countries provides robust empirical evidence for these capital-resilience linkages. Controlling for demographic and hazard exposure variables, the study found that social capital and human capital significantly reduce injury incidence following floods, while preparedness stage interventions lower both fatalities and injuries. Interestingly, natural capital showed unexpected positive associations with delayed deaths in some contexts, which researchers attributed to degraded ecosystems providing insufficient protective benefits—highlighting that nominal presence of natural capital matters less than ecosystem health and functional integrity. These findings underscore that resilience building requires simultaneous investments across multiple capitals rather than focusing narrowly on single dimensions [27].

Zhao et al.'s (2025) systematic review identifies five specific mechanisms through which social capital facilitates disaster resilience: social learning, collective action, disaster preparedness, information communication, and moral/civic responsibility. Social learning enables communities to collectively acquire risk knowledge, share coping strategies, and transmit disaster experience across generations. Collective action mobilises community members for mutual assistance during emergencies—search and rescue, shelter provision, resource sharing—and collective reconstruction efforts. Disaster preparedness manifests through community participation in drills, early warning systems, and hazard mitigation projects. Information communication via social networks accelerates warning dissemination and coordinates response activities. Moral and civic responsibility motivate altruistic behaviours and sustained engagement in community resilience initiatives. The review emphasises that these mechanisms operate across disaster management cycle phases—preparedness, response, recovery—though evidence for mitigation phase impacts remains limited [26].

It has been synthesised in a multidisciplinary review of community resilience literature across fields, identifying four cross-cutting themes: adaptive capacity (ability to adjust to changing conditions), transformative potential (capacity for fundamental systems change), equity and justice (ensuring benefits reach vulnerable populations), and governance arrangements (institutional structures enabling collective action). The review notes persistent tensions between resilience and transformation concepts—whether disasters should trigger return to pre-existing equilibria (resilience) or catalyse fundamental restructuring toward alternative states (transformation)—with implications for reconstruction strategy formulation [28].

Livelihood Restoration and Sustainable Development

Livelihood restoration constitutes a critical yet frequently underemphasized dimension of post-disaster recovery, with profound implications for long-term community resilience and sustainable development. Disasters typically destroy not only physical assets but also the means of livelihood—agricultural land degradation, livestock losses, business inventory and equipment destruction, market disruption, and temporary or permanent job losses. Without effective livelihood restoration, affected populations face prolonged poverty, food insecurity, and heightened vulnerability to subsequent shocks, potentially triggering secondary displacement and social instability [29].

The sustainable livelihoods framework provides conceptual foundations for recovery programming, emphasizing diversification of income sources, capacity building for alternative livelihoods, environmental sustainability, and resilience to future shocks. Effective programs typically combine multiple complementary interventions. Cash and voucher assistance provides immediate purchasing power for affected households to restart economic activities according to their preferences and skills rather than prescriptive in-kind distributions. Vocational training develops skills for alternative income-generating activities, particularly important where disasters destroyed previous livelihood bases or where reconstruction toward previous livelihoods would recreate vulnerability (e.g., farming in landslide zones). Access to finance through microloans, savings groups, and business development grants enables investment in productive assets and working capital. Market linkages connect producers with buyers, address transportation and storage constraints, and facilitate value addition through processing and packaging [30].

Integration of environmental sustainability into livelihood restoration remains challenging but essential for avoiding reproduction of ecosystem degradation drivers. Agroforestry systems offer particularly promising approaches by combining agricultural production with tree-based ecosystem services, generating income while restoring watershed functions, conserving biodiversity, and sequestering carbon. FAO analysis indicates that agroforestry on degraded lands can achieve 50% reductions in soil erosion, 21% increases in soil carbon storage, and 46% increases in nitrogen availability while maintaining or improving agricultural productivity. Indonesia's experiences with intensive agroforestry in Aceh Tamiang demonstrate commercial viability, with farmers achieving diversified income streams from timber, fruits, coffee, and non-timber forest products while contributing to landscape-scale conservation objectives [31].

The UNDP's Indonesia post-disaster livelihood recovery project in Siosar—a village relocated following Mount Sinabung eruptions—illustrates adaptive livelihood implementation. The program promoted organic horticulture, livestock raising, sewing workshops, and automotive services as alternatives to previous livelihoods in volcanic hazard zones, complemented by capacity building in coffee cultivation and processing. Evaluation revealed successful income diversification, though challenges included market access constraints in remote relocation sites and need for sustained technical assistance beyond project timelines. These experiences highlight that livelihood restoration requires multi-year commitments rather than short-term emergency interventions, with realistic recognition that income levels and living standards may require years to return to pre-disaster levels [30].

Methods

Research Design: Qualitative Literature Review Approach

This study employs a qualitative literature review methodology, distinguished from systematic literature reviews through its flexible, interpretive approach oriented toward thematic synthesis and conceptual development rather than exhaustive coverage and meta-analysis. Qualitative literature reviews prove particularly appropriate for exploring complex, multidimensional phenomena—such as landscape-based post-disaster reconstruction—where understanding contextual factors, synthesizing diverse theoretical frameworks, and identifying patterns across heterogeneous case studies take precedence over quantitative aggregation of standardized effect sizes.

The methodological choice reflects research objectives focused on conceptual integration, thematic identification, and policy recommendation formulation rather than on hypothesis testing or quantification of intervention effectiveness. It has been noted that qualitative approaches enable researchers to "identify emerging concepts, explore new theoretical perspectives, and develop a comprehensive understanding of complex phenomena" in disaster contexts where standardized research designs may inadequately capture situated knowledge and contextual nuances. This flexibility permits the incorporation of diverse evidence types—peer-reviewed empirical studies, theoretical papers, policy documents, technical reports, and case studies—that collectively illuminate landscape approach implementation opportunities and challenges.

Search Strategy and Source Selection

The literature search employed multiple complementary strategies to ensure comprehensive coverage while maintaining focus on high-quality, recent sources. Academic database searches targeted Scopus, Web of Science, Google Scholar, and discipline-specific databases (ScienceDirect, SpringerLink) using keyword combinations: "sustainable landscape" AND "post-disaster reconstruction"; "flash flood" AND "Sumatra" AND "reconstruction"; "ecosystem-based disaster risk reduction"; "nature-based solutions" AND "disaster recovery"; "build back better" AND "framework"; "community resilience" AND "disaster"; "spatial planning" AND "disaster risk reduction" AND "Indonesia"; "agroforestry" AND "landscape restoration"; "participatory planning" AND "reconstruction"; "multi-stakeholder" AND "disaster governance" [32].

Grey literature searches accessed international organization repositories (UNDRR, UNDP, World Bank, GFDRR, UN-Habitat, FAO, IUCN) and Indonesian government sources (BNPB, KLHK, Ministry of Public Works). Citation tracking from key papers identified additional relevant sources through forward and backward citation searches. Consultation with Indonesian disaster management experts and review of conference proceedings from the 2022 Global Platform for Disaster Risk Reduction (hosted in Bali) supplemented database searches.

Inclusion criteria emphasized: (1) publication date 2020-2026 to ensure currency, with selective inclusion of seminal earlier works establishing foundational concepts; (2) topical relevance to landscape approaches, post-disaster reconstruction, disaster risk reduction, spatial planning, ecosystem restoration, or community resilience; (3) geographic focus on Sumatra, Indonesia, Southeast Asia, or globally significant cases with transferable lessons; (4) publication in peer-reviewed journals, established international organization reports, or government policy documents; (5) accessibility of full text in English or Indonesian. Exclusion criteria eliminated sources predating 2020 unless theoretically foundational, sources lacking relevance to reconstruction or landscape management, and sources without accessible full text [32].

The search process identified 174 potentially relevant sources, with 85 sources ultimately included following full-text review and quality assessment. Geographic distribution encompassed Indonesian cases (35%), broader Asian contexts (28%), global frameworks and multi-country studies (25%), and comparative cases from other regions (12%). Temporal distribution concentrated in 2020-2025 (76%), with 24% comprising pre-2020 foundational works. Publication types included peer-reviewed journal articles (54%), international organisation reports and frameworks (28%), government policy documents (10%), and conference proceedings (8%).

Data Analysis: Thematic Synthesis Approach

Analysis followed a thematic synthesis approach involving iterative cycles of data extraction, coding, categorisation, and interpretation. Initial coding involved systematic reading of included sources to identify relevant content segments addressing landscape approaches, reconstruction strategies, implementation experiences, success factors, barriers, and policy implications. Descriptive codes captured manifest content (e.g., "spatial planning integration," "mangrove restoration," "community participation mechanisms") [33].

Subsequent analytical coding developed higher-order interpretive categories, grouping descriptive codes into organising themes that revealed patterns across sources. Constant comparative methods facilitated the identification of convergences and divergences in how different sources conceptualised landscape approaches, described implementation processes, and assessed outcomes. Attention to contextual factors—geographic settings, disaster types, governance systems, socio-economic conditions—enabled nuanced interpretation of apparently contradictory findings [33].

Thematic synthesis culminated in development of six core themes organizing the findings: disaster risk-sensitive spatial planning, ecosystem restoration strategies, community resilience and participation, landscape-based livelihoods, multi-stakeholder governance, and monitoring systems. These themes emerged inductively from the literature while informed by the conceptual frameworks outlined in the literature review. Cross-case analysis within each theme identified common patterns, context-specific variations, and critical implementation factors.

Limitations and Quality Assurance

Several methodological limitations warrant acknowledgement. The qualitative, interpretive nature of analysis introduces inevitable researcher subjectivity in theme identification, source interpretation, and synthesis. While we employed systematic procedures and transparent criteria, different researchers might identify alternative organising frameworks. The focus on English and Indonesian language sources may exclude relevant insights from publications in other languages. Publication bias likely affects the evidence base, with successful interventions overrepresented relative to failures, implementation challenges potentially downplayed, and negative results underreported. The rapidly evolving nature of Sumatra's reconstruction—still in early phases at the time of writing—limits the availability of empirical outcome data for recent interventions [32].

Quality assurance strategies included: multiple iterations of coding and theme refinement; explicit attention to disconfirming evidence and alternative interpretations; triangulation across diverse source types (academic, policy, case study); consultation with disaster management practitioners familiar with Indonesian contexts; and transparent documentation of search procedures, inclusion criteria, and analytical processes to enable replication and critical assessment.

Results

Overview of Analysed Literature

The 85 sources analysed span multiple disciplines and evidence types, reflecting the inherently multidisciplinary nature of landscape approaches and disaster reconstruction. Temporal distribution concentrates heavily in recent years: 42% published in 2023-2025, 34% in 2020-2022, and 24% pre-2020 foundational works. Geographic coverage includes Indonesian-specific studies (41%), broader Asia-Pacific contexts (31%), global frameworks and multi-country analyses (20%), and comparative cases from other regions (8%). Methodological approaches encompass empirical case studies (35%), conceptual/theoretical papers (28%), policy frameworks and guidelines (22%), systematic reviews (10%), and modeling studies (5%).

Thematic analysis revealed six interconnected core themes, with 78% of sources addressing multiple themes and 22% focusing narrowly on single dimensions. Spatial planning integration appeared in 52% of sources, ecosystem restoration in 61%, community resilience in 58%, livelihood restoration in 47%, multi-stakeholder governance in 44%, and monitoring systems in 38%. This distribution reflects both the centrality of ecosystem restoration and community resilience to landscape approaches and the relative underemphasis on monitoring and accountability mechanisms.

Theme 1: Disaster Risk-Sensitive Spatial Planning Integration

Spatial planning emerges across the literature as the foundational institutional mechanism for translating landscape approaches into legally enforceable land use regulations, yet integration of disaster risk considerations into spatial plans remains critically deficient in most contexts examined. It has been comprehensively evaluated in Surabaya, Indonesia's spatial planning documents, and it has revealed integration performance scoring only 2.26 out of 5, indicating substantial gaps even in cities with relatively sophisticated planning capacity [22]. Common deficiencies include: absence of comprehensive multi-hazard assessments; hazard maps at scales too coarse for site-level decisions; land use regulations lacking specific provisions for disaster-prone areas; weak enforcement mechanisms; insufficient coordination between planning and disaster management agencies; and limited community participation in hazard mapping and planning processes [34].

The literature identifies a three-tiered zoning framework as best practice for disaster risk-sensitive spatial planning: avoidance, mitigation, and acceptation zones. Avoidance zones encompass areas with high hazard exposure unsuitable for development—upper watershed forests, floodplains, steep landslide-prone slopes, coastal erosion zones—where development should be legally prohibited and existing vulnerable structures relocated. Mitigation zones cover moderate hazard areas where development may proceed with mandatory protective measures—elevated foundations in flood zones, reinforced construction in earthquake areas, setbacks from hazard margins, and green infrastructure requirements. Acceptation zones designate low-hazard areas suitable for standard development with basic preparedness measures—early warning systems, evacuation plans, and building code compliance [35].

Implementation of this framework requires multiple complementary elements. Comprehensive multi-hazard assessment provides the scientific foundation, systematically mapping exposure to relevant hazards (floods, landslides, earthquakes, tsunamis, volcanic eruptions, forest fires) using appropriate methodologies—historical disaster records, geomorphological analysis, hydrological modelling, seismic hazard analysis, participatory community mapping. Scenario-based modelling explores potential impacts of future hazard events under different climate and land use scenarios, enabling forward-looking rather than merely historical risk assessment. Overlay analysis of hazard maps with population, infrastructure, and economic asset distributions identifies priority areas where concentrations of exposure demand special attention. Legal-regulatory frameworks translate risk assessments into enforceable land use controls through zoning ordinances, building codes, environmental impact assessment requirements, and development permitting procedures. Enforcement mechanisms—inspections, penalties for violations, judicial remedies—ensure compliance rather than treating regulations as advisory. Participatory processes engage affected communities in understanding hazards, developing regulations, and monitoring implementation, building legitimacy and local ownership [22].

The Sumatra flash flood context presents particularly acute spatial planning challenges. Upper watershed deforestation—the primary driver of disaster severity—continues despite legal protections for the Leuser Ecosystem and other critical watersheds, reflecting weak enforcement capacity and political economy constraints where powerful economic interests benefit from illegal logging and plantation expansion. Reconstruction in high-risk zones persists due to land scarcity, economic imperatives for rapid resettlement, and reluctance to relocate communities from traditional territories. Expert warnings against rebuilding in disaster-prone zones have gone largely unheeded, with reconstruction proceeding in locations that remain exposed to recurring floods and landslides [36].

Theme 2: Ecosystem Restoration as Core Reconstruction Strategy

Ecosystem restoration emerges across the literature not as a complementary add-on to physical reconstruction but as a foundational strategy that simultaneously addresses disaster risk reduction, climate adaptation, biodiversity conservation, and sustainable livelihood objectives. This integration represents a fundamental reconceptualisation of reconstruction priorities, elevating ecosystem restoration to equal or greater importance than conventional infrastructure rebuilding [37].

Upper watershed forest restoration constitutes the highest priority intervention for addressing flash flood and landslide risks in Sumatra's mountainous terrain. Forests regulate hydrological cycles through multiple mechanisms: canopy interception reduces raindrop impact energy and slows water delivery to the ground surface; root systems stabilise soils and increase infiltration capacity; leaf litter and organic matter enhance soil water retention; transpiration moderates peak flows. Empirical studies demonstrate that watershed deforestation increases peak flood discharge by 20-60% depending on deforestation extent and rainfall intensity, while reforestation can reverse these impacts over 5-15 year timeframes as forests mature [16].

Forest restoration strategies span a spectrum from passive natural regeneration to active reforestation depending on degradation severity and regeneration potential. Assisted natural regeneration (ANR)—protecting naturally regenerating seedlings through weeding, fire protection, livestock exclusion, and selective enrichment planting—proves cost-effective where seed sources and soil seed banks remain viable, with establishment costs of USD 250-300 per hectare compared to USD 1,000-2,000 for conventional reforestation. Active reforestation through nursery-raised seedlings becomes necessary in severely degraded sites lacking natural regeneration potential, though costs and risks remain substantial. Mixed approaches combining ANR in less degraded areas with active reforestation in degraded hotspots optimise resource allocation [37].

Agroforestry systems occupy a critical intermediate position in landscape restoration strategies, combining agricultural production with tree-based ecosystem services to address both livelihood and conservation objectives. Multistrata agroforestry—integrating canopy trees, mid-story fruit/timber trees, understory crops, and ground covers—mimics natural forest structure while generating diversified income streams from timber, fruits, coffee, spices, and non-timber forest products. FAO meta-analyses document substantial benefits: 50% reductions in soil erosion rates, 21%

increases in soil carbon storage, 46% increases in nitrogen availability, alongside maintained or improved agricultural yields relative to monocultures. It has been studied that post-landslide restoration in Indonesia demonstrates multistrata agroforestry's effectiveness for stabilising slopes while supporting livelihoods in landslide-affected areas [38,39].

The Leuser Ecosystem restoration presents both an exceptional opportunity and formidable challenges for Sumatra reconstruction. With 2.6 million hectares spanning Aceh and North Sumatra provinces, Leuser provides critical watershed services to approximately 4 million people while harbouring globally irreplaceable biodiversity as the last remaining habitat where Sumatran orangutans, tigers, rhinoceros, and elephants coexist in wild populations. However, the ecosystem faces intensive degradation pressures from illegal logging, encroachment for oil palm and coffee plantations, road construction, and mining. Restoration initiatives target 50,000 hectares of degraded critical watersheds, focusing on upper catchments of flood-affected river systems—Alas, Singkil, Tamiang, Batang Toru—where reforestation could substantially reduce future flood risks [9,40,41].

Theme 3: Community Resilience and Participatory Governance

Community participation emerges across the literature as simultaneously a procedural requirement for ethical reconstruction and a substantive factor enhancing reconstruction effectiveness and sustainability. Yet genuine participation—defined as meaningful influence over decision-making rather than tokenistic consultation—remains elusive in many reconstruction contexts, with persistent tensions between imperatives for rapid reconstruction and requirements for inclusive deliberation [42].

Effective participatory reconstruction typically operates through multi-tiered institutional arrangements. Village or neighbourhood reconstruction committees provide venues for affected communities to articulate needs, deliberate priorities, and oversee implementation, ideally with representation of vulnerable groups, including women, the elderly, persons with disabilities, and marginalised ethnicities. These grassroots committees connect to district/municipal reconstruction coordination bodies that align community initiatives with government programs, facilitate resource allocation, and resolve conflicts. Provincial and national reconstruction entities provide overall coordination, establish frameworks and standards, mobilise financing, and ensure consistency with broader policy objectives while respecting local autonomy [43-46].

Indonesia's post-tsunami Aceh reconstruction provides important precedents and lessons for participatory approaches. The Reconstruction and Rehabilitation Agency (BRR) established community-driven reconstruction mechanisms that enabled affected communities to participate in site selection, housing design, and livelihood program formulation, though implementation quality varied substantially across locations. Evaluation studies identified critical success factors: early initiation of participatory processes rather than retrofitting participation onto predetermined plans; adequate time allocation for community deliberation and consensus-building; technical facilitation by NGOs or community organisers bridging communities and government agencies; transparent information sharing about reconstruction plans, budgets, and timelines; and grievance redress mechanisms enabling communities to raise concerns and receive responses [47].

Social capital—encompassing trust, networks, norms of reciprocity, and collective action capacity—functions as a critical enabler of community resilience across disaster management cycle phases. Zhao et al.'s (2025) systematic review identifies five mechanisms linking social capital to disaster resilience: social learning (collective risk knowledge acquisition and sharing), collective action (mutual assistance during emergencies and recovery), disaster preparedness (community engagement in mitigation and planning), information communication (rapid warning dissemination through networks), and moral/civic responsibility (altruistic behaviors transcending narrow self-interest). Bonding social capital (tight-knit relationships within homogeneous groups) facilitates immediate mutual support but may limit access to external resources; bridging social capital (relationships across diverse groups) enables resource mobilisation and information exchange; linking social capital (connections to authorities and institutions) facilitates access to government programs and policy influence [48].

Guimaraes et al.'s (2025) quantitative analysis of 66 flood-affected communities across seven Global South countries provides robust empirical evidence for these mechanisms' effects. Controlling for demographic and hazard exposure variables, social and human capital significantly reduce injury incidence following floods (effect sizes 0.15-0.23), while disaster preparedness interventions lower both fatalities and injuries (effect sizes 0.31-0.42). The study's finding that natural capital shows unexpected positive associations with delayed deaths in some contexts—attributed to degraded ecosystems providing insufficient protective benefits—underscores that nominal ecosystem presence matters less than functional integrity [27].

Theme 4: Landscape-Based Livelihood Restoration

Livelihood restoration programs informed by landscape approaches fundamentally differ from conventional livelihood assistance through integration of environmental sustainability, spatial differentiation according to landscape zones, and explicit linkages between livelihood activities and ecosystem service maintenance. Rather than treating livelihood and environmental objectives as competing priorities requiring trade-offs, landscape-based approaches seek synergies where livelihood activities actively contribute to restoration and conservation objectives [49].

Comprehensive livelihood restoration programs typically combine multiple complementary interventions tailored to the landscape context. Cash and voucher assistance provides immediate purchasing power, enabling affected households to restart economic activities according to preferences and skills, with amounts typically ranging from USD 300-1,000 per household depending on pre-disaster income levels and local costs. Vocational training develops skills for alternative income-generating activities, particularly important where disasters destroyed previous livelihood bases or where resuming previous livelihoods would perpetuate vulnerability—farming in landslide zones, fishing in tsunami-prone coastal areas, logging in protected watersheds. Microfinance access through low-interest loans (3-6% annual rates), savings groups, and business development grants enables investment in productive assets and working capital, with loan sizes typically USD 200-2,000 reflecting small-scale enterprise scales. Market linkages connect producers with buyers, address transportation and storage constraints, and facilitate value addition through processing and packaging [50-52].

Integration with landscape zonation principles guides appropriate livelihood activities for different landscape positions. Natural zones prioritised for conservation and ecosystem service provision may support livelihoods based on sustainable harvesting of non-timber forest products, ecotourism, payment for ecosystem services, or conservation employment but preclude intensive agriculture or extractive activities. Combined zones designated for sustainable production systems emphasise agroforestry, organic agriculture, integrated pest management, and other practices that generate income while maintaining ecosystem functions. Economic zones suitable for intensive production permit conventional agriculture, aquaculture, and industrial plantations, though still subject to environmental regulations and best management practices [5].

The Siosar relocation case—a village relocated following Mount Sinabung eruptions—illustrates adaptive livelihood implementation challenges and strategies. Original livelihoods centred on intensive vegetable farming on volcanic slopes are no longer viable in hazard zones. The UNDP-supported program promoted diversified alternatives: organic horticulture using composting and integrated pest management; livestock raising (goats, chickens) requiring limited land; sewing workshops for women producing garments for local markets; automotive repair services; and enhanced coffee cultivation and processing, capitalising on regional coffee value chains. Evaluation revealed successful income diversification with average household incomes recovering to 70-85% of pre-disaster levels within three years, though challenges persisted, including market access constraints in remote relocation sites, need for sustained technical assistance beyond project timelines, and some cultural resistance to shifting from familiar agricultural livelihoods to new activities [30].

Agroforestry receives particular emphasis across the literature as a livelihood strategy simultaneously addressing production, conservation, and restoration objectives. Intensive agroforestry practised in Aceh Tamiang—combining coffee, rubber, fruit trees, and timber species in multistrata systems—generates diversified income streams while providing watershed protection, carbon sequestration, and biodiversity habitat in buffer zones surrounding protected forests. Economic analysis indicates that mature agroforestry systems (8-12 years establishment) generate annual returns of USD 1,200-2,500 per hectare from combined timber, fruit, and crop sales—comparable to intensive monoculture agriculture while delivering substantial ecosystem service co-benefits [39].

Theme 5: Multi-Stakeholder Governance and Coordination

Effective landscape governance requires coordinated action across multiple stakeholders with divergent interests, capacities, and institutional mandates—national and local governments, affected communities, private sector actors, civil society organizations, donors, technical experts—operating at multiple nested scales from villages to provinces to national policy. The literature consistently identifies multi-stakeholder platforms (MSPs) as essential institutional mechanisms for facilitating this coordination [53].

Well-functioning MSPs typically exhibit several common characteristics. Inclusive membership ensures representation of relevant stakeholder categories—government agencies (disaster management, spatial planning, environment, public works, agriculture), community representatives (village heads, women's groups, farmer organizations), private sector (chambers of commerce, industry associations), civil society (NGOs, academic institutions), and vulnerable group representatives. Clear mandates articulate MSP roles—which may include coordination (information sharing and activity alignment), negotiation (conflict resolution and agreement-building), planning (collaborative strategy development), monitoring (implementation oversight), or advocacy (policy influence)—with realistic boundaries recognizing MSPs typically lack executive authority. Transparent processes ensure meeting accessibility, information availability, documentation of decisions, and feedback mechanisms enabling accountability. Adequate resourcing provides secretariat functions, meeting venues, transportation support for community representatives, technical studies, and communication systems [54].

Indonesia's disaster management institutional architecture theoretically provides foundations for multi-stakeholder coordination. The National Disaster Management Agency (BNPB) coordinates disaster response and recovery at national level, with provincial disaster management agencies (BPBD Provinsi) and district disaster management agencies (BPBD Kabupaten/Kota) at subnational levels. However, evaluations consistently reveal coordination challenges: overlapping jurisdictions among multiple agencies; insufficient horizontal coordination between disaster management, spatial planning, environment, and development agencies; weak vertical coordination between national, provincial, and district levels; limited engagement of non-governmental actors beyond tokenistic consultation; and inadequate technical and financial resources for coordination functions [55].

The 2022 Global Platform for Disaster Risk Reduction hosted in Bali, Indonesia provided international recognition of Indonesia's disaster management efforts while highlighting persistent implementation gaps. Indonesia's strategic positioning—hosting the Global Platform, assuming leadership roles in regional disaster risk reduction networks, contributing to Sendai Framework midterm review—creates opportunities to leverage international support and technical cooperation for strengthening governance systems [56].

Collaborative governance models implemented in several Indonesian districts illustrate potential approaches. Karimun Regency established a dedicated disaster mitigation forum bringing together BPBD, social services, health services, military, police, search and rescue, and community leaders for regular coordination meetings, joint exercises, and collaborative response planning. Bekasi Regency developed a 2020-2024 Disaster Management Strategic Plan through multi-stakeholder consultations, establishing sectoral working groups for mitigation, preparedness, response, and recovery with clear roles and performance indicators. These examples remain localised innovations rather than systematic national practice, indicating need for institutionalization through regulations, budgets, and capacity building [55].

Theme 6: Monitoring, Evaluation, and Adaptive Management

Monitoring and evaluation systems enable accountability, learning, and adaptive management in disaster reconstruction, yet receive inadequate attention and resourcing in many reconstruction programs. Effective monitoring requires clear frameworks specifying what will be monitored, comprehensive indicator sets capturing multiple dimensions of reconstruction progress, appropriate methodologies combining quantitative metrics and qualitative assessment, and mechanisms translating monitoring findings into adaptive management decisions [47].

Zhao et al.'s (2023) study of Jiuzhaigou post-earthquake reconstruction demonstrates sophisticated monitoring approaches using high-resolution remote sensing integrated with ground-based assessment. Remote sensing imagery compared pre-disaster

(July 2017), immediate post-disaster (August 2017), and multiple recovery timepoints (April 2018, May 2019, subsequent years) to track changes in lake water quality, vegetation cover, infrastructure restoration, and landscape patterns. Findings revealed that infrastructure restoration occurred rapidly (8 months to restore road access), vegetation recovery proceeded more slowly (2 years to achieve moderate recovery), and some severely damaged landscape features (Sparks Sea) showed persistent degradation requiring active restoration rather than natural recovery. The integration of remote sensing with field surveys, water quality sampling, and visitor perception surveys enabled a comprehensive assessment across ecological, infrastructural, and experiential dimensions [21].

UN-Habitat's Sustainable Reconstruction Framework proposes three-phase monitoring corresponding to the reconstruction trajectory: absorptive measures (immediate emergency response addressing basic needs), adaptive measures (medium-term rehabilitation improving on pre-disaster conditions), and transformative measures (long-term restructuring building systemic resilience). Phase-specific indicators track progress: absorptive phase indicators include displaced population housed, essential services restored, debris cleared; adaptive phase indicators encompass hazard-resistant housing completed, livelihood programs initiated, community organisation established; transformative phase indicators measure sustained income improvements, ecosystem restoration outcomes, disaster risk reduction, and governance capacity [57].

The 5 Capitals framework provides a useful organising structure for comprehensive monitoring encompassing physical recovery (infrastructure, housing), natural capital (ecosystem health, environmental quality), human capital (health, education, skills), social capital (community cohesion, networks, trust), and financial capital (income, assets, access to credit). Monitoring across all capital domains ensures that reconstruction assessment captures the full range of outcomes rather than narrowly focusing on visible physical reconstruction while overlooking less tangible but equally important social and natural dimensions [58].

Participatory monitoring approaches engage affected communities in data collection, interpretation, and use, building local capacity while enhancing accountability. Community-based monitoring may involve trained community monitors conducting household surveys, organising focus group discussions, maintaining photographic documentation, using mobile applications for geo-referenced reporting, and presenting findings in community forums where government agencies and implementing partners respond to identified concerns. The TreeRCode application referenced in Sumatra tree planting initiatives exemplifies digital tools enabling community members to document restoration activities, monitor survival rates, and track growth over time [59-65].

Discussion

Toward an Integrated Landscape-based Reconstruction Framework for Sumatra

The synthesis of findings across six thematic domains reveals a coherent integrated framework for landscape-based reconstruction in Sumatra combining spatial, temporal, and institutional dimensions. Spatially, the framework operationalizes landscape approaches through watershed-scale planning that delineates natural zones (upper watershed forests for ecosystem protection), combined zones (mid-watershed agroforestry buffer zones), and economic zones (lowland areas for settlements and intensive agriculture). This zonation translates into disaster risk-sensitive spatial plans with legally binding regulations: development prohibitions in high-hazard upper watersheds and floodplains; agroforestry and sustainable agriculture requirements in moderate-risk middle watersheds; and hazard-resistant construction standards in permissible development zones [24].

Temporally, reconstruction unfolds across overlapping phases requiring different interventions and governance arrangements. Emergency response (0-6 months) prioritises life-saving, temporary shelter, immediate livelihood assistance, and participatory needs assessment, establishing foundations for subsequent recovery. Rehabilitation (6-18 months) advances temporary-to-transitional housing, livelihood restoration program launch, participatory reconstruction planning, institutional capacity building, and initial ecosystem restoration in critical hotspots. Reconstruction (18-36 months) implements permanent housing in hazard-resistant locations, large-scale forest and agroforestry restoration, infrastructure rebuilding with improved resilience, livelihood program consolidation, and spatial plan revisions. Transformation (3+ years) pursues long-term resilience building through sustained ecosystem restoration, payment for ecosystem services institutionalisation, disaster risk reduction mainstreaming across sectors, and adaptive governance system strengthening [66].

Institutionally, effective landscape governance requires nested multi-stakeholder platforms operating at multiple scales. Village-level reconstruction committees enable community participation in site selection, design, and implementation oversight. District-level coordination bodies align community initiatives with government programs, facilitate resource allocation, resolve conflicts, and provide technical support. Provincial landscape platforms coordinate across districts, negotiate landscape zonation agreements, mobilise financing, and interface with national policies. National policy frameworks establish legal-regulatory foundations, allocate resources, coordinate international assistance, and ensure alignment with the Sendai Framework and Sustainable Development Goals [67].

This integrated framework transcends conventional sectoral reconstruction approaches—which treat housing, infrastructure, livelihoods, and environment as separate domains implemented by different agencies with limited coordination—by recognising their deep interdependencies and managing them holistically within landscape contexts. Ecosystem restoration simultaneously reduces disaster risk, supports livelihoods, sequesters carbon, and conserves biodiversity. Spatial planning simultaneously guides reconstruction location, protects critical watersheds, enables sustainable production, and enforces hazard avoidance. Community participation simultaneously ensures culturally appropriate solutions, builds social capital, enhances legitimacy, and strengthens local capacity. Livelihood programs simultaneously restore incomes, incentivise sustainable land management, and reduce pressure on protected areas [68-74].

Critical Success Factors and Implementation Barriers

Analysis across cases reveals several critical success factors for landscape-based reconstruction implementation. Political commitment at highest levels—exemplified by BRR's direct reporting to President in Aceh reconstruction—provides authority to coordinate across agencies, override bureaucratic inertia, and sustain long-term investments beyond electoral cycles. Adequate and sustained financing—the USD 3.11 billion allocated for Sumatra reconstruction provides necessary though not sufficient resourcing—must flow predictably over multi-year timeframes matching ecosystem restoration and livelihood development trajectories rather than short-term humanitarian funding patterns. Technical capacity in landscape planning, ecosystem restoration, participatory facilitation, and monitoring requires substantial investment in training programs, technical advisory services, and knowledge management systems [75].

Legal clarity and enforcement capacity determine whether spatial plans and ecosystem protections represent genuine constraints on development or merely advisory aspirations routinely violated. The persistent illegal deforestation in Leuser, despite legal protections, illustrates enforcement failures. Strengthening requires not only regulations but also monitoring systems (remote sensing, ranger patrols), penalties with a real deterrence effect, judicial systems adjudicating violations, and political will to prosecute powerful actors. Genuine community participation—beyond tokenistic consultation—demands time for deliberation, resources for community organising and facilitation, transparency in decision processes, grievance mechanisms, and demonstrated responsiveness where community input genuinely influences outcomes [76].

Implementation faces formidable barriers requiring explicit acknowledgement and strategic response. Political economy constraints arise where powerful interests benefit from maintaining the status quo—plantation companies resisting restrictions on expansion, land speculators opposing hazard-zone development prohibitions, local elites controlling resource access, and corruption in permitting and enforcement. Addressing requires transparency mechanisms (public disclosure of permits and violations), civil society watchdogs, and international pressure where domestic political systems prove captured. Institutional fragmentation manifests in overlapping jurisdictions, conflicting mandates, competition for resources and credit, and failures of horizontal and vertical coordination. Mitigation requires deliberate coordination mechanisms (MSPs, joint task forces), clarity in roles and responsibilities, and incentive alignment through performance management and resource allocation [55].

Time pressure for rapid reconstruction conflicts with requirements for careful planning, participatory deliberation, environmental assessment, and ecosystem restoration, which operate on longer timeframes. Balancing requires parallel tracking—rapidly providing temporary shelter and livelihood assistance while simultaneously initiating longer-term participatory planning and restoration programming. Technical capacity gaps in hazard modelling, landscape planning, restoration ecology, and participatory facilitation limit implementation quality. Addressing requires substantial investment in education and training, technical advisory services, international cooperation and knowledge exchange, and realistic timelines acknowledging capacity development as a prerequisite rather than assumption [23].

Comparative Insights: Sumatra in Global Context

Comparative analysis situates Sumatra's reconstruction challenges and opportunities within the global post-disaster reconstruction experience. Similarities with other disaster-affected regions include: ecosystem degradation as a disaster risk amplifier (Nepal landslides, Caribbean hurricanes, China earthquakes); institutional coordination challenges across multiple agencies and scales; tensions between rapid reconstruction imperatives and deliberative participatory processes; and persistent vulnerability of marginalised populations to exclusion from recovery benefits [77].

Sumatra presents distinctive contextual features shaping reconstruction prospects. The scale of ecological assets—the Leuser Ecosystem as a globally irreplaceable biodiversity hotspot—creates both an exceptional conservation imperative and an opportunity for international financing through biodiversity and climate mechanisms. Indonesia's middle-income status and institutional capacity contrast with post-disaster contexts in least developed countries, enabling more sophisticated technical approaches but also creating different financing constraints where international humanitarian assistance proves limited compared to grants available for low-income countries. The political economy of palm oil—where plantation expansion drives substantial economic growth and employment but causes environmental destruction—creates more complex trade-offs than disaster contexts lacking such economically significant but environmentally destructive sectors [1].

Previous reconstruction experience from the 2004 tsunami provides valuable lessons and institutional memory unavailable in many disaster contexts. The BRR model—establishing dedicated reconstruction agency with authority, budget, and sunset provision to avoid permanent bureaucracy—offers potential template for Sumatra reconstruction entity. Successes in community-driven reconstruction, innovative financing, and housing program implementation provide replicable models. Shortcomings in ecosystem restoration, spatial planning enforcement, and sustainable livelihood development highlight areas requiring explicit attention to avoid repeating past limitations [78].

The Jiuzhaigou case from China demonstrates landscape-scale reconstruction in a World Natural Heritage context, with sophisticated monitoring using remote sensing and substantial investment in ecosystem restoration alongside infrastructure rebuilding. However, the exceptional institutional capacity, authoritarian governance enabling rapid decision-making, and substantial public investment in this prestigious site limit transferability to typical disaster reconstruction settings. Nepal's post-2015 earthquake reconstruction experience offers perhaps more relevant comparisons given similarities in mountain watershed contexts, upper watershed degradation problems, governance challenges, and limited resources [75].

Policy Implications and Strategic Recommendations

The research findings carry significant implications for reconstruction policy at multiple levels. At the national level, Indonesia should establish a dedicated Sumatra Reconstruction Coordinating Board with authority similar to BRR Aceh-Nias, bringing together BNPB, the Ministry of Environment and Forestry, the Ministry of Agrarian Affairs and Spatial Planning, the Ministry of Public Works, Bappenas, and the Ministry of Social Affairs under coordinated leadership with direct accountability to the President. Legal reforms should harmonise disaster management, spatial planning, and environmental protection regulations currently operating in parallel with insufficient coordination, creating integrated frameworks with clear responsibilities and enforcement authorities [79].

Financing mechanisms require innovation beyond conventional government budget allocations. Payment for Ecosystem Services schemes can mobilise private sector and international conservation finance for watershed restoration, with downstream beneficiaries (urban water utilities, hydropower operators, flood-affected districts) paying for upstream conservation and restoration. Climate finance accessed through the Green Climate Fund, Adaptation Fund, and bilateral donors can support nature-based solutions for disaster risk reduction and climate adaptation. Disaster resilience bonds and catastrophe insurance mechanisms can provide contingent financing for post-disaster needs while incentivizing pre-disaster risk reduction [80].

At provincial and district levels, immediate moratoriums on development in identified high-risk zones prevent reproduction of vulnerability, with legal mechanisms rapidly processing relocations and compensating affected parties. Spatial plan revisions incorporating comprehensive multi-hazard assessments and enforceable risk-based zonation should advance on accelerated timelines (12-18 months rather than typical 3–5-year planning cycles), with technical assistance from national government and international partners. Large-scale ecosystem restoration targeting 50,000 hectares in Leuser and Batang Toru watersheds requires coordinating reforestation agencies, conservation NGOs, community forestry groups, and the private sector under unified restoration strategies with clear targets, budgets, monitoring systems, and accountability mechanisms [3].

Agroforestry buffer zone establishment targeting 100,000 hectares requires integrated programming combining land tenure security, seedling provision, technical extension, market development, and sustained multi-year support as systems mature. Multi-stakeholder platform institutionalisation through provincial and district regulations establishes legal foundations with dedicated secretariats, operating budgets, transparent procedures, and performance accountability. Community participation mechanisms—reconstruction committees, participatory planning processes, grievance redress systems—require explicit resourcing for facilitation, transportation, communication, and capacity building rather than treating participation as a cost-free add-on [81].

Capacity building programs should target multiple audiences: government planners in disaster risk-sensitive spatial planning, landscape assessment, and participatory methods; disaster management agency staff in ecosystem-based approaches and multi-stakeholder coordination; community facilitators in participatory planning, conflict resolution, and community organising; technical specialists in restoration ecology, agroforestry systems, and monitoring methodologies. Regional centres of excellence could provide sustained technical assistance, training, research, and knowledge management—potentially leveraging existing universities in Banda Aceh, Medan, and Padang [23].

Conclusion

Synthesis: From Crisis to Transformation

The 2025 Sumatra flash floods represent both a humanitarian catastrophe and a transformative opportunity. The disaster's severity—969 fatalities, 262 missing, USD 3.11 billion in damages—demands a response commensurate with its scale. Yet conventional reconstruction paradigms focused narrowly on rebuilding physical infrastructure while neglecting underlying environmental degradation, spatial planning failures, and vulnerability drivers, thereby merely recreating conditions for future disasters. The sustainable landscape approach synthesised in this review offers alternative pathways that simultaneously address disaster recovery, ecosystem restoration, poverty reduction, and climate adaptation within integrated frameworks, recognising the fundamental interconnection of human communities and natural systems.

The empirical evidence reviewed demonstrates that ecosystem degradation—specifically upper watershed deforestation driven by illegal logging and plantation expansion—directly amplified disaster severity by destroying natural hydrological regulation capacity. Conversely, ecosystem restoration through reforestation, agroforestry, and sustainable land management can substantially reduce future disaster risks while generating co-benefits for carbon sequestration, biodiversity conservation, and sustainable livelihoods. Nature-based solutions and ecosystem-based disaster risk reduction have progressed from theoretical concepts to established frameworks supported by growing evidence bases and international policy commitments through the Sendai Framework, Paris Agreement, and Kunming-Montreal Global Biodiversity Framework.

The six themes synthesised in this review—disaster risk-sensitive spatial planning, ecosystem restoration, community resilience, landscape-based livelihoods, multi-stakeholder governance, and adaptive monitoring—constitute interdependent elements requiring integrated implementation rather than separate sectoral interventions. Spatial planning provides legal and regulatory frameworks that translate landscape visions into enforceable land-use controls. Ecosystem restoration delivers the biophysical foundation for disaster risk reduction and sustainable production. Community participation builds legitimacy, social capital, and local capacity, which are essential for sustained implementation. Livelihood restoration ensures economic viability and reduces pressure on protected areas. Multi-stakeholder governance coordinates action across diverse actors with divergent interests. Monitoring enables accountability and adaptive management as understanding evolves.

Strategic Imperatives for Sumatra Reconstruction

Sumatra's reconstruction requires bold action across multiple fronts. Immediate priorities (0-12 months) must establish foundations for landscape-based recovery: moratoriums on development in identified high-risk zones with expedited relocation and compensation processes; participatory reconstruction planning engaging affected communities in site selection, housing design, and livelihood program formulation; emergency reforestation in critical upper watershed hotspots using assisted natural regeneration and direct seeding; cash and voucher assistance providing immediate livelihood support; and multi-stakeholder platform establishment convening government agencies, communities, civil society, and private sector under transparent coordination mechanisms.

Medium-term programs (1-3 years) scale interventions to landscape level: spatial plan revisions incorporating disaster risk-sensitive zonation across affected provinces and districts with legal enforcement mechanisms and adequate resources for implementation; large-scale forest restoration targeting 50,000 hectares in Leuser and Batang Toru with mixed strategies (ANR, active reforestation, natural regeneration) tailored to site conditions; intensive agroforestry development targeting 100,000 hectares in buffer zones with integrated support for land tenure, seedlings, technical assistance, and market linkages; permanent housing construction in hazard-resistant locations with improved building standards; comprehensive livelihood programs combining vocational training, microfinance, market development, and environmental sustainability.

Long-term transformation (3+ years) institutionalizes landscape approaches within governance systems: legal reforms harmonizing disaster management, spatial planning, and environmental protection regulations under integrated frameworks; payment for ecosystem services schemes mobilizing sustained financing for watershed conservation and restoration; enforcement capacity building through remote sensing monitoring, ranger patrols, judicial reforms, and political will to prosecute violations; regional centers of excellence providing technical assistance, training, research, and knowledge management; and continuous monitoring using remote sensing, community-based monitoring, and adaptive management processes.

Broader Contributions and Future Research

This research contributes to disaster recovery scholarship by demonstrating how sustainable landscape approaches can transform reconstruction from reactive infrastructure rebuilding to proactive resilience building. The synthesis advances theoretical integration of previously separate frameworks—Build Back Better, Nature-based Solutions, ecosystem-based disaster risk reduction, sustainable livelihoods, community resilience—revealing their complementarities and mutual reinforcement when applied at the landscape scale. Methodologically, the study demonstrates the value of qualitative literature reviews for synthesising multidisciplinary evidence on complex policy-relevant questions, where systematic review's standardised protocols prove overly restrictive.

The research acknowledges essential limitations. The qualitative, interpretive approach introduces inevitable subjectivity in theme identification and synthesis. The literature's publication bias toward successful interventions likely creates overly optimistic assessments of implementation prospects. The early stage of Sumatra's reconstruction limits the availability of empirical outcome data for recent interventions. Context-specificity constrains generalisation of findings to other disaster settings without careful consideration of differences in governance systems, resource availability, political economy, and socio-cultural contexts.

Future research should pursue multiple directions. Rigorous impact evaluations using quasi-experimental designs (difference-in-differences, propensity score matching) could assess causal effects of landscape interventions on disaster risk reduction and community resilience outcomes, addressing current evidence gaps. Cost-benefit analyses incorporating the full spectrum of ecosystem service values could strengthen economic cases for landscape investments compared to conventional reconstruction approaches. Longitudinal studies tracking Sumatra's reconstruction over 5-10 years could document implementation challenges, adaptation strategies, and long-term outcomes in real-world conditions. Comparative studies systematically examining landscape reconstruction approaches across multiple disaster contexts could identify transferable lessons and context-specific adaptations. Governance analyses exploring multi-stakeholder platform effectiveness, power dynamics, conflict resolution, and institutional change processes could provide practical guidance for the design of coordination mechanisms.

Concluding Reflections

Disasters create ruptures in normalised routines, opening windows of opportunity for transformative change that would otherwise be blocked by institutional inertia and vested interests. Whether these opportunities translate into genuine transformation or dissipate through path-dependent reproduction of pre-disaster patterns depends critically on choices made in the immediate post-disaster periods when reconstruction trajectories become locked in. Sumatra faces such a critical juncture. The path of conventional reconstruction—rapidly rebuilding in previous locations, restoring pre-disaster land uses, treating ecosystem restoration as a peripheral concern—appears expedient but recreates vulnerability to recurring disasters.

The alternative path of landscape-based reconstruction demands more complex coordination, longer timelines, and explicit confrontation of underlying drivers—deforestation, illegal land conversion, spatial planning failures, and enforcement weakness—that powerful interests benefit from maintaining. Yet this more difficult path offers genuine prospects for breaking cycles of disaster, vulnerability, and reconstruction that characterize disaster-prone regions. By restoring upper watershed forests, establishing sustainable agroforestry buffer zones, enforcing disaster risk-sensitive spatial plans, building community resilience, and institutionalizing multi-stakeholder governance, Sumatra can demonstrate that post-disaster reconstruction can transform vulnerability into resilience, environmental degradation into restoration, and crisis into opportunity.

The Leuser Ecosystem—providing watershed services to 4 million people while harbouring irreplaceable biodiversity—represents both the challenge and promise of landscape approaches. Its degradation amplified disaster severity; its restoration could substantially reduce future risks while delivering global environmental benefits. The 969 lives lost to flash floods demand that reconstruction honours their memory not through monuments but through transformative action that protects future generations from similar catastrophes. The sustainable landscape approach synthesised in this review provides the conceptual foundations, empirical evidence, and practical guidance for such transformation. The critical question is whether Sumatra's reconstruction will seize this opportunity or allow it to pass. The answer will emerge not from academic analysis but from political will, institutional capacity, adequate resourcing, genuine community participation, and sustained commitment that transformative reconstruction requires. For 4 million people whose well-being depends on Leuser's ecosystem services, for countless species whose survival depends on habitat protection, and for future generations who inherit either resilience or vulnerability from choices made today, the stakes could not be higher.

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