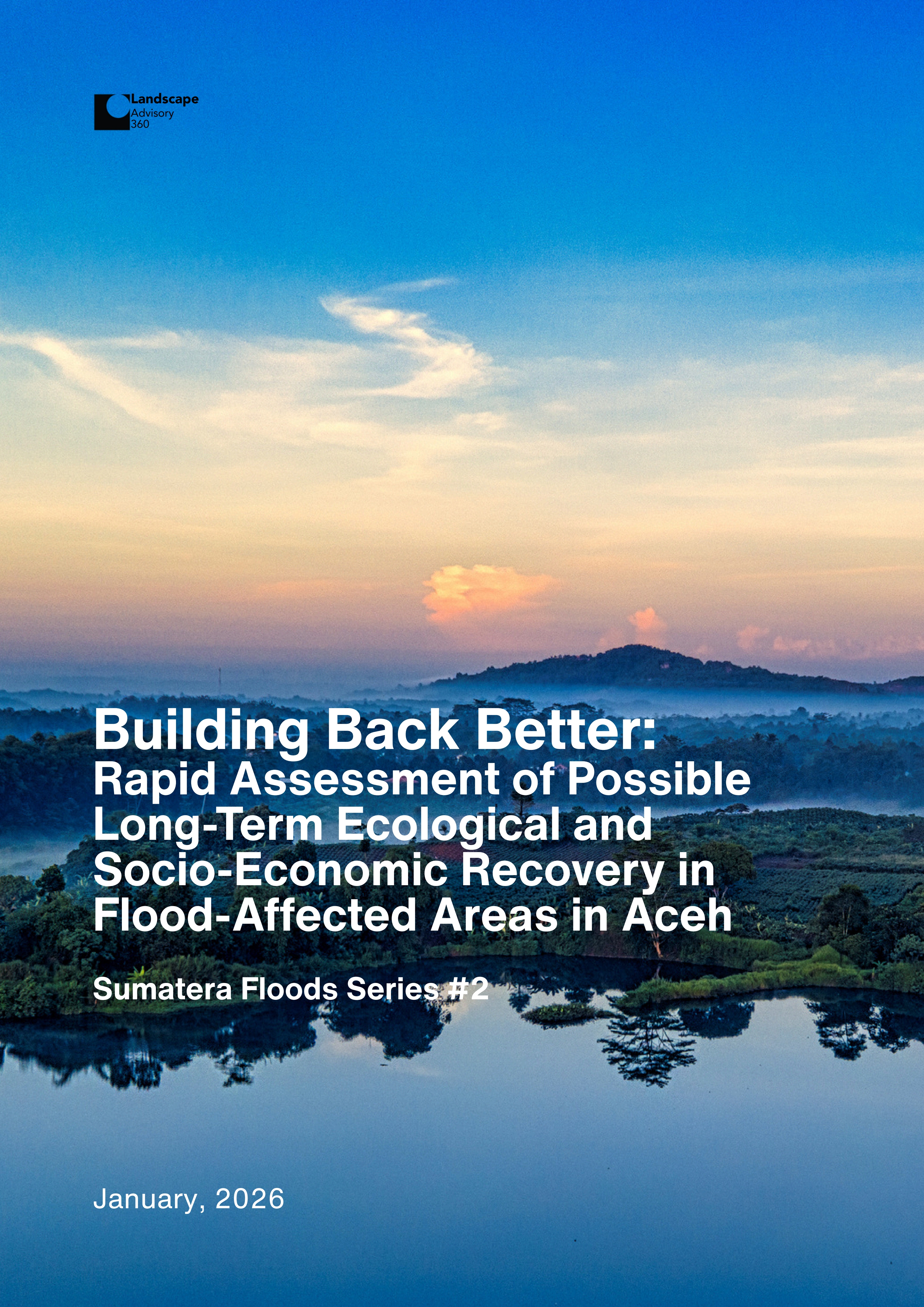

Landscape Advisory 360

Building Back Better:
Rapid Assessment of Possible Long-Term Ecological and Socio-Economic Recovery in Flood-Affected Areas in Aceh

Sumatera Floods Series #2

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Building Back Better:

Rapid Assessment of Possible Long-Term Ecological and Socio-Economic Recovery in Flood-Affected Areas in Aceh

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Executive Summary

The late-November 2025 floods and landslides across Aceh, North Sumatra, and West Sumatra were not "natural disasters" in any simple sense — they were the foreseeable result of climate-amplified extreme rainfall colliding with degraded watersheds shaped by decades of land-use change and weak governance. In Aceh, the disaster unfolded along a familiar ridge-to-plain pathway: steep headwaters and mid-slopes generated rapid runoff and sediment, while lowland river corridors and floodplains bore the brunt of inundation, housing damage, and displacement. As of December 27, 2025, official figures indicated 1,138 deaths and 163 missing across the three provinces, with 449,864 displaced; Aceh alone recorded 511 fatalities. Preliminary reconstruction needs were estimated at Rp 51.82 trillion across the three provinces (Aceh Rp 25.41 trillion), while wider economic losses were estimated at roughly Rp 68.6–68.7 trillion.

This rapid assessment proposes a "building back better" agenda for Aceh centered on a jurisdictional landscape approach that links ecological recovery to long-term socio-economic resilience. The report maps interventions from watershed to coast, prioritizing (1) conservation of remaining natural assets that stabilize hydrology and protect communities, including key forest and peat landscapes; (2) large-scale rehabilitation and restoration in the mid-slope belt and along river corridors where degradation has amplified flood peaks, sediment loads, and channel instability; (3) targeted recovery of productive systems — paddy, smallholder oil palm, fisheries and aquaculture, and Gayo highland commodities — through climate-smart, deforestation-free upgrading and restored logistics; and (4) risk-informed settlement re-planning, including strict river setbacks, safer siting, and, where unavoidable, managed retreat in repeatedly inundated zones.

The recommendations integrate nature-based solutions with engineered measures calibrated to watershed geomorphology, including differentiated responses for low-, moderate-, and high-relief catchments. Complementary investments are proposed for modernized early warning systems and last-mile preparedness. Underpinning the technical agenda is a governance reform package: watershed-based authority and planning; strengthened Strategic Environmental Assessment and Environmental Impact Assessment requirements that explicitly account for hydrology, sediment, and cumulative impacts; time-bound audits of high-risk permits with revocation where violations are found; One Map–based transparency; and stronger enforcement and anti-corruption safeguards so that accountability matches the scale of harm.

The report concludes that Aceh's recovery must be treated as an investable, multi-year transition rather than a short-term reconstruction program. A blended financing strategy is required — mobilizing national and subnational public finance, philanthropy, multilateral support, and private-sector participation aligned with measurable outcomes in risk reduction, ecosystem services, and sustainable livelihoods. Done well, Aceh can reduce future disaster risk while protecting its remaining natural capital and rebuilding a more resilient, competitive economy.

1
Devastating Cost of Ecological Negligence

1.1 Warned by Nature

At least 1,138 deaths and 163 missing across Aceh, North Sumatera, and West Sumatera. There are 449,864 people still displaced, though some have started returning home. Aceh has the most fatalities (511), followed by North Sumatra (365) and West Sumatra (262), according to Indonesia's National Disaster Management Agency (Badan Nasional Penanggulangan Bencana, BNPB) as of December 27, 2025.[1]

BNPB has also communicated an initial estimate from the Ministry of Public Works (Kementerian Pekerjaan Umum) that total rehabilitation and reconstruction needs across the three provinces could reach Rp 51.82 trillion, with Aceh accounting for the largest share at Rp 25.41 trillion (compared with Rp 12.88 trillion for North Sumatra and Rp 13.52 trillion for West Sumatra).[2] Separately, the Center of Economic and Law Studies (CELIOS) has estimated wider economic losses from the disaster sequence at Rp 68.67 trillion, with Aceh's regional economic losses projected in the low single-digit trillions (around Rp 2.2 trillion in CELIOS's own summary, with some outlets reporting a nearby figure of about Rp 2.04 trillion depending on assumptions and data cutoffs).[3]

For Aceh specifically, the crisis is now defined by two overlapping realities: a still-evolving casualty picture and a reconstruction bill that is already enormous.

While BNPB's island-wide update does not break down the 163 missing by province, BNPB-linked reporting and Aceh's situation dashboards in mid-December consistently placed the number of people still missing in Aceh at around 31 (with the expectation that this could shift as search operations and identifications continue).

Earlier, *Warned by Nature* argues that the late-November 2025 floods and landslides across Aceh, North Sumatera, and West Sumatera should be read as a foreseeable outcome of climate-amplified rainfall colliding with watersheds that have been structurally weakened by decades of land-use change, rather than as an isolated "extreme weather" anomaly.[4] The report centers the rare, near-equatorial tropical cyclone Senyar as a hazard multiplier whose defining feature was extraordinary rainfall intensity and persistence, pushing 24-hour totals beyond the absorptive capacity of soils and rivers and triggering compound flood–landslide cascades.[5] But it insists the scale of human loss and fiscal strain is best explained by the "second half" of the equation: fragmented forests, altered slopes, and sediment-choked river systems shaped by logging, plantations, mining, and road-building — a political economy in which profits are concentrated while risks and losses are pushed onto downstream communities and public budgets.[6]

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[1] Kriswaningsih,T A., 2025. "Update Bencana Sumatera per 27 Desember 2025, BNPB: Korban Jiwa 1.138 Orang," Kompas TV. https://www.kompas.tv/nasional/640127/update-bencana-sumatera-per-27-desember-2025-bnpb-korban-jiwa-1-138-orang (accessed on December 27, 2025).

[2] Anggrainy, F.C., 2025. "BNPB Ungkap Estimasi Biaya Pemulihan Bencana Sumatera Tembus Rp 51,8 T", *Detiknews* (December 8, 2025). https://news.detik.com/berita/d-8248411/bnpb-ungkap-estimasi-biaya-pemulihan-bencana-sumatera-tembus-rp-51-8-t (accessed on December 22, 2025).

[3] CELIOS (Center for Economic and Law Studies), 2025. *Dampak Kerugian Ekonomi Bencana Banjir Sumatera: Hasil modelling tim CELIOS menggunakan data per 30 November 2025*. Center for Economic and Law Studies, Jakarta.

[4] Sari, A.P., 2025. *Warned by Nature: A Quick Assessment of Floods and Forests in Northern Sumatera and the Need for Reform*. Landscape Advisory, Jakarta.

[5] Chang, C.-P., C.H. Liu, and H.C. Kuo, 2003. "Typhoon Vamei: An equatorial tropical cyclone formation", *Geophysical Research Letters*, 30 (3), p. 1150; Roxy, M.K., J.S. Saranya, A. Modi, A. Anusree, W. Cai, L. Resplandy, J. Vialard, and T.L. Frolicher, 2024. "Chapter 20, Future projections for the tropical Indian Ocean" in Ummenhofer, C.C., and R.R. Hood (eds.), *The Indian Ocean and its Role in the Global Climate System*. Elsevier, Amsterdam.

[6] Sari, 2025, *op cit*.; Chang, 2003, *op cit*.

For Aceh, the report's analytical warning is sharper because the province remains Sumatra's critical forest stronghold, yet the specific forests being lost are humid primary forests in steep, high-rainfall catchments whose hydrological value is disproportionately large. Aceh still held about 3.37 million hectares of primary forest in 2001 (about 59 percent of the province), but Global Forest Watch data suggest around 320,000 hectares of humid primary forest loss between 2002–2024, with clearing clustered along road corridors, the margins of the Leuser ecosystem, and expanding oil palm and smallholder zones.[7]

This matters because quantitative evidence links upstream forest loss and oil palm expansion to higher village-level flooding incidence in Aceh, with the poorest communities bearing the greatest exposure, while basin studies (including the Krueng Aceh watershed) show land-use change increasing runoff and reducing infiltration.[8] In response, the report calls for a time-bound "tobat ekologis" — ecological repentance — translated into watershed-by-watershed action: no new concessions in headwaters and steep high-risk slopes; Strategic Watershed Protection Zones treated as vital national objects; a brutally honest audit and reordering of permits; climate-risk-updated AMDAL requirements; and large-scale restoration in already-failed basins, backed by fiscal and enforcement instruments that reward protection over clearing.[9]

1.2 Aceh at a Glance

Aceh sits at the northern tip of Sumatra, shaped by a steep ecological gradient: short, fast rivers dropping from the Bukit Barisan mountain range to a low coastal plain, with globally significant rainforest landscapes tied to the Gunung Leuser National Park and the wider Tropical Rainforest Heritage of Sumatra (a UNESCO World Heritage property).[10] This geography helps explain Aceh's "double exposure" to risk and opportunity: the same upland forests that stabilize watersheds and regulate water supply for millions also sit alongside densely settled coastal and riverine zones that are highly exposed to tsunami, floods, and landslides.[11] In demographic terms, Aceh's population reached 5,554,820 in 2024, growing about 1.32 percent from the previous year, with Statistics Indonesia (Badan Pusat Statistik) noting that net migration trends negative (more people leaving than entering), often for work or education.[12]

Economically, Aceh's structure is still anchored in land- and resource-linked activity, with a large "state footprint" as well. In 2024, Aceh's Gross Regional Domestic Product (GRDP) at current prices reached Rp 65.36 trillion, and the provincial economy grew 4.66 percent year-on-year.[13] Sectorally, agriculture, forestry, and fisheries remain the biggest contributor (around one-third of output), followed by wholesale and retail trade (around 15 percent), and public administration (around 9 percent), with construction and transport also significant.[14] This profile translates into a development pattern that is often spatially uneven: commodity and logistics corridors, public spending, and legacy energy infrastructure can generate growth, but poverty reduction remains a central challenge (12.33 percent in March 2025, compared with the national

[7] Global Forest Watch, World Resources Institute, data cited in Sari, A.P., 2025.
[8] Lubis, M.I., M. Linkie, and J.S.H. Lee, 2024. "Tropical forest cover, oil palm plantations, and precipitation drive flooding events in Aceh, Indonesia, and hit the poorest people hardest", *PLOS ONE*, 19 (10).
[9] Muis, B.A., 2019. "Impact of Land Use Change on Hydrological Response of Krueng Aceh Watershed in Aceh Province, Indonesia", *Nature Environment and Pollution Technology* (2019).
[10] UNESCO World Heritage Center, *op cit*.; UNESCO, 2025. "Gunung Leuser," UNESCO Man and the Biosphere Programme (MAB). https://www.unesco.org/en/mab/gunung-leuser (accessed on December 22, 2025).
[11] "Gunung Leuser", UNESCO.
[12] Hasanah, N., 2024. "Jumlah penduduk Aceh 2024 capai 5,55 juta jiwa, populasi terpadat di Banda Aceh", *Antara News Aceh* (December 16, 2024).
[13] BPS Aceh (Badan Pusat Statistik Provinsi Aceh), 2025. "Aceh's economy in 2024 will grow 4.66 percent" *Official Statistics News*. Badan Pusat Statistik Provinsi Aceh, Banda Aceh; "BPS: Ekonomi Aceh bertumbuh 4,66 persen pada 2024" *Antara News Aceh* (February 5, 2025).
[14] *Antara News Aceh*, 2025, *op cit*.; BPS Aceh, 2025. "Siaran Pers Badan Pusat Statistik Provinsi Aceh 5 November 2025," *Official Statistics News* (November 5, 2025).

poverty rate figure of 8.47 percent), alongside labor-market pressures (open unemployment rate 5.64 percent as of August 2025).[15]

Historically, these development dynamics are inseparable from Aceh's long arc: from an influential sultanate and a prolonged anti-colonial war against the Dutch (1873–1904), to post-independence cycles of insurgency and negotiation. Armed conflict in Aceh is commonly traced to the emergence of the Free Aceh Movement (Gerakan Aceh Merdeka, GAM) in December 1976, when it issued a "Declaration of Independence of Aceh-Sumatra," and then evolved through cycles of insurgency and counterinsurgency.[16] The violence escalated sharply after Aceh was designated an "area of military operations" (daerah operasi militer, DOM) in 1990, a period that Human Rights Watch documents as marked by heavy counterinsurgency and widespread abuses against civilians, including killings, disappearances, torture, and sexual violence.[17] Efforts to halt the fighting through the Cessation of Hostilities Agreement (COHA) signed in December 2002 proved short-lived; in May 2003 the United Nations publicly expressed concern about renewed fighting and the imposition of martial law, and later warned about serious impacts on civilians.[18]

The conflict ultimately ended through the Helsinki negotiations, culminating in the Memorandum of Understanding (MOU) signed on August 15, 2005, which the United Nations described as a comprehensive settlement after nearly thirty years of conflict and which was subsequently monitored through the EU-ASEAN Aceh Monitoring Mission (AMM).[19]

The Helsinki MoU was immediately followed by Law No. 11/2006 on the Governance of Aceh, institutionalized special autonomy and reconfigured the center–province relationship — an essential political context for any long-term recovery and "build back better" agenda that must align livelihoods, public finance, and watershed-scale ecological stability.[20]

1.3 The Devastation

Aceh appears to suffer the most extent of damages among the three affected provinces. Damages from the late-November 2025 floods and landslides in Aceh are best understood as a compound of (1) high-fatality, high-destruction pockets along fast-flowing channels and unstable slopes, and (2) wide-area inundation across densely settled lowlands that produced extraordinary displacement, service disruption, and asset losses even where buildings were not fully destroyed. Across 18 regencies and cities, Aceh recorded 449 deaths and 571,201 displaced people as of mid-December, alongside 106,058 damaged houses (36,328 heavily damaged, 22,951 moderately damaged, and 46,779 lightly damaged).[21]

This profile contrasts sharply with North Sumatera and West Sumatera. While Aceh accounted for about 42.6 percent of reported deaths across the three provinces, it represented roughly 94.3 percent of reported displacement at the same reporting point,

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[15] BPS Aceh, 2025. "Poor Population Percentage of Aceh in March 2025 was 12.33 percent," *Official Statistics News* (July 25, 2025); BPS Aceh, 2025. "The Open Unemployment Rate (TPT) is 5.64 percent," *Official Statistics News* (November 5, 2025); "Persentase Penduduk Miskin Maret 2025 turun menjadi 8,47 persen", Badan Pusat Statistik (July 25, 2025). https://www.bps.go.id/id/pressrelease/2025/07/25/2518/--in-march-2025--the-percentage-of-the-poor-population-decreased-into-8-47-percent-.html (accessed on December 22, 2025).

[16] Ansori, M.H., 2012. "From Insurgency to Bureaucracy: Free Aceh Movement, Aceh Party and the New Face of Conflict," *Stability: International Journal of Security and Development*, 1 (1).

[17] HRW (Human Rights Watch), 2003. *Aceh Under Martial Law: Inside the Secret War*. Human Rights Watch, New York.

[18] UN (United Nations), 2003a. "Statement attributable to the Spokesman for the Secretary-General on Indonesia (Aceh)" (May 19, 2003). United Nations, New York; UN, 2003b. "Statement attributable to the Spokesman for the Secretary-General on the situation in Aceh, Indonesia," (May 29, 2003). United Nations, New York.

[19] UN, 2003b, *op cit*.; United Nations Peacemaker, 2005. "Memorandum of Understanding between the Government of the Republic of Indonesia and the Free Aceh Movement" (August 15, 2005).

[20] United Nations Peacemaker, 2005, *op cit*.; RI (The Government of the Republic of Indonesia), 2006. Undang-Undang No11/2006 tentang Pemerintahan Aceh.

[21] Agus, M.H.S., 2025. "Update Bencana Aceh, rumah rusak terdampak bencana 106.058 unit," Antara News Aceh (December 16, 2025).

indicating that Aceh's disaster footprint was spatially broader across settled areas even as the fatality burden was shared substantially by the other two provinces.[1] In practical terms, this is the difference between "many communities underwater at once" versus "fewer communities, but with higher lethality where landslides and flash flows struck."

A second province-level lens is reconstruction and recovery cost. Senior officials, as reported by Reuters, estimated recovery needs of about 25.41 trillion rupiah for Aceh, compared with 12.88 trillion rupiah for North Sumatera and 13.52 trillion rupiah for West Sumatera (51.82 trillion rupiah total).[2] Aceh therefore represents about 49 percent of the recovery financing requirement across the three provinces, implying that the built-environment and infrastructure replacement burden in Aceh is not only humanitarian but also macro-fiscal in scale.[2]

1.4 The Short Term Relief

The first phase of response was shaped less by "what should be done" than by a simple operational constraint: large parts of the affected area were intermittently cut off. As roads and bridges failed, the response had to prioritize life-saving evacuation and basic survival needs while simultaneously re-establishing access. The Province of Aceh formalized this posture through an emergency response status and its extension in mid-December 2025, which provided the administrative basis for accelerated mobilization, inter-agency tasking, and emergency spending.[22]

Within that emergency framework, government actions concentrated on five immediate functions. The National Search and Rescue Agency (Badan Nasional Pencarian dan Pertolongan Nasional, Basarnas) focused on evacuating people from isolated locations and sustaining search-and-rescue operations where access allowed. Reporting from 30 November 2025 indicates that operations were oriented toward hard-to-reach sites and that evacuations reached into the thousands, underscoring how quickly the emergency became an access-and-mobility problem as much as a hydrological one.[23]

Emergency logistics were pushed through alternative routes when land corridors were unreliable. The National Disaster Management Agency (Badan Nasional Penanggulangan Bencana, BNPB) sent 27 tons of relief supplies and evacuation equipment by sea on 30 November 2025 to reach five districts where land access had not fully recovered.[24] Analytically, this is an important signal: once the response depends on sea lift for last-mile reach, relief delivery becomes highly sensitive to port capacity, onward transport, and coordination at docking points — and relief effectiveness is often determined by distribution management after arrival rather than by the volume shipped.

Immediate food security and shelter support were scaled through mass feeding and essential household items. The Ministry of Social Affairs (Kementerian Sosial, Kemensos) reported establishing 28 public kitchens (dapur umum) across Aceh and neighboring provinces, with production on the order of 100,000 packed meals per day and a stated service coverage of around 50,000 evacuees.[25] In practice, this kind of response stabilizes displacement sites quickly, but it also implies a continuous supply-chain requirement (fuel, rice, clean water, cooking facilities) that becomes fragile if access remains uncertain or warehouses are depleted.

Water, sanitation, and hygiene (WASH) became a frontline health intervention, not a secondary service. At the district level, the Regional Disaster Management Agency (Badan Penanggulangan Bencana Daerah,

[22] Pemerintah Aceh, 2025. Keputusan Gubernur Aceh Nomor 300.2/1446/2025 tentang Penetapan Perpanjangan Status Keadaan Tanggap Darurat Bencana Hidrometeorologi di Aceh Tahun 2025.
[23] Agus, M.H.S., 2025. "Basarnas fokus jangkau masyarakat terjebak banjir di Aceh." *Antara News* (November 30, 2025).
[24] "BNPB ships 27 tons of relief supplies to inaccessible Aceh districts." *Antara News* (November 30, 2025).
[25] Irda, S., 2025. "Kemensos Dirikan 28 Dapur Umum Layani 50 Ribu Korban Banjir Sumatera." *detik.com* (December 1, 2025). https://news.detik.com/berita/d-8238173/kemensos-dirikan-28-dapur-umum-layani-50-ribu-korban-banjir-sumatera (accessed on December 22, 2025).

BPBD) of Nagan Raya documented the distribution of 8,000 liters of clean water on 28 November 2025, reflecting early recognition that household water sources were disrupted or contaminated.[26] At the national level, the Ministry of Public Works (Kementerian Pekerjaan Umum, Kementerian PU) reported deployments of water and sanitation facilities to support basic service restoration, including in Aceh Tamiang.[27] The public-health logic is straightforward: when clean water and sanitation are not stabilized early, evacuation sites predictably face spikes in skin disease, acute respiratory infections, diarrhea, and other preventable conditions.

Health services were expanded through both public health logistics and mobile clinical capacity. The Ministry of Health (Kementerian Kesehatan, Kemenkes) emphasized that post-disaster health logistics should include hygiene kits and emergency kits — not only medicines — as a core disease-prevention measure in affected provinces including Aceh.[28] Complementing this, a naval hospital ship, KRI dr. Soeharso 990, arrived to provide medical services for flood-affected communities in Aceh Utara and surrounding areas, adding surge capacity where routine facilities and supply chains were under pressure.[29]

Alongside state action, communities and civil society helped close the "last-mile" gap — particularly where formal logistics could reach district centers but struggled to penetrate isolated highland settlements. A volunteer network in the Gayo highlands reported physically carrying 12 tons of rice into areas that remained isolated after floods and landslides.[30] Digital fundraising also accelerated rapid mobilization of cash support; as of 3 December 2025, *Kitabisa* reported approximately Rp31 billion raised through verified campaigns for the broader Sumatra response, including Aceh-linked efforts.[10]

One of the most visible examples of frontline solidarity was Ferry Irwandi's decision to pair rapid fundraising with hands-on distribution. Through a 24-hour livestream, he mobilized more than Rp10.37 billion from 87,605 donors, then framed his role not as a distant benefactor but as a "courier" prioritizing remote and isolated communities that were least likely to be reached quickly by formal relief chains.[31] In practical terms, this helped convert public empathy into time-critical purchasing power and credible last-mile delivery when access constraints and information gaps were still severe. As conditions began to stabilize, he also pushed an early-recovery innovation by using empty return legs of relief flights to send roughly 10 tons of Aceh chili to Jakarta — an attempt to prevent post-disaster income collapse among farmers while keeping humanitarian logistics moving in the opposite direction.[32]

Farwiza "Wiza" Farhan positioned her work as both immediate relief and real-time diagnostics of what was failing on the ground. Through Yayasan Hutan Alam dan Lingkungan Aceh (HAKA), she helped keep civilian aid moving when conventional delivery channels became a bottleneck — including rerouting community shipments from air freight to overland trucking after flights prioritized official cargo, and then mapping

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[26] Iskandar, T.D., 2025. "BPBD Nagan Raya distribusi 8.000 liter air bersih untuk korban banjir." *Antara News* (November 28, 2025).
[27] Cakti, A., 2025. "Kementerian PU kirim bantuan sarana air bersih ke Aceh Tamiang." *Antara News Jawa Timur* (December 7, 2025).
[28] Muhawarman, A., 2025. "Logistik Kesehatan Tak Hanya Obat, Hygiene Kit dan Emergency Kit Diperlukan Pasca Bencana." Kementerian Kesehatan (December 16, 2025). https://www.kemkes.go.id/eng/logistik-kesehatan-tak-hanya-obat-hygiene-kit-dan-emergency-kit-diperlukan-pasca-bencana (accessed on December 22, 2025).
[29] "Gratis, KRI DR Soeharso 990 siap layani kesehatan korban banjir Aceh." *Antara Video* (December 7, 2025). https://www.antaranews.com/video/5291806/gratis-kri-dr-soeharso-990-siap-layani-kesehatan-korban-banjir-aceh (accessed on December 22, 2025).
[30] Fajri, R., 2025. "Relawan peduli Gayo pikul 12 ton beras ke daerah terisolir Aceh." *Antara News* (December 2025).
[31] Naufal, I., 2025. "Galang Donasi 24 Jam, Ferry Irwandi Kumpulkan Rp10,3 Miliar untuk Korban Banjir Sumatera," *Inilah.com* (December 2, 2025). https://www.inilah.com/galang-donasi-24-jam-ferry-irwandi-kumpulkan-rp103-miliar-untuk-korban-banjir-sumatera (accessed on December 22, 2025).
[32] Nuranisa, A., 2025. "6 Potret Aksi Ferry Irwandi Kirim Cabai Aceh ke Jakarta, Jadi Jembatan Ekonomi," *Liputan6.com* (December 18, 2025). https://www.liputan6.com/showbiz/read/6239762/6-potret-aksi-ferry-irwandi-kirim-cabai-aceh-ke-jakarta-jadi-jembatan-ekonomi (accessed on December 22, 2025).

distribution across multiple affected districts to reduce blind spots in last-mile delivery.[33] At the same time, she used her public voice to highlight that "stabilization" claims were premature because isolation, communications disruption, and basic energy scarcity (including dwindling generator fuel) were still shaping who could be reached and how fast.[34] In effect, her intervention strengthened short-term relief in two ways: pushing supplies into the field despite logistics constraints, while also making the access-and-energy constraints visible as the binding limitations of the emergency response.[35]

The analytical takeaway is that community-led initiatives functioned as a parallel distribution mechanism, often converting generalized public solidarity into targeted delivery when formal access constraints persisted.

1.5 The Problems with Governance

Aceh's floods should be read not only as a hydrometeorological shock, but as a governance stress-test of how Indonesia manages land rents in watersheds — because the fastest way to turn extreme rainfall into catastrophe is to allow (or quietly tolerate) land-use change that contradicts ecological function, especially in steep ridge-to-river systems where upstream decisions translate into downstream inundation. The political economy problem is well-known: forests and riparian buffers generate public benefits (flow regulation, sediment control), while clearing and conversion generate private, monetizable rents — creating constant incentives for regulatory capture, "permit laundering," and selective enforcement. In late-2025, the Ministry of Forestry itself explicitly framed the Aceh–North Sumatera flood emergency as a moment to evaluate policy bias that has leaned too far toward economic extraction, while also signaling a harder enforcement line — including investigations of timber "log runs" observed during floods, tighter oversight of land-use change, and a shift toward corrective action in the most exposed watersheds.[36]

1.6 The Unfortunate Responses from Public Officials

In Aceh's first days after the floods, public communication became part of the relief system — and several official statements instead worked like sand in the gears. When senior disaster officials framed the catastrophe as "mencekam" (terrifying) mainly because it was "berseliweran di media sosial" (circulating on social media), the message was received not as reassurance but as denial, especially by families who were still cut off from roads, power, and basic supplies. The problem was not simply one phrase; it was the implied hierarchy of reality — that what officials could see (a moment without rain, a press visit, a partial reopening of access) mattered more than what survivors were living through in places that remained unreachable.[37]

The confusion deepened when the same leadership later apologized for underestimating the scale of devastation. A correction is better than stubbornness, but in a disaster it also signals that earlier assessments — and therefore earlier decisions — may have been wrong. For communities in Aceh, these oscillations were not "PR issues." They affected trust, the

[33] Puspa, A., 2025. "HAKA Salurkan Bantuan untuk Korban Bencana di Aceh Lewat Jalur Darat," *Media Indonesia* (December 7, 2025).
[34] Dewi, S., 2025. "Tangis Aktivis Aceh Saat Kondisi Disebut Membaik Usai Banjir Sumatra," *IDN Times* (December 3, 2025).
[35] Puspa, 2025, *op cit*.; Dewi, 2025, *op cit*.
[36] "Menhut Sampaikan Duka Cita Mendalam Bencana Banjir Yang Melanda Aceh–Sumut, Jadikan Momentum Evaluasi Kebijakan," Press Release, Kementerian Kehutanan (Ministry of Forestry of the Republic of Indonesia) (November 30, 2025). https://www.kehutanan.go.id/pers/menhut-sampaikan-duka-cita-mendalam-bencana-banjir-yang-melanda-aceh-sumut-jadikan-momentum-evaluasi-kebijakan (accessed on December 25, 2025).
[37] Ritonga, R.H., 2025. "Kepala BNPB soal Banjir Sumatera Belum Bencana Nasional: Mencekamnya di Medsos," *Detiknews* (November 29, 2025). https://news.detik.com/berita/d-8235025/kepala-bnpb-soal-banjir-sumatera-belum-bencana-nasional-mencekamnya-di-medsos (accessed on December 22, 2025); Safitri, R.D., 2025. "Ketika Pernyataan Pejabat Malah Memperkeruh Situasi Bencana," *tirto.id* (December 2, 2025). https://tirto.id/ketika-pernyataan-pejabat-malah-memperkeruh-situasi-bencana-hmZZ (accessed on December 22, 2025).

urgency of mobilization, and the public's willingness to believe that the state was accurately reading the field.[38] The same mismatch appeared in the national narrative of "conditions being under control" — statements that may reflect what a leader sees at a handful of sites, but can clash sharply with testimony from civil society and local networks describing isolation, missing people, and stalled assistance.[39]

Sectoral agencies also stumbled. The controversy over log piles carried by floodwaters illustrated how quickly technical explanations can sound like deflection when they arrive before credible investigation. In public perception, early framing that leaned toward natural causes or legal sources — while social media circulated videos of neatly cut logs — felt dismissive, and the subsequent clarifications only reinforced the sense of an improvised narrative rather than transparent fact-finding.[40] Even explanations that are operationally valid can land as condescending if they are not paired with empathy and accountability: the Panglima Tentara Nasional Indonesia (TNI) explanation for rice scattered after being dropped from a helicopter may be logistically understandable, yet the optics of people picking grains from the ground demanded a different communication posture — one that first acknowledges dignity, then explains constraints, then states corrective action.[41]

What these moments share is a failure to treat speech as an emergency instrument. In a province like Aceh — where geography, broken infrastructure, and layered authority already slow response — confusing or defensive statements do not merely irritate; they can redirect blame onto victims, dampen solidarity, and fracture coordination at the exact time coherence is needed most.[42] A disciplined approach is straightforward: lead with empathy, communicate uncertainty honestly (what is known, unknown, and being verified), align all spokespersons to one shared data picture, and elevate credible local voices as part of the official narrative rather than as an inconvenient rebuttal.[43]

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[38] "Kepala BNPB Minta Maaf soal Bencana di Tapsel: Saya Tidak Mengira Sebesar Ini," *Liputan6.com* (December 1, 2025a). https://www.liputan6.com/news/read/6225751/kepala-bnpb-minta-maaf-soal-bencana-di-tapsel-saya-tidak-mengira-sebesar-ini (accessed on December 22, 2025).
[39] Dewi, S., 2025, *op cit*.; Rochman, F., 2025. "Dua hari tinjau lokasi bencana, Prabowo: Keadaan terkendali," *Antara News* (December 13, 2025).
[40] "Kontroversi Pernyataan Kemenhut soal Asal Muasal Gelondongan Kayu Besar Terbawa Arus Banjir di Sumatera," *Liputan6.com* (December 1, 2025b); Safitri, 2025, *op cit*.
[41] Marison, W., 2025. "Panglima jelaskan penyebab tercecernya beras bantuan korban banjir," *Antara News* (December 3, 2025).
[42] Ritonga, 2025, op cit.; Safitri, 2025, *op cit*.; *Liputan6.com*, 2025b, *op cit*.
[43] Safitri, 2025, *op cit*.; Dewi, 2025, *op cit*.; Rochman, 2025, *op cit*.

2
The Anatomy of Destruction

2.1 Spatial Anatomy of Destruction within Aceh

East-coast and northeast lowland belt: large-area inundation and settlement exposure. Aceh's most severe housing impacts concentrated in the low-elevation belt where rivers overtop into broad floodplains and where settlements, roads, electricity distribution, and service nodes cluster. The clearest quantitative example is North Aceh, where a single regency-level update recorded 117,291 houses inundated, with at least 38,053 houses categorized as damaged (heavy, moderate, or light), plus 1,219 houses reported swept away. The same update reported 27 subdistricts and 852 villages inundated and a disaster-affected population of 428,271 people, with 71,637 displaced.[44]

Two implications follow directly from these numbers. First, the "inundated-to-damaged" ratio is extremely high. Even if only one-third of inundated houses were classified as damaged, the remaining two-thirds still imply large-scale non-structural losses (furniture, appliances, school materials, small tools, food stocks) and months of de-mudding, drying, and repair. This is a major reason why displacement in Aceh can dwarf that of neighboring provinces: when floodwater and mud persist across many villages at once, return is delayed not only by water levels but also by sanitation, debris, and service restoration constraints.

Second, the "swept away" figure (1,219 houses) indicates that within the wider inundation footprint, there were high-energy channels capable of structural removal. The same update notes one hamlet (Dusun Lhok Pungki, Gampong Gunci, Sawang) was effectively erased by the flow, underscoring the micro-spatial variability of hazard intensity even inside one regency.[45]

Central-highland access belt: road breaks, isolation economics, and price inflation. Damage in the central highlands manifests less as mass inundation and more as access failure — road breaks, landslides, and logistics collapse — producing acute "isolation economics". In Aceh Tengah and Bener Meriah, a field account described farmers walking up to four hours while carrying 25–33 kilograms of chili to reach markets because road access was cut, including a roughly 20-kilometer stretch traversed on foot under muddy, landslide-affected conditions. The same account documents a rapid food price shock: rice reportedly rose from about 230,000 rupiah per sack pre-disaster to 400,000–500,000 rupiah post-disaster (an increase of roughly 74–117 percent), while chili prices diverged sharply between production areas and accessible markets (about 10,000 rupiah/kg locally versus 40,000 rupiah/kg in Lhokseumawe).[46]

This matters for "damage accounting" because household welfare losses are not limited to destroyed assets. When roads fail, the damage function propagates through (1) higher food prices in isolated communities, (2) forced distress sales of produce at low farmgate prices, and (3) delayed restoration because construction materials and machinery cannot move reliably.

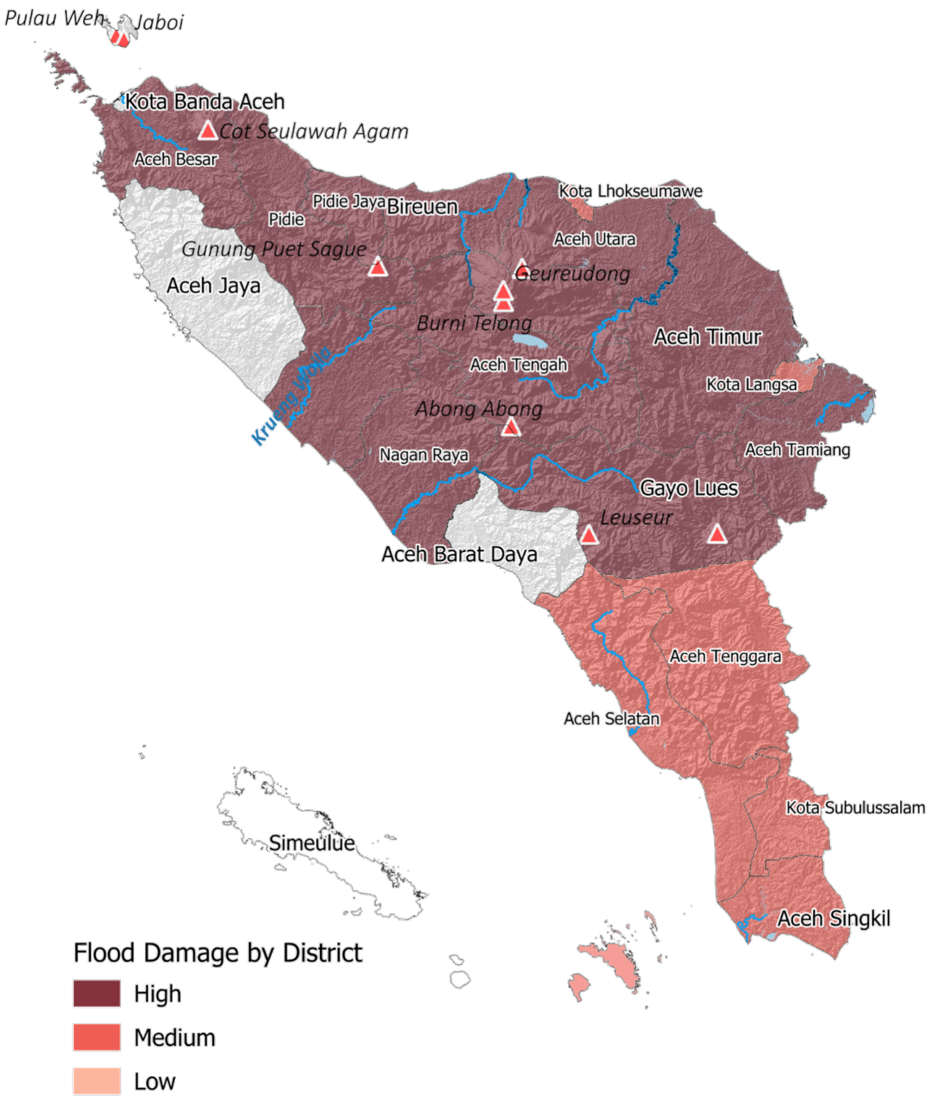
2.2 Regency-by-Regency Damage Profile for Key Hotspots

North Aceh: the provincial epicenter of housing exposure. North Aceh alone plausibly represents roughly one-third of Aceh's damaged housing stock, given the regency's reported 38,053 damaged houses (by severity classification) against the province-wide 106,058.[47] Beyond housing, the regency update explicitly identifies

[44] Ifdhal, M., 2025. "Sebanyak 1.219 rumah hilang disapu banjir bandang di Aceh Utara," *Antara News Aceh* (December 17, 2025).
[45] *ibid*.

[46] Qonita, 2025. "Update Bencana Aceh, Petani pikul cabai lewati jalur ekstrem dari Ketol ke Lhokseumawe," Antara News Aceh (December 13, 2025).
[47] Agus, 2025, *op cit*.; Ifdhal, 2025, *op cit*.

continuing constraints in electricity and communications, which in turn impede logistics distribution, clean-water availability, and systematic damage assessment.[48]



Indicators	Low	Medium	High
Human impacts			
Death	<50	51-99	≥100
Missing	<100	100-2999	≥3000
Injured	<100	100–2999	≥3000
Evacuated	<1000	1000-6999	≥7000
Environmental damages			
Damaged houses	<500	500-2999	≥3000
Damaged infrastructures	<50	50–499	≥500
Damaged land (ha)	<100	100-1999	≥2000

Figure 2.1. The extent of damages in Aceh. Most areas have been considered highly damaged with a few in the southern area considered moderately damaged.

[48] Ifdhal, *op cit*.

High	Medium	Low
Aceh Barat, Aceh Besar, Aceh Tamiang, Aceh Tengah, Aceh Timur, Aceh Utara, Bener Meriah, Bireuen, Gayo Lues, Nagan Raya, Pidie, Pidie Jaya	Aceh Selatan, Aceh Singkil, Aceh Tenggara, Kota Langsa, Kota Lhokseumawe, Kota Subulussalam	

Table 2.1. The extent of damages among kabupatens (districts) in Aceh. See the map in Figure 2.1 for where they are.

East Aceh: agriculture and plantation systems as the main loss channel. In East Aceh, agricultural and plantation losses appear as large contiguous production landscapes damaged by prolonged inundation and soil disruption. One government update reported 11,010 hectares of rice fields inundated, alongside impacts to irrigation networks, paddy bunds, and farm access roads, which together can delay replanting even after surface water recedes.[49] Another update quantified plantation impacts at 5,060 hectares affected, with 4,510 hectares of smallholder oil-palm replanting area damaged (moderate to heavy), and provided subdistrict-level damaged area estimates spanning Birem Bayeun, Rantau Selamat, Ranto Peureulak, Banda Alam, Peureulak, Peureulak Timur, Idi Tunong, Julok, Indra Makmu, Pante Bidari, and Peunaron.[50]

Aceh Tamiang: depth, duration, and water insecurity. A field narrative from Karang Baru (Desa Pahlawan) describes flood depths approaching three meters, multi-day isolation with power outages and loss of telecommunications signal, and households filtering and drinking floodwater to survive. Even without a complete quantitative inventory in that account, the damage signature is clear: water and sanitation failure becomes a primary driver of risk (disease transmission, child health impacts, and prolonged displacement), and the hazard is not only "water in houses" but "loss of safe water systems" at community scale.[51]

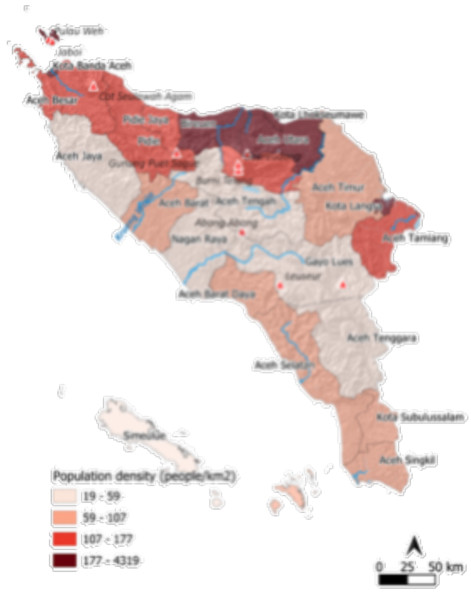


Figure 2.2. Population distribution and density across Aceh.

2.3 The Fatal Combination of Flood Intensity and Population Density

Read together, the maps on Figure 2.1and Figure 2.2 show a clear north-coast exposure belt where high disaster extent intersects with relatively high population density. The highest damage class covers much of the province's northern and northeastern arc — Aceh Besar (including the Banda Aceh metropolitan area), Pidie, Pidie Jaya, Bireuen, Aceh Utara (including the Lhokseumawe area), and continuing eastward through Aceh Timur and Aceh Tamiang. This same arc contains many of Aceh's densest districts (notably the 172–

[49] Agus, M.H.S., 2025. "Pemkab: 11.010 hektare sawah di Aceh Timur terendam banjir," *Antara News* (December 7, 2025).
[50] Agus, M.H.S., 2025. "Ribuan hektare lahan peremajaan sawit Aceh Timur rusak akibat banjir," *Antara News* (December 22, 2025),
[51] Hasanah, N., 2025. "Penyintas bencana di Aceh Tamiang minum air banjir untuk bertahan hidup," Antara News Aceh (December 3, 2025).

Province	Death	Displaced	Destroyed Homes	Destroyed Land
Aceh	511	429,577	133,634	104,072
North Sumatera	365	10,335	12,033	15,658
West Sumatera	262	9,935	25,712	10,335
Total	**1,138**	**449,864**	**171,379**	**130,065**

Table 2.2. Aceh suffers the most extent of damages among the three affected provincees. Source; "Dashboard Penanganan Darurat Banjir dan Longsor Propinsi Aceh, Sumatera Utara, dan Sumatera Barat Tahun 2025", Update per 27 Desember 2025. BNPB (Badan Nasional Penanggulangan Bencana). https://gis.bnpb.go.id/bansorsumatera2025/ (accessed on December 27, 2025).

4,319 people per square kilometer class clustered along the north coast, plus adjacent districts in the 102–172 class). In practical terms, this overlap converts a hydrological shock into an outsized social and economic shock: the same inundation footprint translates into far larger absolute numbers of affected households, higher displacement loads, more severe service interruptions (health, education, water, and electricity), and larger cascading losses because the affected districts sit on the main logistics and labor corridor of the province.

At the same time, the maps also indicate that high damage is not confined to dense areas, which is analytically important for separating where impacts concentrate from where risk is produced. Several interior and upland districts categorized in the lowest density class (19–59 people per square kilometer) — including Aceh Tengah and Gayo Lues — still fall in the high-damage category, suggesting that severe impacts can occur where exposure is low when geomorphology and watershed connectivity are unfavorable (steep headwaters feeding into settled floodplains, constrained valleys, and river corridors that rapidly transmit flood peaks and sediment).

Conversely, portions of the west and offshore areas with low density — such as Aceh Jaya, Aceh Barat Daya, and Simeulue — appear in the low-damage class, underscoring that sparse settlement does not automatically mean high impact, and that local hydrological settings and upstream land conditions matter.

The implication for interpreting disaster outcomes is that population density is best treated as an impact multiplier (how many people and assets are in harm's way), while the spatial pattern of high damage across both dense coastal districts and sparsely populated uplands points to watershed-scale drivers that determine where flood energy is generated and how it is delivered downstream.

2.4 Cross-Province Interpretation

When placed side-by-side with North Sumatera and West Sumatera, Aceh's distinctive damage profile is the combination of (a) province-wide displacement at extreme scale and (b) severe housing destruction concentrated in particular regencies (with North Aceh as a dominant hotspot).[52]

Meanwhile, Reuters' recovery-cost estimates indicate that Aceh's reconstruction requirement is of similar order to the combined burden of the other provinces, despite Aceh's much larger displacement count — consistent with a narrative where Aceh's losses span both human settlement

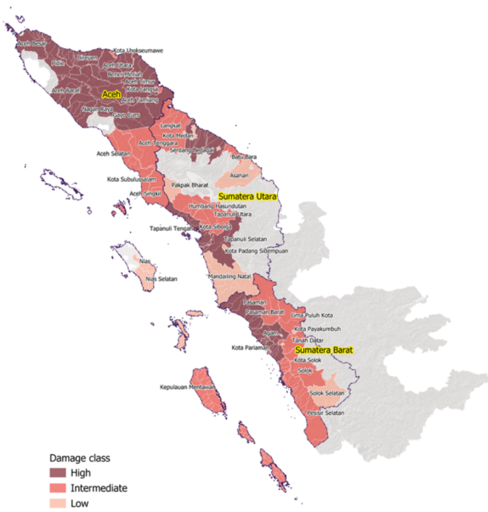


Figure 2.3. Aceh suffers the most extent of damages among the three provinces affected by the floods. The scale of damages is the same as that in Figure 2.1.

[52] Agus, 2025, *op cit*.; Ifdhal, 2025, *op cit*.

exposure and broad infrastructure rehabilitation, not only isolated slope failures.[53]

At the national level, *Reuters* reported a total death toll exceeding 1,000 and a missing count exceeding 200 by mid-December, highlighting that continued search-and-recovery and data reconciliation remained integral to the damage picture even weeks after the initial events.[54]

The spatial signal is important: these subdistricts map onto a wide east-coast production belt, meaning the shock is not a single "failed harvest" but a broad-based disruption of multiple commodity nodes (rice, oil palm, cocoa) with downstream implications for household incomes, milling and transport services, and local government revenue.

[53] Teresia, 2025, *op cit*.
[54] Widianto, S., and S. Sulaiman, 2025. "Indonesia president expects flood-stricken Sumatra to return to normal in 2-3 months as death toll exceeds 1,000," *Reuters* (December 15, 2025).

3
A Remaining Critical Forest Stronghold

3.1 One of a Few Forest Stronghold in Indonesia

As of the end of 2023, Aceh still retained about 2.94 million hectares of forest cover, about 55 percent of the province's land area. HAKA also records that forest loss continues despite Aceh's comparatively strong baseline — with 8,906 hectares of forest cover lost in 2023 alone — and, critically, about 4,502 hectares of that loss occurred inside the Leuser ecosystem, indicating that degradation pressure is not confined to peripheral zones but is also encroaching into the province's most important ecological backbone.[55] This is the central strategic tension for Aceh: its forests remain large enough to anchor a development model based on ecological security and landscape resilience, yet incremental clearing continues to erode precisely the hydrological and biodiversity functions that make Aceh exceptional.

The vast majority of Aceh's most intact and biodiverse forests sit within the Leuser Ecosystem (Kawasan Ekosistem Leuser), a roughly 2.6 million-hectare interconnected

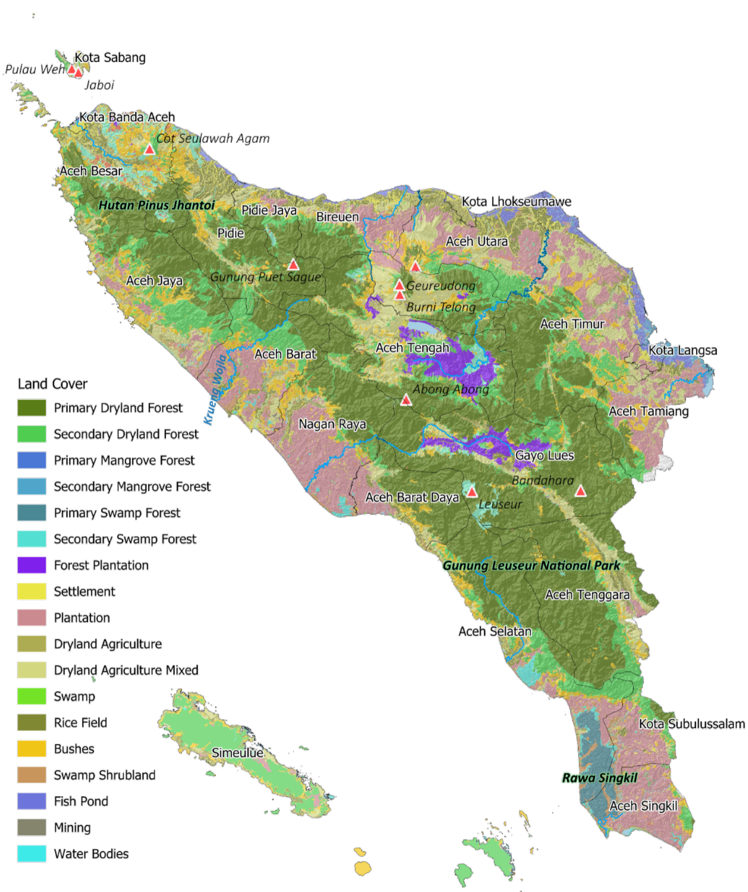


Figure 3.1. Forest cover in Aceh in 2021. Most of the cover is within the Gunung Leuser National Park and the surrounding Gunung Leuser Ecosystem.

[55] "HAKA: Aceh Loses 8,906 Hectares of Forest Cover in One Year," Yayasan HAKA, July 16, 2024. https://haka.or.id/en/haka-aceh-loses-8906-hectares-of-forest-cover-in-one-year-2/ (accessed on December 22, 2025).

landscape spanning Aceh and North Sumatra that has been recognized in Indonesian policy as a nationally strategic environmental area.[56] Within this broader Leuser mosaic, Gunung Leuser National Park (Taman Nasional Gunung Leuser) forms the core protected-area nucleus, covering about 1,092,692 hectares across the two provinces, and is one of the three component parks that make up the United Nations Educational, Scientific and Cultural Organization (UNESCO) World Heritage property Tropical Rainforest Heritage of Sumatra.[57] In practical terms, this nested structure matters because it is not only about iconic endangered wildlife habitat — orangutans, tigers, elephants, and rhinos — but also about maintaining a contiguous, functioning watershed system: when forest integrity is maintained across Leuser's protected areas and surrounding production and use zones, Aceh retains a province-scale "safety infrastructure" that buffers extreme rainfall, reduces sediment and debris flows, and stabilizes slopes; when it is fragmented, disaster risks and economic losses rise downstream.[58]

3.2 The Remaining Forest Cover in Aceh

The land-cover map in Figure 3.1 shows Aceh's forest estate as a still-large but increasingly edge-fragmented block that tracks the province's mountainous spine and headwaters. Primary dryland forest remains most continuous in the southeast, aligned with the Gunung Leuser National Park landscape, extending across the uplands of Gayo Lues and Aceh Tenggara and northward into the central highlands (Aceh Tengah) where it interlocks with secondary dryland forest along the mid-slope transition. A second, important forest concentration sits in the west-central interior, spanning the Aceh Jaya–Pidie–Aceh Besar hinterland around the Gunung Puet Sague massif and adjoining uplands. These two interiors function as Aceh's main "water towers": the largest, most contiguous forest blocks sit where slopes are steepest and river networks are born, which is precisely where forest cover has the highest leverage over runoff timing, sediment generation, and downstream flood peaks.

Around these core interiors, the map depicts a pronounced lowland conversion ring that compresses forests into the uplands while replacing natural cover in floodplains and coastal plains with plantations, mixed dryland agriculture, settlements, and rice fields. This is especially visible along the north coast corridor from Aceh Besar through Pidie–Pidie Jaya–Bireuen and into Aceh Utara (including the Kota Lhokseumawe area), where non-forest land covers dominate the flatter terrain and forest persists mainly as upland blocks set back from the coast. A similar pattern appears along the east coast from Aceh Timur toward Kota Langsa and Aceh Tamiang, where the coastal plain is largely non-forest and the remaining forest cover is pushed inland into higher ground. In the south, the Singkil lowlands are a distinct wetland system: the map highlights swamp-related land covers around Rawa Singkil, with patches of swamp forest and swamp interspersed with plantations and other non-forest covers, indicating a landscape where hydrology is as important as tree cover.

Across the province, scattered forest plantations are visible in the mid-slope belt (notably around parts of the central highlands and the Aceh Besar uplands), suggesting that even where "tree cover" remains, the structure and hydrological function can differ

[56] "Foto: Indahnya Leuser, Hutan Alami yang Harus Kita Pertahankan," *Mongabay Indonesia* (August 2, 2017). (accessed on December 22, 2025). https://mongabay.co.id/2017/08/02/foto-indahnya-leuser-hutan-alami-yang-harus-kita-pertahankan/ (accessed on December 22, 2025); "Minister of Environment and Forestry: 95% of SM Rawa Singkil Peat Forest in Aceh Remains Intact," (press release text republished by HAKA), (August 8, 2024). (diakses pada December 22, 2025). https://haka.or.id/en/minister-of-environment-and-forestry-95-of-sm-rawa-singkil-peat-forest-in-aceh-remains-intact/ (accessed on December 22, 2025).

[57] "Gunung Leuser National Park," ASEAN Heritage Parks, ASEAN Centre for Biodiversity. (accessed on December 22, 2025). https://www.aseanbiodiversity.org/asean-heritage-parks/gunung-leuser-national-park/ (accessed on December 22, 2025); "Tropical Rainforest Heritage of Sumatra," UNESCO World Heritage Center. https://whc.unesco.org/en/list/1167%26lang%3Den (accessed on December 22, 2025).

[58] HAKA, 2024, *op cit*.; United Nations Educational, Scientific, and Cultural Organization (UNESCO) World Heritage, *op cit*.

materially from primary or older secondary forests.

3.3 The Gunung Leuser National Park as the Ecological "Anchor" of Aceh

Gunung Leuser National Park (GNLP, Taman Nasional Gunung Leuser, TNGL) and the broader Leuser Ecosystem (Kawasan Ekosistem Leuser, KEL) function as Aceh's ecological anchor because they concentrate the province's remaining contiguous "mountain-to-lowland" rainforest system in the Bukit Barisan spine while still retaining critical lowland components (including peat swamps). GLNP is part of the UNESCO-listed Tropical Rainforest Heritage of Sumatra, which is globally significant not only for sheer species richness (for example, the wider heritage property is documented as supporting thousands of plant species and hundreds of mammal and bird species) but also because Leuser remains one of the last landscapes where multiple critically endangered "wide-ranging" species persist in the same ecological network.[59].

In Aceh's geography, that anchor is most visible in the southeast and south: the large, continuous forest block spanning Aceh Tenggara and Gayo Lues and extending toward Aceh Selatan forms the highland core (headwaters, steep-slope protection, and habitat refugia), while the ecological integrity of the whole system depends on what happens at the forest edge and in the lowlands that connect to it. This is why the legal framing matters: national law explicitly assigns Aceh responsibility for protection, restoration, and sustainable use of KEL and prohibits the issuance of forest utilization licenses within it — a strong statutory intent that, in practice, is only as effective as boundary governance and enforcement.[60]

The threat profile is spatially legible and increasingly "infrastructure-led." UNESCO's World Heritage Committee decisions on the Tropical Rainforest Heritage of Sumatra repeatedly flag the combined risks of encroachment and ecological isolation, and they identify specific projects in and around GLNP and the Leuser landscape — including the Muara Situlen–Gelombang road alignment cutting through GLNP and a cluster of proposed hydropower dams (Soraya, Jambo Aye, Kluet, and Samarkilang) — because linear infrastructure tends to convert intact forest into an accessible frontier, accelerating edge effects, land speculation, and follow-on clearance.[61] The result is a familiar pattern in Aceh's spatial political economy: the highland core may remain forested, but the functional landscape (wildlife corridors, watershed buffers, and flood-moderation services) is weakened where plantation belts, road corridors, and settlement expansion press directly against the protected-area boundary — notably along the north and northeast plains and foothills (Bireuen–Aceh Utara–Aceh Timur–Aceh Tamiang) and along parts of the west and southwest lowlands (Aceh Barat–Nagan Raya–Aceh Barat Daya), where non-forest land covers and plantation matrices are already extensive.

The most acute and actionable encroachment risks sit in Aceh's lowland peat systems that are ecologically tied to Leuser but politically and operationally governed as "convertible" frontiers. Rawa Singkil (Aceh Singkil) is a prime example: reporting based on satellite interpretation and field-linked investigation describes sustained illegal forest loss and the establishment of oil palm within the protected reserve over recent years, indicating that the lowland peat margin is being steadily transformed even where formal protection exists.[62] Tripa's peat swamp landscape on the west/southwest side of

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[59] "Tropical Rainforest Heritage of Sumatra". UNESCO World Heritage Centre. https://whc.unesco.org/pg.cfm?cid=31&id_site=1167 (accessed on December 26, 2025); "Leuser Ecosystem", Re:wild. https://www.rewild.org/wild-about/leuser-ecosystem (accessed on December 26, 2025)..

[60] RI, 2006. Undang-Undang Republik Indonesia No. 11/2006 tentang Pemerintahan Aceh (Pasal 150).

[61] "Tropical Rainforest Heritage of Sumatra", UNESCO, *op cit*.

[62] "RAN Unveils Alarming Findings on Illegal Deforestation in Indonesia's Rawa Singkil Wildlife Reserve Using Unprecedented Satellite Imagery," Press Release, RAN (Rainforest Action Network) (November 10, 2024). https://www.ran.org/press-releases/ran-unveils-alarming-findings-on-illegal-deforestation-in-indonesias-rawa-singkil-wildlife-reserve-using-unprecedented-satellite-imagery/ (accessed on December 26, 2025).

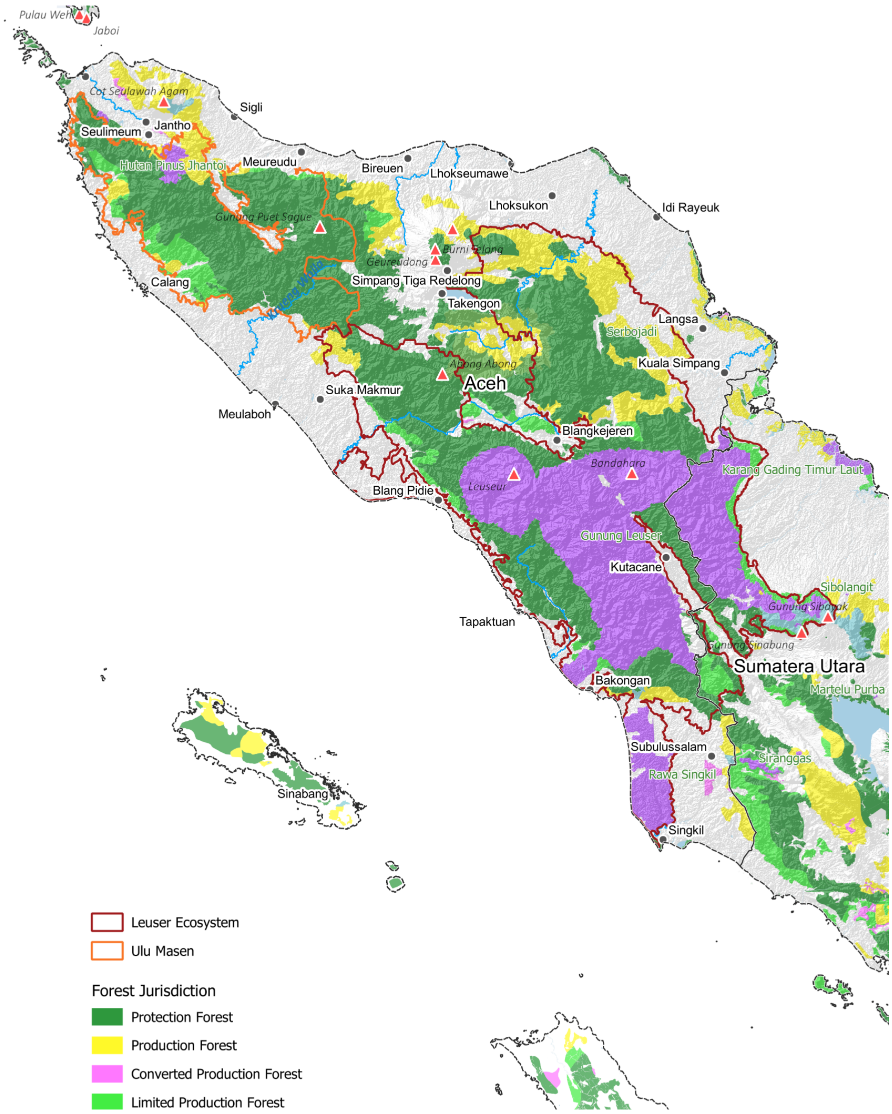

Figure 3.2. The Gunung Leuser National Park and the broader Leuser Ecosystem (Kawasan Ekosistem Leuser).

Aceh (around Nagan Raya and Aceh Barat Daya) is another critical pressure point: analysis of the Tripa case shows how plantation-driven clearing in peat forests can proceed through permitting and governance failures, triggering long, contested enforcement processes while the ecological damage (hydrological disruption, subsidence risk, loss of fire resilience, and habitat contraction) accumulates quickly.[63] These peat lowlands matter disproportionately because they are not "optional add-ons" to the Leuser system; they are where carbon storage, biodiversity, and flood-buffering functions are concentrated — and where hydrological degradation (drainage canals, compaction, loss of swamp forest cover) can lock in long-term vulnerability.

Rehabilitation priorities therefore need to be framed as targeted, place-based interventions that rebuild landscape function, not just tree cover. In the Singkil and Tripa peat complexes, the first-order rehabilitation task is hydrological: rewetting to raise water tables and reduce drainage-driven oxidation

[63] Ruysschaert, D. and M. Hufty, 2020. "Building an effective coalition to improve forest policy: Lessons from the coastal Tripa peat swamp rainforest, Sumatra, Indonesia," Land Use Policy, 99 (December 2020), 103359.

and fire susceptibility, combined with revegetation using appropriate peat-swamp species and livelihood revitalization strategies that do not depend on drainage-dependent crops.[64]

In practical spatial terms, this means prioritizing canal-blocking and water-control structures across drained peat blocks, restoring peat-swamp forest cover in the most degraded compartments, and hardening protection along the reserve boundary where illegal expansion is occurring (so that "restoration investments" are not immediately re-cleared). In parallel, along the GLNP–KEL upland boundary, rehabilitation should focus on the forest edge and river corridors that connect the Leuser interior to Aceh's settled plains: restoring riparian buffers, stabilizing steep mid-slope mosaics where forest has been thinned into secondary cover, and (critically) protecting and re-vegetating roadsides and corridor pinch-points where fragmentation pressure is highest — consistent with UNESCO's emphasis on restoration in ecologically sensitive areas, wildlife corridors, and roadsides as a condition for preventing further isolation of the system.[65].[2]

3.4 Normalized, No Longer Extreme

Tropical cyclones have long been treated as an anomaly for Indonesia's northern rim because the country sits close to the equator, where the Coriolis force is weaker and typically makes cyclone formation and landfall less likely than in the main tropical-cyclone belts. That is precisely why Tropical Cyclone Senyar was meteorologically unusual: the Indonesian Agency for Meteorology, Climatology, and Geophysics (Badan Meteorologi, Klimatologi, dan Geofisika, BMKG) tracked Senyar forming from a tropical disturbance in the Malacca Strait and, as of November 26, 2025, placing its center near 5.0°N with peak winds around 43 knots (about 80 km/h) and a minimum central pressure of about 998 hPa — a rare low-latitude configuration for a system that then delivered extreme rainfall over northern Sumatra.[66] Yet the climate-crisis implication is not that Indonesia will suddenly become a "normal" cyclone landfall region; it is that when rare systems do form unusually close to Indonesia (or when intense cyclones form in adjacent basins, like Koto in the Philippine Sea), the physics of a warmer ocean–atmosphere system makes their rainfall and flood impacts substantially more severe.

Quantitatively, Senyar's defining hazard in Aceh was torrential rain. A detailed event note from Syiah Kuala University's Tsunami and Disaster Mitigation Research Center (TDMRC), drawing on BMKG station data, reported 24-hour totals across Aceh on November 25–26, 2025 reaching 411 mm (Kuala, Bireuen), 397.4 mm (Karang Baru, Aceh Tamiang), 382 mm (Langsa Baro), and around 376.6 mm (Pasie Raja, South Aceh; and Meureudu, Pidie Jaya).[67] BMKG's weekly outlook for November 28–December 4 further recorded "extreme" daily rainfall totals during November 25–27, including 310.8 mm/day in North Aceh (Aceh Utara), alongside similarly extreme totals elsewhere in Sumatra.[68]

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[64] Ramsar Convention on Wetlands, 2021. *Global Guidelines for Peatland Rewetting and Restoration*, Ramsar Technical Report No. 11. Ramsar Convention Secretariat, Gland; Giesen, W. and E.N.N. Sari, 2018. *Tropical Peatland Restoration Report: the Indonesian Case*. Millennium Challenge Account – Indonesia (Berbak Green Prosperity Partnership), Jakarta.

[65] "Tropical Rainforest Heritage of Sumatra", UNESCO, *op cit*.

[66] Zahro, A.A., 2025. "Siklon Tropis Senyar Terbentuk, BMKG Minta Siaga Cuaca Ekstrem di Aceh dan Sumut," Badan Meteorologi, Klimatologi, dan Geofisika (November 26, 2025). https://www.bmkg.go.id/berita/utama/siklon-tropis-senyar-terbentuk-bmkg-minta-siaga-cuaca-ekstrem-di-aceh-dan-sumut (accessed on December 22, 2025).

[67] TDMRC (Tsunami and Disaster Mitigation Research Center, Universitas Syiah Kuala), 2025. "Extreme Rainfall from Tropical Cyclone Senyar Triggers Widespread Flooding and Infrastructure Damage Across Aceh," TDMRC (November 29, 2025). https://tdmrc.usk.ac.id/2025/11/29/extreme-rainfall-from-tropical-cyclone-senyar-triggers-widespread-flooding-and-infrastructure-damage-across-aceh/ (accessed on December 22, 2025).

[68] Damanik, R.A., 2025. "Prospek Cuaca Mingguan Periode 28 November–4 Desember 2025: Siklon Tropis 'SENYAR' Punah, Gelombang Atmosfer Pengaruhi Cuaca Signifikan di Indonesia," Badan Meteorologi, Klimatologi, dan Geofisika (November 27, 2025). https://www.bmkg.go.id/cuaca/prospek-cuaca-

BMKG's daily rainfall classification (mm/day), rainfall is generally grouped as light (0.5–20), moderate (20–50), heavy (50–100), very heavy (100–150), and extreme (>150 mm/day).[69] Meanwhile, BMKG's Aceh climate profile describes annual rainfall on the order of 2,500 mm/year, with typical monthly totals roughly in the 150–320 mm range (peaking around November–December). A month with 150–320 mm spread over ~30 days implies an average of about 5–11 mm/day (and the annual mean implied by 2,500 mm/year is ~6.8 mm/day).[70] Against that baseline, a 24-hour total of 310–411 mm is on the order of 30–80 times the average day, and it can exceed what Aceh normally receives in an entire month.

These magnitudes matter because they are far beyond what most catchments, drainage networks, and hillslopes can safely absorb — meaning even "short" episodes can translate into flash floods, debris flows, landslides, and cascading infrastructure failure, especially where watersheds are already degraded.

The reason this becomes a "new normal" is that global heating loads the atmosphere and ocean with additional moisture and energy, increasing the likelihood that any given storm (including rare, low-latitude or "indirect impact" cyclones) produces higher rainfall rates than the historical baseline. The Intergovernmental Panel on Climate Change (IPCC) summarizes a key thermodynamic constraint: near-surface air can hold about 7 percent more water vapor for each 1°C of warming, which fuels heavier rainfall when storms organize. For tropical cyclones specifically, the IPCC assessment finds high confidence that tropical cyclone rain rates increase with warming; multi-model assessments project increases on the order of about 14 percent for rainfall rates near the storm for a 2°C warmer world (with a range across studies).[71] Event-based attribution work on the late-November 2025 Asian floods (covering Sri Lanka and the Malacca Strait region, including northern Sumatra) similarly concluded that warmer oceans materially intensified the rainfall potential: Reuters and the Associated Press reported researchers' findings that sea surface temperatures in the relevant region were about 0.2°C above the 1991–2020 average, and would have been about 1°C cooler without human-caused warming — increasing the moisture supply available to storms.[72] In other words, cyclones like Senyar may remain infrequent, but the rainfall extremes they can generate are being systematically "supercharged" by the climate crisis.

Koto illustrates the second pathway by which the "anomaly" becomes operationally normal: indirect impacts. In the same BMKG weekly outlook, Cyclone Koto — tracked at about 65 knots and 975 hPa — was forecast to influence Indonesia not primarily through direct landfall, but through altered wind fields and moisture transport that increase moderate-to-heavy rainfall and drive high waves (up to ~4 meters) across northern Indonesian seas and parts of the Riau Islands (Kepulauan Riau).[73] This is an emerging regional risk pattern: even when cyclones form outside Indonesian waters, a warmer background climate and more energetic atmospheric wave activity can translate those systems into heavier rain episodes and higher coastal/ocean hazards for Indonesia — pushing disaster planning toward a posture

mingguan/prospek-cuaca-mingguan-periode-28-november-04-desember-2025-siklon-tropis-senyar-punah-gelombang-atmosfer-pengaruhi-cuaca-signifikan-di-indonesia (accessed on December 22, 2025).

[69] BMKG (Badan Meteorologi, Klimatologi, dan Geofisika), 2025. *Ikhtisar Cuaca 22 Desember 2025*. Badan Meteorologi, Klimatologi, Geofisika, Jakarta.

[70] "Karakteristik Iklim Aceh", Badan Meteorologi, Klimatologi, dan Geofisika, Informasi Iklim. https://www.bmkgaceh.org/pages/iklim.html (accessed on December 22, 2025).

[71] Trenberth, K.E., P.D. Jones, P. Ambenje, R. Bojariu, D. Easterling, A. Klein Tank, D. Parker, F. Rahimzadeh, J.A. Renwick, M. Rusticucci, B. Soden and P. Zhai, 2007. "Observations: Surface and Atmospheric Climate Change", in *Climate Change 2007: The Physical Science Basis*. Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change [Solomon, S., D. Qin, M. Manning, Z. Chen, M. Marquis, K.B. Averyt, M. Tignor and H.L. Miller (eds.)]. Cambridge University Press, Cambridge and New York.

[72] "Deadly November Asian storms 'supercharged' by climate change, researchers say," *Reuters* (December 10, 2025).; Arasu, S., and A.L. Delgado, 2025. "Ocean warmed by climate change fed intense rainfall and deadly floods in Asia, study finds," *Associated Press News* (December 2025).

[73] Damanik, 2025, *op cit*.

where “rare track” does not mean “rare impact.”

3.5 Aceh Watersheds: Today’s Cost of Past Degradation

Aceh’s watershed system is formally organized under nine Wilayah Sungai (WS, river basin territories) in the government’s river-basin framework. Within those nine WS, Balai Wilayah Sungai Sumatera I publishes an official table that lists the named Daerah Aliran Sungai (watersheds, DAS) under each WS; counting the DAS names in that table yields 151 named DAS for Aceh.[74]

Error! Reference source not found. above s hows the elevation and the relief ratios of watersheds in Aceh. Relief ratio is a basin-scale proxy for how quickly elevation drops from headwaters to outlet (a compact way to describe overall steepness and “flashiness”). Higher relief-ratio watersheds concentrate runoff faster, generate higher peak discharges for the same rainfall, and are more prone to slope failure and sediment pulses that turn floods into debris-laden, high-velocity events. Lower relief-ratio watersheds route water more slowly, but they are structurally prone to long-duration inundation where gradients flatten, drainage becomes inefficient, and backwater effects accumulate.

What the maps show is a very clear spatial partitioning of Aceh’s flood mechanisms:

High relief-ratio watersheds (34–45): short, steep, high-energy basins — flash flood and landslide dominated. These basins cluster where the Bukit Barisan mountains sit close to the coast, so rivers drop rapidly over short distances. On the map, the most prominent examples are: Teunom (west-central belt), and Kluet (southwest/south belt, Aceh Selatan interior-to-coast).

Flood susceptibility here is driven by short concentration time: rainfall is converted to channel flow quickly, warning time is short, and peak flows are high relative to channel capacity. The dominant damage mode is not just “water depth” but flow energy — bank erosion, channel avulsion, boulder and

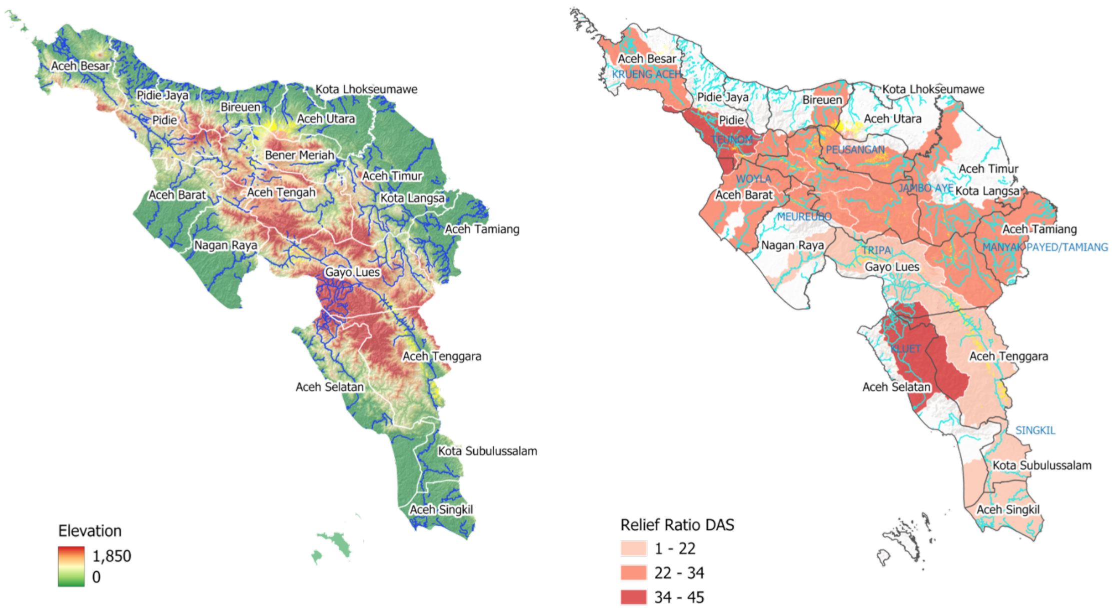

Figure 3.3. Elevation and relief ratios of the watersheds in Aceh. The higher the relief ratio, the higher the propensity of floods is due to the steepness of the slopes from upstream to downstream areas in the watersheds. The map shows that Teunom, Woyla, Peusangan, Jambo Aye, Tamiang, Kluet, and Krueng Aceh are the watersheds with the highest relief ratio.

[74] Balai Wilayah Sungai Sumatera I, 2013. “Nama Wilayah Sungai Prov. Aceh Berdasarkan Kepres. No. 12 Tahun 2012,” Balai Wilayah Sungai Sumatera I (May 23, 2013).

woody-debris transport — and the flood wave can be highly destructive even if the inundated area is spatially smaller than in the lowlands. These are also the most landslide-sensitive watersheds because steep relief and high drainage incision couple hillslopes tightly to river networks.

Moderate relief-ratio watersheds (22–34): composite basins with steep headwaters feeding broad lowlands — compound flooding. Most of Aceh's large "spine-to-plain" watersheds fall in this class, covering much of the interior and the long runout toward the north and east coasts. Key labeled systems include:

- Peusangan (north-central belt)
- Jambo Aye (north–northeast belt)
- Krueng Tamiang (east belt)
- Woyla (west belt)
- Tripa (southwest-to-central belt)
- Krueng Aceh (Aceh Besar to Banda Aceh)

These watersheds are where Aceh's flood impacts tend to become large-area disasters: steep upstream subcatchments generate rapid inflow and high peaks, while the downstream plains (lower gradients, meandering channels, and wider floodplains) spread and retain water. Susceptibility is therefore "compound": upstream, flash floods, slope failures, high sediment delivery, channel widening; while downstream, prolonged riverine flooding, levee/overtopping failure, and multi-day waterlogging of settlements and cropland.

This is the most dangerous topographic combination for human impacts at scale because it aligns high runoff generation (steep headwaters) with high exposure (dense settlement and agriculture on low-gradient floodplains).

Low relief-ratio watersheds (1–22): flat, coastal-plain and lowland systems — prolonged inundation dominated
These occur as smaller patches, especially along coastal fringes and the far south/southeast lowlands (including parts of the Singkil area). Here, flood susceptibility is less about rapid peaks and more about drainage inefficiency: water spreads widely, recedes slowly, and can be reinforced by backwater from main rivers, high tides, or sediment-choked outlets.

This class can still produce severe damages (especially to housing contents, sanitation, and crops) because duration is the killer: even moderate depths become catastrophic when standing water persists and access is cut, but the immediate flow velocities are generally lower than in the high-relief basins.

What this means for flood susceptibility in Aceh, spatially? The west and southwest steep-coast watersheds (high relief ratio, like Teunom and Kluet) are structurally predisposed to high-velocity flash floods and landslides, with the highest lethality risk concentrated in narrow valleys, road cuts, and alluvial fans at mountain fronts.

The north and east belts (mostly moderate relief ratio, including Peusangan, Jambo Aye, and Krueng Tamiang) are the most prone to province-scale displacement events because they combine fast upstream runoff with extensive lowland floodplains where people and assets are concentrated.

The flattest coastal-plain pockets (low relief ratio) are predisposed to long-duration inundation and service collapse (water, sanitation, access), even when the hydrodynamic force is lower.

In short: high relief ratio predicts where floods become fast and destructive; moderate relief ratio predicts where floods become widespread and socially catastrophic; low relief ratio predicts where floods become persistent and debilitating.

3.6 The Watershed Degradation and the Actual Destruction

In the post-flood situation reporting to Parliament, the Minister of Forestry stated that 31 DAS in Aceh were affected by the floods and landslides (i.e., flood/landslide impacts were identified within 31 watersheds). Read against the 151 named DAS listed by Balai Wilayah Sungai Sumatera I, that implies roughly one-fifth of Aceh's officially listed watersheds (about 20.5 percent) were flagged as impacted in that ministerial assessment.[75]

If 31 of Aceh's 151 officially listed watersheds were flagged as impacted (about 20.5 percent), that subset is unlikely to be a random "one-fifth" of watersheds; it is more plausibly the one-fifth where topography and land-cover change make extreme rainfall translate into visible, high-consequence outcomes. Read against the relief-ratio and deforestation pattern, the ministerial count is consistent with impacts concentrating in moderate-to-high relief basins (22–34 and 34–45) where deforestation is occurring in the 500–2,000 meter bands: these are precisely the settings that shorten concentration time, raise peak discharge, and amplify sediment pulses that reduce channel capacity and trigger avulsions and debris-laden surges.

Conversely, low-relief coastal-plain basins can produce severe, long-duration inundation but may be less likely to be "counted" in a post-disaster watershed-impact tally if the damage signal is diffuse and dominated by waterlogging rather than dramatic slope failures and channel scour; that creates an inherent reporting bias toward steeper, more geomorphically active systems. The analytical implication is that the 31 impacted DAS likely represent the intersection of high routing efficiency (relief) and destabilized headwaters (deforestation at elevation), which is exactly the risk mechanism identified in the relief-ratio–deforestation analysis.

Floods are not only "how much rain fell," but how a basin converts rainfall into runoff and how quickly that runoff is delivered to the outlet. Topography sets the delivery speed; land cover and land use set much of the conversion efficiency. Relief ratio is useful here because it compresses a watershed's overall steepness into a single metric (total relief divided by basin length), which correlates with shorter concentration time, higher stream power, and tighter coupling between hillslopes and channels.[76]

Against that topographic template, deforestation changes the partitioning of rainfall into interception, infiltration, evapotranspiration, and quickflow, and it typically increases soil disturbance, overland flow connectivity, and sediment delivery — effects that are often most visible in small to medium headwater basins and in small to moderate floods, while very extreme floods can overwhelm many local land-cover controls[77] The key point is that the same amount of forest loss can have radically different flood consequences depending on whether it occurs in a high-relief, fast-routing basin versus a lower-relief, slow-draining basin.[78]

The maps in **Error! Reference source not found.** and Figure 3.5 line up in a way that is hydrologically consequential: much of the deforestation signal sits in the 500–1,000 meter band (yellow) and, critically, the 1,000–2,000 meter band (orange), with smaller patches above 2,000 meters (red), tracking the Bukit Barisan spine from Aceh into North Sumatera and toward West Sumatera. Those elevation bands are not "just higher ground"; they are where many basins generate fast runoff and where slope instability and sediment production are most easily triggered when vegetation and soils are disturbed.[79]

In Aceh's high relief-ratio watersheds (34–45) — the short, steep mountain-to-coast systems concentrated on the west and southwest (for example, Teunom and the Kluet/ Aceh Selatan cluster in the relief-ratio map in Figure 3.3 — mid- to upper-slope

[75] Aulia, S., 2025. "Temuan Kemenhut: Ratusan Titik Banjir dan Lahan Kritis Kepung 3 Provinsi di Sumatera," tvOnenews.com, December 4, 2025. https://www.tvonenews.com/berita/nasional/395248-temuan-kemenhut-ratusan-titik-banjir-dan-lahan-kritis-kepung-3-provinsi-di-sumatera (accessed on December 22, 2025).

[76] For example, for early theories explaining the relationships between relief rate and run-off, see Schumm, S.A., 1956. "Evolution of Drainage Systems and Slopes in Badlands at Perth Amboy, New Jersey," *Geological Society of America Bulletin*, 67 (5), pp. 597–646.

[77] Bruijnzeel, L.A., 2004. "Hydrological functions of tropical forests: not seeing the soil for the trees?," *Agriculture, Ecosystems & Environment*, 104 (1), pp. 185–228; Bathurst, J.C., S.J. Birkinshaw, F. Cisneros Espinosa, and A. Iroumé, 2017. "Forest Impact on Flood Peak Discharge and Sediment Yield in Streamflow," in Sharma, N. (ed.), *River System Analysis and Management*. Springer Singapore, Singapore, pp. 15–29.

[78] Bathurst, *et al*., 2017, *op cit*.

[79] Bruijnzeel, 2004, et al.; Sidle, R.C., and H. Ochiai, 2006. *Landslides: Processes, Prediction, and Land Use*. American Geophysical Union, Washington, DC.

deforestation is effectively placed on the most efficient lever arm of the flood system. Travel times are already short, so any increase in quickflow translates rapidly into higher peak discharge and higher flow energy at the valley bottom. At the same time, slope disturbance and reduced root reinforcement raise the likelihood of shallow landslides and debris slides, which can transform a "water flood" into a debris-laden surge with outsized destructive power.[80] In other words, in the 34–45 class, deforestation in the 1,000–2,000 meter belt is not a marginal amplifier; it is one of the most direct ways to increase flash-flood and landslide susceptibility basin-wide.

Aceh's moderate relief-ratio watersheds (22–34) are where the two maps imply the most socially catastrophic flood geometry: steep headwaters feeding broad, populated lowlands. This is the dominant class on the relief-ratio map (including major "spine-to-plain" systems like Peusangan, Jambo Aye, Krueng Tamiang, Woyla, Tripa, and Krueng Aceh). Here, deforestation at 500–2,000 meters increases peak inflows from the upper basin, but the downstream disaster footprint is magnified because these watersheds typically have longer low-gradient reaches and wider floodplains where settlements, roads, and agriculture concentrate. The second-order effect is sediment: disturbed headwaters deliver more material downstream, which can aggrade channels, reduce conveyance, and make overbank flooding more frequent for a given discharge — meaning the hazard shifts from only "bigger peaks" to "earlier overtopping and wider inundation".[81] The practical implication is that the 22–34 relief-ratio class is where deforestation most readily converts extreme rainfall into multi-subdistrict inundation and prolonged displacement, because it couples fast runoff generation with high exposure and reduced channel capacity.

In Aceh's low relief-ratio watersheds (1–22) — coastal-plain systems such as Singkil in your relief-ratio map — deforestation is less likely to manifest as violent flash flooding and more likely to worsen duration and drainage failure. Flood susceptibility here is dominated by slow gradients, backwater effects, and limited outlet capacity; additional sediment from upstream disturbance can further reduce channel and drainage efficiency, extending waterlogging and compounding water and sanitation disruption even when flow velocities are relatively low.[82]

Read at the island scale, the same interaction appears in different proportions. North Sumatera shows extensive deforestation in the 1,000–2,000 meter band along the mountain spine, which is structurally the most effective place to increase fast runoff and sediment delivery into downstream plains. West Sumatera's deforestation signal appears comparatively more concentrated in the 500–1,000 meter band, but because many West Sumatera basins are short mountain-to-coast systems, mid-slope disturbance can still translate quickly into high peaks and sediment pulses downstream. The general rule holds across all three provinces: where relief ratio is moderate-to-high, deforestation at mid-to-high elevations disproportionately increases flood susceptibility because it acts directly on the fast-routing parts of the hydrologic network and on sediment production and channel adjustment.

3.7 Deforestation in Aceh

In the months and years leading up to the late-November 2025 floods, many of Aceh's wahtersheds (Daerah Aliran Sungai, DAS) were already operating with diminished "hydrological buffering" — not because Aceh had become a treeless province, but because forest loss and degradation had been concentrated in the upstream positions that matter most for slowing runoff, stabilizing slopes, and reducing peak flows. The *Warned by Nature* assessment notes that Aceh entered the 21st century as Sumatra's last large block of relatively intact forest, with about 3.37 million hectares of primary forest in 2001 (around 59 percent of the province's

[80] Sidle and Ochiai, 2006, *op cit*.
[81] Bathurst, et al., 2017, *op cit*.; Vázquez-Tarrío, D., V. Ruiz-Villanueva, J. Garrote, G. Benito, M. Calle, A. Lucía, and A. Díez-Herrero, 2024. "Effects of sediment transport on flood hazards: Lessons learned and remaining challenges," *Geomorphology*, 446, 108976.
[82] Vázquez-Tarrío, 2024, *op cit*.

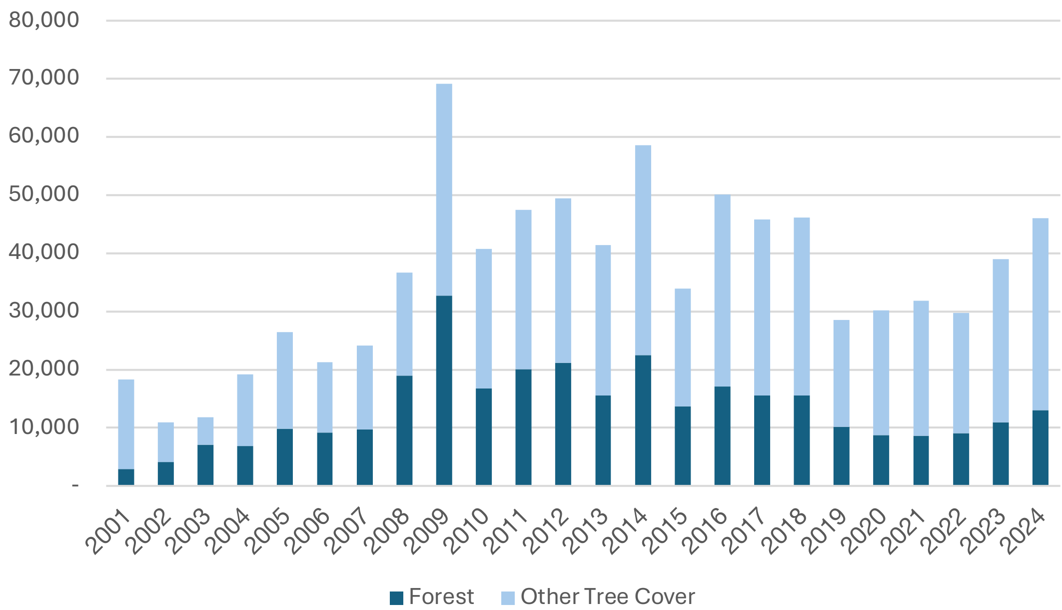

Figure 3.4. Historical deforestation in Aceh from 2001 to 2024, based on forest and other tree cover loss. The figure shows that deforestation in Aceh increased but peaked at 2014 (with an acute increase in 2009). From 2014, it showed a decrease but a slow rebound starting in 2021. Source: Global Forest Watch of the World Resources Institute, based on data from Global Land Analysis and Discovery Laboratory, University of Maryland.

land mass). Over 2002–2024, however, it estimates a loss of roughly 320,000 hectares of humid primary forest (about a 9 percent decline), with clearing clustering along road corridors, the margins of the Leuser Ecosystem, and expanding oil palm and smallholder agriculture zones, alongside additional pressures linked to mining and hydropower development. Forest loss totaled around 200,000 hectares in 2001–2014 (15,100 ha/year) and fell to about 120,000 hectares in 2015–2024 (13,600 ha/year). Other vegetative cover loss was higher: 280,000 hectares in 2001–2014 (21,400 ha/year) and climbed to 260,000 hectares in 2015–2024 (29,000 ha/year).[83]

The loss was not random: it was disproportionately located in steep, high-rainfall catchments and riparian buffers — the very landscape elements that function as natural flood infrastructure. The report also stresses a legacy effect: risk was "built in" by early-2000s to mid-2010s clearing, meaning that even if new deforestation stopped, flood hazard would remain elevated without deliberate, large-scale restoration and upstream land-use rebalancing.

Aceh Tamiang illustrates what this looked like on the ground just before Senyar: a watershed whose upper catchment had been progressively stripped and subdivided by overlapping permits and informal expansion. *Warned by Nature* describes logging concessions operating in both the upper and lower reaches of the watersheds since the 1970s, followed by progressive conversion to oil palm from the 1980s onward; by the early 2000s, it reports more than 10,000 hectares of upper-catchment forest severely damaged and around 4,000–5,000 hectares converted into illegal oil palm, alongside a major shrinkage of the broader forest estate in Aceh Tamiang (from about 221,000 hectares to about 92,000 hectares).[84]

It further notes that recent multi-watershed analyses classified about 36.45 percent of the roughly 494,988-hectare Aceh Tamiang watershed as degraded. The report also characterizes the upstream as "a map of permits," citing official data that more than

[83] Sari, 2025, *op cit*.

[84] Sari, A.P., 2025, *op cit*.

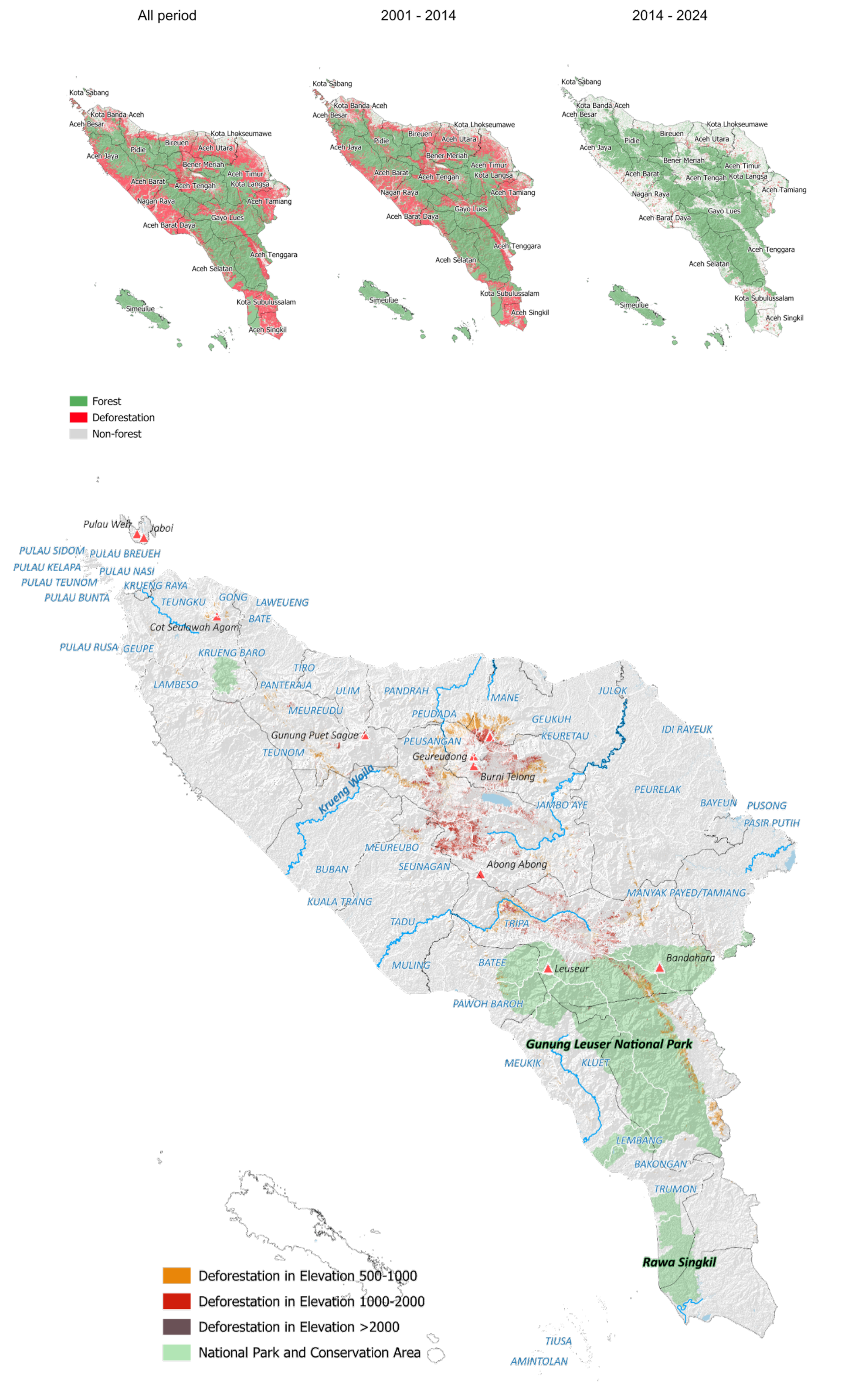

Figure 3.5. Deforestation in Aceh over time and over different elevationa. Source: Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." *Science* 342 (15 November): 850-853.

plantation and business permits in Aceh Tamiang alone, covering roughly 46,000 hectares, with additional areas reportedly operating without valid land-use titles and a "shadow layer" of irregular and illegal expansion beyond licensed blocks. The encroachment was not limited to community smallholders; investigative reporting on the Gunung Leuser National Park (Taman Nasional Gunung Leuser, TNGL) block in Blok Tenggulun documented 971 hectares of park forest damaged by encroachment and more than 300 hectares planted with oil palm, involving actors "from various backgrounds," including business interests and elements of local authority, with some land already reclaimed by the state while a substantial portion remained unresolved as of September 2025.[85]

Hansen, M. C., P. V. Potapov, R. Moore, M. Hancher, S. A. Turubanova, A. Tyukavina, D. Thau, S. V. Stehman, S. J. Goetz, T. R. Loveland, A. Kommareddy, A. Egorov, L. Chini, C. O. Justice, and J. R. G. Townshend. 2013. "High-Resolution Global Maps of 21st-Century Forest Cover Change." *Science* 342 (15 November): 850-853. Data available on-line at: https://glad.earthengine.app/view/global-forest-change.

10.1126/science.1244693 Data available on-line at: https://glad.earthengine.app/view/global-forest-change.

The ministerial statement on the "31 affected watersheds (daerah aliran sungai, DAS)" above is consistent with (and actually reinforces) the relief-ratio–deforestation mechanism: extreme rainfall becomes disaster when a catchment's response is fast (short time of concentration, high relief energy) and its storage/roughness is weakened (loss of forest structure and soil infiltration). In Aceh, a subset of watersheds with moderate–high relief ratios function as "runoff and sediment amplifiers" because steep headwaters connect directly to densely occupied alluvial fans and coastal plains; when land-cover change is concentrated in mid-to-upper elevations (the same belt that controls infiltration, shallow landslide initiation, and debris supply), flood peaks sharpen and sediment-laden flows propagate rapidly downstream. The ministerial briefing that situates Aceh's late-November flooding within 31 DAS (with 71 flood points) therefore likely reflects not a diffuse, province-wide hydrologic failure across all basins, but a concentration of impacts in the geomorphically "responsive" basins — and this aligns with the multi-watershed degradation figures reported by WALHI, including 36.45 percent degradation in the Aceh Tamiang watershed.[86] The same parliamentary reporting also quantifies that those 31 impacted DAS contain 217,301 hectares of critical land (7.1 percent), while North Sumatera shows fewer impacted DAS (13) but a higher critical-land share (14.7 percent), implying that Aceh's disaster footprint is spread across more basins whereas North Sumatera's degradation (relative to impacted area) is more concentrated — a pattern that matters because, in relief-driven systems, concentrated headwater degradation can produce outsized flood response.[87] Finally, the scientific hydrology point is not abstract: field-based work on the Tamiang River Basin classifies it as flood-prone and "critical," showing soil physical conditions that can limit infiltration and increase runoff generation — exactly the pathway through which mid–

[85] *ibid*.; Batubara, N.F., 2025. "Di Balik Hancurnya Ribuan Hektare Hutan Taman Gunung Leuser", *Tirto* (September 15, 2025). https://tirto.id/di-balik-hancurnya-ribuan-hektare-hutan-taman-gunung-leuser-hhMf (accessed on December 22, 2025).
[86] WALHI (Wahana Lingkungan Hidup Indonesia), 2025. "Legalisasi Bencana Ekologis di Sumatera Barat, Aceh dan Sumatera Utara dan Tuntutan Tanggung Jawab Negara Serta Korporasi," WALHI (December 2, 2025). https://www.walhi.or.id/legalisasi-bencana-ekologis-di-sumatera-barat-aceh-dan-sumatera-utara-dan-tuntutan-tanggung-jawab-negara-serta-korporasi (accessed on December 24, 2025); Hestyarini, F., 2025. "Menhut Beberkan Titik Banjir Di DAS Sumatera, Aceh Terbanyak," *Rakyat Merdeka* (December 4, 2025). https://rm.id/baca-berita/government-action/292072/menhut-beberkan-titik-banjir-di-das-sumatera-aceh-terbanyak (accessed on December 24, 2025); Nur Rahmah, N., 2025. "1,4 Juta Hektare Hutan Hilang, WALHI Sebut Banjir Sumatra Akumulasi Deforestasi," *Katadata* (December 2, 2025). https://katadata.co.id/ekonomi-hijau/ekonomi-sirkular/692e55dc88da7/1-4-juta-hektare-hutan-hilang-walhi-sebut-banjir-sumatra-akumulasi-deforestasi (accessed on December 24, 2025).
[87] Hestyarini, 2025, *op cit*.

upper elevation forest loss becomes downstream flood risk.[88]

Other major basins that contributed to the November 2025 disaster were also described in governance and land-use terms. *Warned by Nature* reports that WALHI Aceh's mapping linked the floods and landslides to years of forest clearing, oil palm expansion, and mining inside key watersheds, including Krueng Peusangan, which drains into flood-hit districts such as North Aceh (Aceh Utara) and Bireuen.[89] At the provincial scale, the report's framing is blunt: the watersheds that failed were not pristine forests awaiting protection, but landscapes already "deeply scarred" — logged-over areas, fragmented stands, abandoned roads, and unstable slopes — in which the hydrological cost of land-use change had accumulated silently until it was "priced in" by an extreme storm.

Against that backdrop, the meteorological forcing from Senyar was simply beyond what degraded catchments could absorb. BMKG's weekly outlook recorded daily rainfall reaching the "extreme" category in multiple locations during November 25–27. *Warned by Nature* emphasizes the same mechanism in hydrological terms: 24-hour totals climbed beyond the absorptive capacity of soils and rivers, converting mountain rivers into violent torrents and triggering landslides that destroyed settlements.

The reason these watersheds "could not have stood" the rain is not that forests are a magical flood wall; it is that deforestation and degradation shift how quickly rainfall becomes hazardous surface runoff. *Warned by Nature* draws on hydrological work in the Krueng Aceh basin indicating primary forest cover collapsed from more than half of the watershed area to a small fraction within a few decades, with land-use change increasing runoff and reducing infiltration — the exact opposite of the "slower, lower, longer" hydrograph response that intact forests tend to support. It also notes a hard physical limit that matters under Senyar-like cloudbursts: when rainfall intensity and duration are high enough, even healthy forest soils saturate; what degradation changes is how fast saturation is reached, how sharp the peak flow becomes, and how destructive the flood wave is downstream.[90] In Aceh Tamiang and similar basins, where steep slopes and riparian buffers had been cleared or converted (legally and illegally) and where roads and extraction corridors had fragmented the upper catchment, the storm water did not fall onto an "anonymous landscape"; it fell onto a land-use map that had already removed much of the watershed's capacity to intercept, store, and delay water — leaving the torrential rainfall to translate directly into catastrophic runoff, sediment-laden flows, and infrastructure failure.

3.8 The Problem with Governance

In Aceh's flood-prone geography, corruption and weak governance in the natural-resource sector function as risk multipliers: they do not create rainfall, but they shape where forests disappear, where slopes are opened, where river corridors are narrowed, and where enforcement stops at the paper boundary. The Ministry of Forestry reported that across Aceh, North Sumatera, and West Sumatera, 218 flood points were identified across 57 watersheds (Daerah Aliran Sungai), with land-cover change during 2019–2024 and roughly 464,000 hectares of critical land becoming the core rehabilitation agenda — implicitly acknowledging that the hazard is being amplified by managed landscapes, not "nature alone".[91] Aceh sits at the sharp end of this equation because many basins drain steep-to-coastal profiles: when permitting and supervision fail in upper and mid-slopes, the system's runoff response accelerates and sediment pulses increase, reducing river

[88] Azizah, C., H. Pawitan, B.D. Dasanto, I. Ridwansyah, and M. Taufik, 2019. "Sifat Fisik Tanah dan Hubungannya dengan Kapasitas Infiltrasi DAS Tamiang," *Jurnal Tanah dan Iklim*, 43 (2) (December 2019), pp. 167–173.
[89] Sari, 2025, *op cit*.
[90] *ibid*.
[91] "Kementerian Kehutanan Perkuat Penanganan Lahan Kritis dan Tata Kelola DAS Pascabencana Banjir di Sumatera," Press Release, Kementerian Kehutanan (December 4, 2025). https://www.kehutanan.go.id/news/kementerian-kehutanan-perkuat-penanganan-lahan-kritis-dan-tata-kelola-das-pascabencana-banjir-di-sumatera (accessed on December 25, 2025).

conveyance just when peak flow arrives. This is why corruption in licensing matters for flood outcomes: it can legalize conversion in places that should function as hydrological infrastructure, or neutralize sanctions through bargaining and delay.

Indonesia has repeatedly seen how bribery and collusion can shape land outcomes. The Buol oil palm bribery case is a canonical illustration of how permits can be bought to unlock large-scale conversion rents, even when the public-interest case is weak.[92] More recently, the Corruption Eradication Commission (Komisi Pemberantasan Korupsi, KPK) conducted a 2025 sting operation tied to alleged bribery in cooperation arrangements for forest-area management — underlining that forest governance remains a live corruption frontier, not a closed chapter.[93] Yet the structural challenge is that forestry cases have historically been a small share of total anti-corruption prosecutions, suggesting that complexity, fragmented authority, and evidentiary burdens can keep enforcement below the level needed to change incentives.[94] In Aceh specifically, corruption risks are not abstract: high-profile cases involving provincial leadership have demonstrated how public authority can be monetized through illicit payments and gratuities, weakening trust in enforcement and complicating coordinated recovery.[95]

At the same time, the Ministry of Forestry is now signaling and operationalizing a more assertive reform posture that is directly relevant to Aceh's flood risk. First, it has demonstrated willingness to revoke Forest Utilization Business Licenses (Perizinan Berusaha Pemanfaatan Hutan, PBPH), publishing a 2025 list of 18 revoked PBPH — including a revoked industrial forest permit located in Aceh Utara — and framing revocation as a consequence of non-compliance rather than an anti-investment stance.[96] Second, the Minister has publicly committed to further revocations (around 20 additional PBPH), proposed a moratorium on new logging-related PBPH in natural and plantation forests, and emphasized "no compromise" in pursuing actors linked to forest damage observed through flood-linked timber flows — moving the narrative from "restoration only" to "restoration plus accountability.[97] Third, enforcement messaging is being paired with tools and pipeline-building: the Ministry has highlighted automatic wood identification (Alat Identifikasi Kayu Otomatis) and field operations as part of its enforcement package.[98] and forestry law-enforcement units have publicly referenced criminal penalties — including multi-year imprisonment and substantial fines — for illegal encroachment and forest use, reinforcing that the state is at least preparing the legal posture required to "put people in jail" when evidence supports prosecution.[99]

The Aceh implication is straightforward: if recovery is to reduce future flood risk, governance reform must be treated as watershed engineering. It means re-auditing high-risk permits in steep and river-adjacent

[92] Saturi, S., 2012. "Dugaan Suap Izin Kebun Sawit, Bupati Buol Ditangkap KPK," *Mongabay Indonesia* (July 7, 2012). https://mongabay.co.id/2012/07/07/dugaan-suap-izin-kebun-sawit-bupati-buol-ditangkap-kpk/ (accessed on December 25, 2025); Eryan, A., 2019. "Dari Inpres Moratorium Sawit Hingga Kebijakan Tata Kelola Industri Sawit Presiden Jokowi: Studi Kasus Penerbitan SK Pelepasan Kawasan Hutan PT Hardaya Inti Plantations di Buol, Sulawesi Selatan," *Jurnal Hukum Lingkungan Indonesia*, 6(1), pp. 1–18.

[93] "KPK Tangkap Tangan Suap Izin Pengelolaan Kawasan Hutan," Komisi Pemberantasan Korupsi (August 14, 2025), https://kpk.go.id/id/ruang-informasi/berita/kpk-tangkap-tangan-suap-izin-pengelolaan-kawasan-hutan (accessed on December 25, 2025)

[94] Schütte, S.A. and L.M. Syarif, 2020. *Tackling forestry corruption in Indonesia: Lessons from KPK prosecutions*. Chr. Michelsen Institute (U4 Issue 2020:15), Bergen.

[95] Natalia, D.L., 2019. "Irwandi Yusuf divonis 7 tahun penjara," *Antara News Aceh* (April 8, 2019).

[96] "Pengenaan Sanksi Terhadap Perizinan Berusaha Pemanfaatan Hutan (PBPH)," Press Release, Kementerian Kehutanan (February 24, 2025). https://www.kehutanan.go.id/news/pengenaan-sanksi-terhadap-perizinan-berusaha-pemanfaatan-hutan-pbph (accessed on December 25, 2025).

[97] "Menhut Raja Antoni Akan Cabut 20 Izin PBPH dan Kejar Pelaku Perusakan Hutan," Press Release, Kementerian Kehutanan (December 4, 2025). https://www.kehutanan.go.id/news/menhut-raja-antoni-akan-cabut-20-izin-pbph-dan-kejar-pelaku-perusakan-hutan (accessed on December 25, 2025).

[98] Kementerian Kehutanan (December 4, 2025), *op cit*.

[99] Prihatini, Z., and N.N.W. Widyanti, 2025. "Kemenhut Musnahkan 98,8 Hektar Kebun Sawit Ilegal di TN Berbak Sembilang Jambi", *Kompas* (December 17, 2025). https://lestari.kompas.com/read/2025/12/17/112507386/kemenhut-musnahkan-988-hektar-kebun-sawit-ilegal-di-tn-berbak-sembilang (accessed on December 25, 2025).

zones, hardening transparency (public permit maps and a credible one-map forestry baseline), protecting whistleblowers, ensuring that cases move beyond administrative action into prosecutorial readiness when warranted, and aligning provincial and district incentives so that “growth” cannot be booked upstream while disaster costs are paid downstream. The Ministry’s recent moves indicate momentum; the problem statement is that momentum must now be made Aceh-specific, measurable, and corruption-resistant — because in a steep watershed, compromised governance is not an ethical footnote, it is a physical driver of loss.

Finally, there is politics “with a capital P”. It is not an optional add-on to governance reform; it is the missing enabling condition that determines whether reforms become real constraints on behavior or remain paper rules. In Aceh, the technical agenda — watershed protection, permit audits and enforcement, spatial planning discipline, and risk-informed infrastructure — will not hold if the recovery effort is experienced as something done to people rather than with them. This is the line between small-p politics that drains attention into transactional bargaining and contestation, and a deeper politics of humanity, civility, and shared national purpose that restores dignity and trust. For a post-disaster recovery program, that trust is not “soft” — it is operational: it shapes compliance with river setbacks, cooperation in restoration and rehabilitation, legitimacy for permit revocations, and the credibility of enforcement when it inevitably confronts entrenched interests.

This is why the governance problem in Aceh should be stated not only as fragmentation, weak accountability, and corruption risks, but also as a legitimacy deficit — a fragile relationship between institutions and citizens after repeated cycles of extraction, uneven development, and disaster response. The early battle, as past reconstruction experience in Aceh demonstrated, is to “win hearts and trust” — to make communities visible as subjects of policy and co-owners of outcomes, not merely beneficiaries of projects. If that legitimacy-building phase is treated as a first-order task — through transparent trade-offs, structured co-decision mechanisms, credible local leadership, and a grievance system that resolves disputes quickly and fairly — then the reform agenda has a realistic pathway to durability. Without it, even technically sound reforms will be continuously re-politicized, selectively enforced, and gradually hollowed out by bureaucratic incentives, small-p national politics, and external indifference — leaving the next extreme rainfall event to expose, again, the same governance fault lines.

4
The Long Term Recovery through Landscape Approach

4.1 Sustainable Landscape Recovery

Ecological recovery in Aceh should be built on a landscape approach: the unit of action is the watershed-to-coast system, not isolated “project sites.” A landscape approach is designed for exactly this kind of problem — where flood risk, forest condition, farming systems, infrastructure, and settlement patterns interact — and it works by aligning multiple stakeholders around shared outcomes at landscape scale, with iterative learning and adaptive management.[100]

In practice, that starting point immediately changes what “recovery” means. The goal is not simply to replant trees, but to restore hydrological function (infiltration, slope stability, riparian buffering, sediment control) while keeping livelihoods viable and governance enforceable. This is consistent with the United Nations Environment Programme (UNEP) framing of ecosystem restoration as halting and reversing degradation to recover biodiversity and ecosystem services, using a continuum of approaches tailored to local conditions.[101]

From that premise, sustainable long-term ecological recovery in Aceh should prioritize six interlocking moves. First, define the landscape units and agree on a single “shared map.” The Province of Aceh should anchor recovery planning on priority watersheds (Daerah Aliran Sungai, DAS) and their sub-watersheds from ridge to reef, integrating upland headwaters, mid-slope production mosaics, and downstream floodplains and coasts. The key is a spatially explicit baseline that all parties accept — forest condition, erosion-prone slopes, landslide susceptibility, riparian integrity, peat and mangrove extent, and settlement exposure — so that “restoration” does not become a scattered collection of good intentions without system-level impact. This is also where monitoring must begin: if the landscape is the unit of management, then landscape-scale indicators (not only hectares planted) must become the unit of performance.[102]

Second, secure what remains intact before spending heavily on what is already lost. In flood-driven landscapes, the remaining intact forests in upper catchments, steep slopes, and riparian corridors are the cheapest and fastest form of risk reduction. Aceh should treat these areas as non-negotiable protection zones — strengthened through clear legal status, boundary clarity, enforcement presence, and community co-management arrangements — because once they tip into degradation, recovery costs rise and disaster risk increases. A landscape approach explicitly emphasizes negotiated and transparent objectives and the importance of resilient institutions and long-term commitments; this is where those principles become tangible.[103]

Third, restore hydrological function through targeted ecological interventions, not blanket

[100] Sayer, J., T. Sunderland, J. Ghazoul, J,-L. Pfund, D. Sheil, E. Meijaard, M. Venter, A.K. Boedhihartono, M. Day, C. Garcia, C.J. van Oosten, and L.E.Buck, 2013. “Ten principles for a landscape approach to reconciling agriculture, conservation, and other competing land uses,” *Proceedings of the National Academy of Sciences of the United States of America (PNAS)* 110 (21), pp. 8349–8356; “Landscape approaches: key concepts,” Food and Agriculture Organization of the United Nations, Climate Smart Agriculture Sourcebook. https://www.fao.org/climate-smart-agriculture-sourcebook/concept/module-a3-landscapes/chapter-a3-1/en/ (accessed on December 22, 2025); UNDER (United Nations Decade on Ecosystem Restoration), 2021. Principles for ecosystem restoration to guide the United Nations Decade 2021–2030. United Nations Environment Programme and Food and Agriculture Organization of the United Nations).

[101] UNDER, 2021, *op cit*.; “Decade on Ecosystem Restoration,” United Nations Environment Programme (April 16, 2024). https://www.unep.org/explore-topics/ecosystems-and-biodiversity/what-we-do/decade-ecosystem-restoration (accessed on December 22, 2025).

[102] Sayer, et al., 2013, *op cit*.; Chervier, C., M.-G. Piketty, and J. Reed, 2020. “Territorial approaches and deforestation,” in *Operationalizing integrated landscape approaches in the tropics*, Reed, J., M.A.F. Ros-Tonen, and T.C.H. Sunderland [eds]. Center for International Forestry Research, Bogor.

[103] Sayer, et al., 2013, *op cit*.; Food and Agriculture Organization of the United Nations, n.d., *op cit*.

planting. The priority should be (1) riparian restoration (re-establishing vegetated buffers along rivers and tributaries), (2) hill-slope stabilization in erosion hot spots (assisted natural regeneration where possible, enrichment planting where needed, and ground-cover management to reduce runoff), (3) peatland rewetting and fire prevention in peat-influenced landscapes (where relevant), and (4) mangrove and coastal wetland recovery to restore natural flood retention and shoreline protection. Restoration should follow a "right intervention, right place" logic — selecting natural regeneration, assisted regeneration, or active planting depending on pressure levels and ecological feasibility — consistent with the UN Decade's emphasis on a restoration continuum rather than a single technique.[104]

Fourth, convert production areas into a recovery asset rather than a continuing pressure. Long-term recovery will fail if commodity landscapes remain managed in ways that accelerate runoff, erosion, and river sedimentation. The landscape approach is designed to reconcile production, conservation, and inclusion of smallholders; in Aceh, that implies enforceable "good practice" packages for key commodities (erosion control, slope limits, riparian set-asides, reduced road impacts, and restoration of unproductive or ultra-high-risk plots) coupled with support to smallholders so compliance is feasible. This is the core logic of landscape and jurisdictional approaches: collaboration at scale, with local government playing a central role in land-use governance beyond what individual farms or companies can do alone.[105]

Fifth, make community stewardship and local livelihoods part of the restoration architecture, not an afterthought. Restoration that excludes communities is rarely maintained; restoration that creates dignified, predictable local benefits is far more likely to last. Practically, Aceh can scale community-based restoration contracts (nurseries, maintenance, monitoring), co-managed conservation, and locally anchored enterprises compatible with landscape goals (for example, agroforestry-based value chains and nature-positive micro-enterprises), tied to clear performance metrics. UNDP's recent framing of landscape-based management in Indonesia emphasizes community-driven innovation and participatory restoration; that is a relevant operational direction for Aceh as well.[106]

And sixth, finally, hardwire accountability: enforce risk-based permitting and transparent compliance, or ecological recovery will be outpaced by new degradation. A landscape approach depends on governance that can manage trade-offs over time. For Aceh, that means a watershed-based governance mechanism with authority to coordinate across districts; systematic permit audit and compliance follow-up; enforcement against illegal activities; and risk-based licensing anchored in Environmental Impact Assessment (Analisis Mengenai Dampak Lingkungan, AMDAL) and hydrological risk screening. Credible restoration is ultimately a governance proposition: without stopping the drivers of degradation, "recovery" becomes a revolving door.[107]

Applying a landscape approach in Aceh means treating the province as a connected "ridge-to-reef" system — what happens in the headwaters of the Bukit Barisan range will determine sediment loads, runoff peaks, and flood impacts in the midstream valleys and coastal plains. Within that logic, spatial priorities for (1) ecosystem conservation, (2) ecosystem rehabilitation, and (3) rehabilitation of agricultural and agribusiness landscapes can be specified as follows.

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[104] UNDER (United Nations Decade on Ecosystem Restoration), 2021, *op cit*.; UNEP, 2024, *op cit*.

[105] Sayer, *et al*., 2013, *op cit*.; Chervier *et al*., 2020, *op cit*.

[106] UNDP (United Nations Development Programme) Indonesia, 2025. "Indonesia secures major opportunity to safeguard its rich biodiversity and natural resources," UNDP Indonesia (June 9, 2025). https://www.undp.org/indonesia/press-releases/indonesia-secures-major-opportunity-safeguard-its-rich-biodiversity-and-natural-resources (accessed on December 22, 2025).

[107] Sayer, *et al*., 2013, *op cit*.; FAO, n.d., *op cit*.; Sahide, M.A.K., M.R. Fisher, A. Maryudi, A. Dhiaulhaq, C. Wulandari, and Y.-S. Kim, 2021. "Governance challenges to landscape restoration in Indonesia," *Environmental Science & Policy*, 123, pp. 113–122.

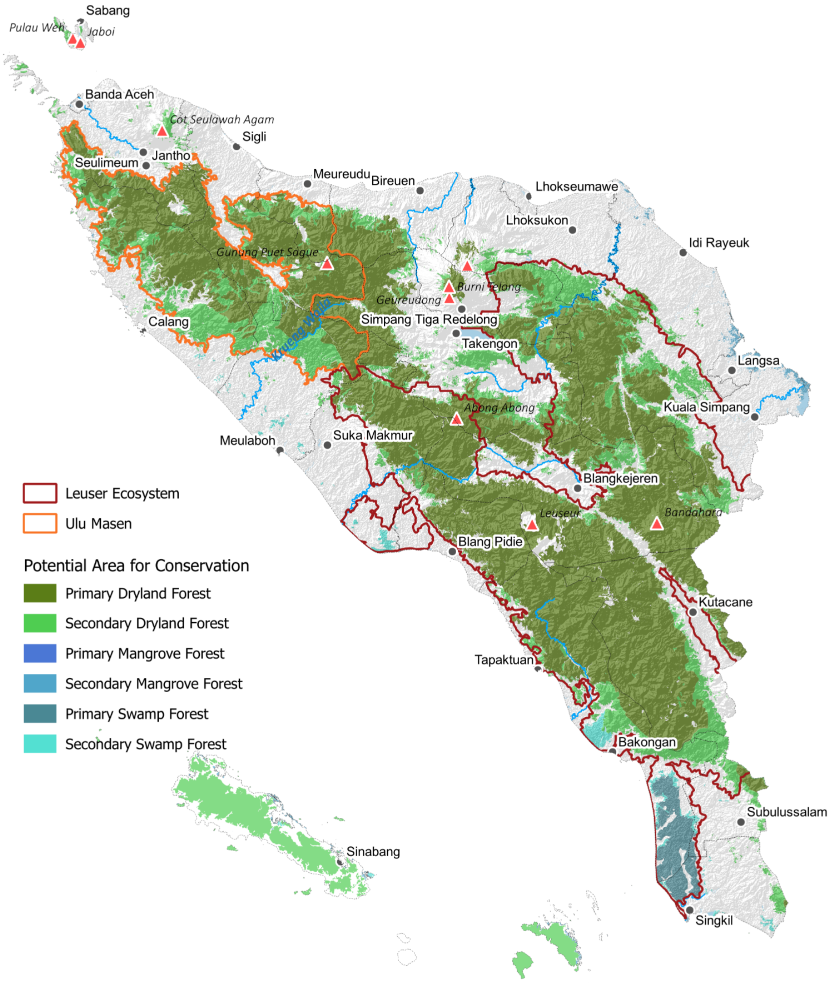

Figure 4.1. Potential areas for ecological conservation in Aceh.

4.2 Conserve What We Still Have

Aceh's highest conservation priority is to keep its remaining large, contiguous forest and wetland blocks intact — not only for biodiversity, but as natural infrastructure that moderates flood peaks and stabilizes slopes.

Leuser Ecosystem (Kawasan Ekosistem Leuser, KEL) and its core protected areas. The Leuser Ecosystem spans Aceh and North Sumatera and is described as covering more than 2.6 million hectares of diverse ecosystems (including lowland rainforest, peat swamp, montane forest, and coastal ecosystems).[108] In Aceh, conservation focus should be placed on:

- the upper and mid-catchments in the Leuser block (notably across the southeastern to central highlands), where forest cover functions as the primary rainfall buffer; and
- peat and wetland conservation nodes that are hydrologically decisive for downstream flood attenuation, including the Singkil peat landscape and associated protected areas.

[108] "Kawasan Ekosistem Leuser," HAKA. https://haka.or.id/tentang-kami/kawasan-ekosistem-leuser/ (accessed on December 23, 2025).

A practical "no-regrets" conservation target is to prevent further fragmentation of remaining intact forest in "Leuser-facing" districts, and to keep headwater ridgelines and steep upper slopes in permanent natural cover.

Ulu Masen forest block (northwestern Aceh). A major conservation anchor in Aceh is the Ulu Masen ecosystem, described in the Ulu Masen project design documentation as a 750,000-hectare forest focus area spanning Aceh Besar, Aceh Jaya, Aceh Barat, Pidie, and Pidie Jaya.[109] In flood-risk terms, this is an upstream safety asset for the northern and western seaboard — maintaining intact canopy and soil structure here is materially cheaper than downstream dredging and repeated repairs.

Remaining peat swamp and wetland systems (hydrological "shock absorbers"). Peat and freshwater wetlands should be treated as conservation-critical wherever they still hold near-natural hydrology, because once drained they become chronic sources of subsidence, fire risk, and faster runoff. In Aceh, this is most prominent around the Singkil landscape and other coastal-lowland peat systems embedded within the broader Leuser geography.[110]

Coastal mangroves as the first line of coastal protection. Mangroves should be conserved as protective green infrastructure, especially along the east coast where remaining mangrove area is already limited. One reporting synthesis citing the 2021 National Mangrove Map (Peta Mangrove Nasional, PMN) states that remaining mangroves along the east coast (Aceh Timur, Aceh Tamiang, and Kota Langsa) total only 22,204 hectares.[111] Even if the immediate recovery agenda is flood-focused inland, losing mangroves increases compound risks (storm surge, coastal erosion, saline intrusion) that can lock communities into repeated losses.

4.3 Rehabilitate Degraded Ecologically Sensitive Areas

Ecosystem rehabilitation focuses on areas where degradation occurs despite formal protection. It should be a targeted investment, giving priority to places where damaged land causes issues like increased peak flows, sediment surges, or river failures.

Districts showing the most recent forest loss signals. Recent forest-loss reporting identifies Aceh Selatan as the largest contributor to forest cover loss over the last three years, and notes for 2024 that Aceh Selatan lost 1,357 hectares, followed by Aceh Timur (1,096 hectares) and Kota Subulussalam (1,040 hectares).[112] From a landscape planning perspective, these figures should trigger a rehabilitation-and-enforcement package that is spatially concentrated on:

- upper catchments feeding densely settled valley systems;
- steep-slope production mosaics where erosion control is weakest; and
- river corridors where bank instability and sedimentation amplify flood heights.

Ulu Masen buffer and "edge" rehabilitation (northwest Aceh). Because Ulu Masen is explicitly defined across Aceh Besar, Aceh Jaya, Aceh Barat, Pidie, and Pidie Jaya, rehabilitation should focus on the forest edge — the belt where encroachment, road opening, and small-scale conversion typically occur.[113] In practice, this means:

[109] Government of Aceh, FFI (Fauna & Flora International), CCL (Carbon Conservation Ltd.), 2007. *Reducing Carbon Emissions from Deforestation in the Ulu Masen Ecosystem, Aceh, Indonesia: A Triple-Benefit*, Project Design Note for CCBA Audit, Final Ulu Masen CCBA Project Design Note (on the Convention on Biological Diversity). https://www.cbd.int/financial/climatechange/indonesia-climateulumasen.pdf (accessed on December 23, 2025).

[110] Hanafiah, J., 2025. "Tutupan Hutan Aceh Berkurang Setiap Tahun?" *Mongabay Indonesia* (March 3, 2025). https://mongabay.co.id/2025/03/03/tutupan-hutan-aceh-berkurang-setiap-tahun/ (accessed on December 23, 2025).

[111] Hanafiah, J., 2024. "Hutan Mangrove di Pesisir Timur Aceh Rusak Akibat Perambahan." *Mongabay Indonesia* (November 4, 2024). https://mongabay.co.id/2024/11/04/hutan-mangrove-di-pesisir-timur-aceh-rusak-akibat-perambahan/ (accessed on December 23, 2025).

[112] Hanafiah, 2025, *op cit*.

[113] Government of Aceh, *et al*., 2007, *op cit*.

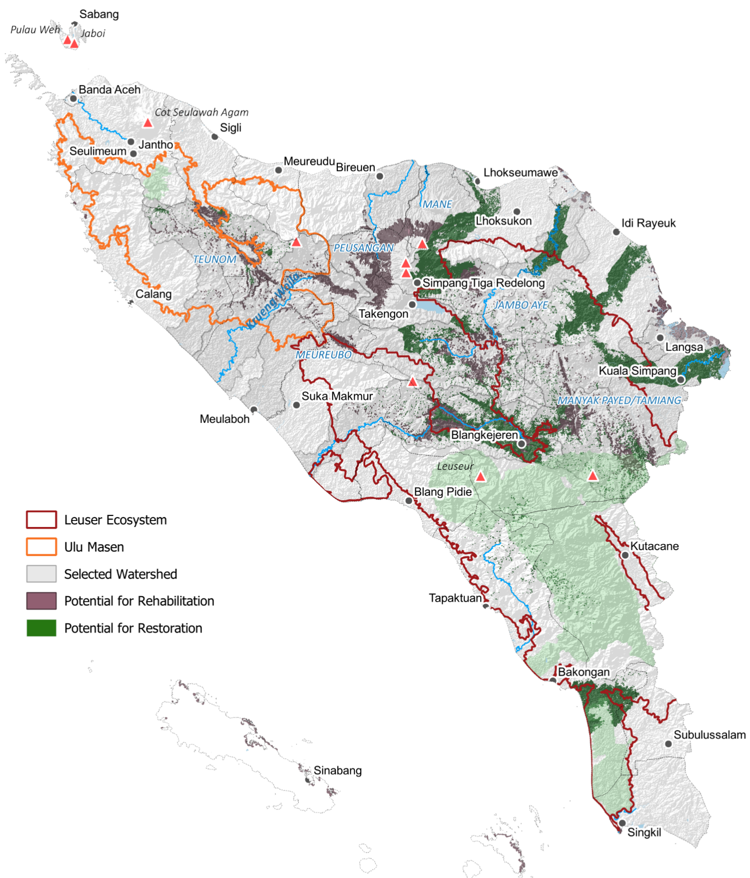

Figure 4.2. Potential areas for ecological rehabilitation and restoration in Aceh.

assisted natural regeneration on degraded protection forests, stabilization of landslide-prone slopes above settlements and roads, and restoration of riparian vegetation along rivers that drain the Ulu Masen block toward the coast.

Peatland hydrological restoration where peat has been drained or fragmented. In peat landscapes, "rehabilitation" should be defined first as restoring water tables (rewetting), not simply replanting. The working principle is that canal blocking, rewetting, and protection from new drainage delivers faster flood-mitigation benefits than tree planting alone, because it slows runoff and reduces subsidence-driven flood exposure over time. In Aceh, this is particularly relevant where peat is adjacent to oil palm and settlement expansion pressures in lowland districts within the broader Leuser and Singkil-associated landscapes.[114]

Mangrove rehabilitation where conversion has already occurred (east coast). Given the limited remaining mangrove extent along the east coast cited above, the rehabilitation priority is to restore degraded mangrove belts that have been converted to ponds and settlements — especially where these belts are needed to protect coastal communities and estuaries.[115] This is a direct "risk-reduction" rehabilitation: it reduces erosion, buffers storm water, and stabilizes river mouths that otherwise silt up and worsen upstream flooding.

[114] "Kawasan Ekosistem Leuser", HAKA, *op cit*.

[115] Hanafiah, 2024, *op cit*.

4.4 Restore What We Have Lost

In Aceh, "restoration" (in the strict sense that means land that should function as protected hydrological infrastructure but has already been converted) should be treated as a targeted intervention on a small number of basin control surfaces. Relief ratio shows which watersheds are intrinsically fast and energetic; the deforestation-by-elevation map tells you where conversion is occurring in the parts of those watersheds that matter most for peak formation and sediment delivery (especially 500–2,000 meters). In combination, they point to priority restoration geography that is both Aceh-specific and operationally mappable: the Bukit Barisan headwater belt that feeds the major north and east lowlands, the steep west–southwest mountain-to-coast basins, the lowland river corridors where floodwater must be given space, and Aceh's peat-swamp hydrological units where drainage-dependent conversion structurally lengthens flood duration.[116]

Headwater and mid-slope restoration in the Leuser–Bukit Barisan "water-tower belt" (500–2,000 meters). This is the most decisive restoration geography for the province's flood safety because it sits upstream of the largest exposure corridor (North Aceh–East Aceh–Aceh Tamiang). The deforestation map in Figure 3.5 shows conversion concentrated along the mountain spine in the 500–1,000 meter and 1,000–2,000 meter bands; the relief ratio map in Error! Reference source not found. shows t hat the major "spine-to-plain" watersheds are predominantly moderate relief ratio (22–34), which is exactly the class where disturbed headwaters can generate sharper peaks while the downstream lowlands convert those peaks into large-area inundation. Restoration should therefore be concentrated in converted headwater and mid-slope patches (the yellow and orange clusters on Error! R eference source not found.) inside the upper parts of Peusangan, Jambo Aye, and Krueng Tamiang — especially where those upper catchments sit in the Central Aceh–Bener Meriah–Gayo Lues–Aceh Tenggara arc (the Leuser landscape and its periphery). The analytical logic is not "more trees everywhere," but restoring the critical source areas where forest loss and soil disturbance most efficiently increase flood-event likelihood and severity — a linkage shown empirically in Aceh, where reported flood events were more likely in areas with lower tree cover and more oil palm, controlling for precipitation.[117]

High-relief (34–45) west and southwest basins: restoring converted valley bottoms, lower slopes, and mountain-front transition zones. In the high-relief mountain-to-coast systems highlighted in the relief map in Error! Reference source not f ound. (notably the Teunom cluster on the west-central coast and the Kluet/Aceh Selatan cluster in the southwest), restoration should concentrate on converted land in narrow valleys, steep lower slopes, and alluvial fan and mountain-front transition zones. These are the places where high stream power, short concentration time, and slope–channel coupling produce the most damaging flood modes (flash floods with heavy sediment and debris, rapid bank collapse, avulsion). In these basins, restoring a relatively small converted area can yield outsized risk reduction because travel times are short and sediment pulses propagate quickly downstream. The objective is to re-establish roughness and slope stability in the lowest parts of the steep terrain that are already geomorphically "wired" to deliver water and debris to settlements.[118]

Lowland river-corridor and floodplain restoration in the displacement belt: Aceh Utara–Aceh Timur–Aceh Tamiang. The earlier damage accounting showed that North Aceh, East Aceh, and Aceh Tamiang dominate housing impacts and displacement. In these lowlands, the most important "restoration" is not upland reforestation but restoring space and function to river corridors that have been converted into housing,

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116 Schumm, 1956, *op cit*.; Bruijnzeel, 2004, *op cit*.; Sidle and Ochiai, 2006, *op cit*.

117 Lubis, 2024, *op cit*.; Global Forest Watch, 2015. Indonesia Leuser Ecosystem (dataset description). Global Forest Watch, World Resources Institute, Washington, DC. https://data.globalforestwatch.org/datasets/indonesia-leuser-ecosystem/about (accessed on December 24, 2025).

118 Bruijnzeel, 2004, *op cit*.; Sidle and Ochiai, 2006, *op cit*.

roads, and cultivation right up to the banks. Specifically, restoration should prioritize: (1) converted riparian strips along the main rivers and distributaries; (2) former wetlands and flood-storage depressions that have been planted or built over; and (3) channel-adjacent areas where conversion has removed bank-stabilizing vegetation. This is where relief-ratio and deforestation interact through sediment: upland disturbance increases sediment delivery, and lowland corridor conversion removes the system's ability to dissipate energy and store water, forcing flooding to occur as destructive overtopping and erosion rather than managed inundation. Riparian and floodplain reconnection approaches are strongly supported as flood-risk reduction measures because they expand the area available to store and convey floodwater while reducing exposure of assets placed in inevitable inundation corridors.[119]

Peat-swamp and coastal wetland restoration as hydrological restoration: Tripa and Singkil Aceh's peatlands are not "optional biodiversity sites"; they are hydrological units where drainage-dependent conversion structurally shifts flood behavior toward longer duration inundation, water-quality collapse, and recurring fire risk. Two restoration geographies are especially concrete and Aceh-specific, as follows.

Tripa peat swamp (administratively Nagan Raya and Aceh Barat Daya): The deforestation map's low-to-mid elevation conversion signal (Figure 3.5) is consistent with long-standing conversion pressure in Tripa. Restoration should focus on rewetted peat hydrology (blocking drainage canals and restoring water tables) and re-establishing peat-swamp forest cover in converted blocks — because peat restoration is primarily hydrological first, vegetative second. Global technical guidance emphasizes that restoring peatlands requires raising and stabilizing water tables; without rewetting, replanting alone does not restore function.[120] Tripa's conversion dynamics and ecological consequences have been documented in analytic briefs and peer-reviewed work, underscoring that this is a known conversion frontier rather than a speculative target.[121]

Singkil peatland / Rawa Singkil Wildlife Reserve (Aceh Singkil and surrounding): This is the coastal-plain restoration geography most directly tied to hydrological regulation and long-duration flooding. Restoration should focus on canal management and peat hydrology restoration, alongside strict protection of remaining peat-swamp forest blocks. Technical restoration planning and hydrology management interventions in Rawa Singkil have been documented, and local scientific work emphasizes the peat swamp's role in regulating water systems and maintaining ecosystem function.[122]

In summary, an Aceh-specific rule for "where restoration should happen" is this: restore converted land first where (1) it sits in the 500–2,000 meter belt of moderate-to-high relief watersheds that feed the North and East Aceh lowlands (Peusangan, Jambo Aye, Krueng Tamiang, and Krueng Aceh headwaters), (2) it occupies valley bottoms and mountain-front transition zones in the high-relief west–southwest basins (Teunom and Kluet clusters), and (3) it has removed flood storage and conveyance function in the lowland river corridors of Aceh Utara, Aceh Timur, and Aceh Tamiang, and in peat hydrological units (Tripa and Singkil). This is where restoration converts most directly into reduced flood peaks, reduced debris/ sediment amplification, increased floodplain storage, and shorter flood duration — the four mechanisms that decide whether extreme rainfall becomes a province-scale disaster.[123]

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119 Naiman, R.J., and H. Décamps, 1997. "The ecology of interfaces: riparian zones," Annual Review of Ecology and Systematics, 28, pp. 621–658; Opperman, J.J., G.E. Galloway, J. Fargione, J.F. Mount, B.D. Richter, and S. Secchi, 2009. "Sustainable floodplains through large-scale reconnection to rivers," *Science*, 326 (5959), pp. 1487–1488.
120 Ramsar Convention on Wetlands, 2021, *op cit*.
121 Widayati A, H.L. Tata, S. Rahayu, and Z. Said, 2012. *Conversions of Tripa peatswamp forest and the consequences on the loss of Sumatran Orangutan (Pongo abelii) habitat and on aboveground CO2 emissions*, Brief No. 33: Tripa series. World Agroforestry Center (ICRAF), Southeast Asia Regional Program, Bogor.
122 "Restoring Wetlands in Rawa Singkil Wildlife Reserve, Indonesia", U.S. National Park Service (2017). https://www.nps.gov/articles/wetland-restoration-indonesia.htm (accessed on December 24, 2025.
123 Bruijnzeel, 2004; Lubis *et al*., 2024, *op cit*.; Naiman and Décamps, 1997, *op cit*.; Ramsar Convention on Wetlands, 2021, *op cit*.

4.5 Rehabilitate Agricultural and Agribusiness Landscapes

The objective here is not to eliminate production, but to redesign production landscapes so they stop behaving like runoff accelerators and sediment factories. In Aceh, the two most hydrologically consequential commodity systems are smallholder oil palm in lowlands and Arabica coffee in highlands.

Smallholder oil palm rehabilitation in the main planting districts (lowland floodplains and peat-adjacent areas). Badan Pusat Statistik (Statistics of Aceh Province) reports smallholder oil palm planted area (luas tanam kelapa sawit perkebunan rakyat) totaling 258,992 hectares in 2022, with the largest areas concentrated in Nagan Raya (53,151 ha), Aceh Singkil (33,050 ha), Aceh Timur (28,510 ha), Aceh Tamiang (23,382 ha), Aceh Barat Daya (20,620 ha), Kota Subulussalam (19,304 ha), Aceh Utara (18,185 ha), and Aceh Jaya (16,504 ha).[124] These are precisely the districts where production rehabilitation can have outsized flood-mitigation impact if it delivers:

- restoration and enforcement of riparian buffers (revegetation, bank stabilization, and prohibition of planting right up to the river edge);
- peat-safe management where applicable (no new drainage, gradual rewetting in appropriate zones, and preventing expansion into deep peat);
- soil and water conservation in estate layouts (contour-based drains, infiltration features, ground cover management, and reduced bare-soil exposure); and
- road and culvert redesign so plantation access roads do not become embankments that trap water in villages or redirect flows into settlements.

Highland Arabica coffee landscape rehabilitation in Aceh Tengah and Bener Meriah (the Gayo highlands). The 2023 Coffee Outlook (Outlook Kopi 2023) compiled by the Ministry of Agriculture's data center (Pusat Data dan Sistem Informasi Pertanian, Pusdatin) reports that Aceh's smallholder Arabica coffee production in 2021 totaled 67,372 tons, with production highly concentrated in Aceh Tengah (36,060 tons; 53.52 percent) and Bener Meriah (29,172 tons; 43.30 percent).[125] Because these are steep, high-rainfall headwaters, "rehabilitation" should prioritize slope hydrology and erosion control rather than yield maximization alone. A credible package includes:

- shade-based agroforestry (maintaining canopy interception and root structure);
- contour planting, terracing, and vegetated strips on steep slopes;
- gully and landslide scar stabilization in micro-catchments above villages and roads; and
- strict avoidance of new clearing on the steepest slopes and ridge tops that function as water towers for downstream districts.

Coastal production interfaces (aquaculture, mixed agriculture, and settlement edges). In coastal and estuarine zones, production rehabilitation should explicitly integrate mangrove recovery (where feasible) and "setback" management so that ponds, fields, and settlements do not erase the last protective belts. Given the cited constraint of remaining mangrove extent on the east coast, the highest-return measure is to rehabilitate degraded mangrove fringes and prevent further conversion in Aceh Timur, Aceh Tamiang, and Kota Langsa.[126]

Community (smallholder) coconut replanting in Aceh Utara, Bireuen, Lhokseumawe, Aceh Tamiang, Aceh Singkil, and Aceh Selatan. Community (smallholder) coconut replanting is one

[124] BPS, 2024. "Luas Tanam dan Produksi Kelapa Sawit Perkebunan Rakyat menurut Kabupaten/Kota, 2022", Badan Pusat Statistik Aceh. https://aceh.bps.go.id/id/statistics-table/2/MTIwIzI%3D/luas-tanam-dan-produksi-kelapa-sawit.html (accessed on December 24, 2025).

[125] Kementerian Pertanian Republik Indonesia (Ministry of Agriculture of the Republic of Indonesia), 2023. *Buku Outlook Komoditas Perkebunan Kopi 2023*. Pusat Data dan Sistem Informasi Pertanian, Sekretariat Jenderal, Kementerian Pertanian, Jakarta.

[126] Hanafiah, 2024, *op cit*.

component of rehabilitating agricultural landscapes in the flood-affected lowlands of Aceh, particularly where coconut stands sit on coastal plains and deltaic floodplains that experienced prolonged inundation, sediment deposition, and localized saltwater influence. In practical spatial terms, this is most relevant along the north and east-coast belt where river systems transition from the mid-slope "spine" to the coastal "plain" — including coconut-producing pockets in the lower reaches and coastal hinterlands of basins such as Peusangan (Bireuen), Jambo Aye and adjacent lowlands (Aceh Utara–Lhokseumawe), and Krueng Tamiang (Aceh Tamiang), where floodwaters can spread laterally across flat terrain and remain for days. A second set of coconut areas to consider are the peat-influenced coastal lowlands in Singkil and parts of the west and southwest coastal strip, where drainage constraints and tidal backwater effects can compound post-flood waterlogging and raise the likelihood of salinity stress near estuaries and coastal margins.

The replanting approach should be geographically differentiated by exposure and site condition rather than applied uniformly. In deltaic and near-coastal settings where salinity and waterlogging are recurring risks, replanting should be bundled with field-level hydrological rehabilitation (micro-drainage repair, sediment removal where it smothers roots, raised planting mounds on poorly drained soils, and stabilization of field drains to reduce erosion and silt re-entry). In floodplain settings dominated by sediment deposition rather than salinity, the emphasis should be on stand rejuvenation and productivity recovery: removal of dead or structurally compromised palms, soil conditioning to restore aeration and nutrient availability, and phased replanting to avoid an abrupt income gap while new palms mature. Across both settings, implementation should be organized through village-based farmer groups and cooperatives, anchored by locally managed nurseries to ensure seedling supply and varietal suitability, and complemented by interim livelihood strategies (intercropping and ground cover management) that maintain cash flow and improve infiltration. Safeguards are essential: replanting should be confined to existing agricultural footprints and explicitly paired with riparian buffer restoration along river corridors and canals, so that coconut rehabilitation strengthens, rather than undermines, watershed-to-coast flood risk reduction and downstream water quality.

4.6 Select Initiatives in Aceh That Can Be Strengthened

HAKA (Yayasan HAKA)'s core work in Aceh is to make forest loss and ecological pressure visible, actionable, and politically hard to ignore — especially across the Leuser Ecosystem and other critical landscapes. It runs routine monitoring using satellite analysis and then verifies priority signals through field checks, including drone-based aerial observation and on-the-ground validation using the Global Forest Watch Forest Watcher workflow. In practice, this is not just "remote sensing"; it is operational monitoring tied to specific geographies (for example, forest-loss checking in Aceh Tamiang and East Aceh, aerial observation in Subulussalam, and peatland fire/forest checks in Nagan Raya), combined with community engagement and advocacy that turn maps into enforcement and prevention agendas.[127] Those monitoring outputs are directly relevant to both field protection and jurisdictional commodity governance: they can guide where Forum Konservasi Leuser patrols should concentrate, and they can provide an evidence base for the deforestation monitoring and grievance-response commitments embedded in the Aceh Sustainable Palm Oil Roadmap process facilitated by IDH.[128]

Forum Konservasi Leuser (FKL, advised by Rudi Putra, a Goldman Environmental Prize awardee) is the field enforcement backbone

[127] HAKA, https://haka.or.id/en/; "Forest Monitoring", HAKA. https://haka.or.id/en/strategy/forest-monitoring/ (accessed on December 24, 2025); "Drones Monitoring", HAKA. https://haka.or.id/en/strategy/drones-monitoring/ (accessed on December 24, 2025.

[128] "Forest Monitoring", HAKA, *op cit*.; "Convening a Sustainable Palm Oil Landscape in Aceh, Indonesia," IDH (September 9, 2025). https://idh.org/resources/convening-a-sustainable-palm-oil-landscape-in-aceh-indonesia (accessed on December 24, 2025).

of Leuser protection in Aceh: a patrol-and-response institution designed for daily reality, not paper commitments. FKL states it operates dozens of wildlife protection teams across the Leuser Ecosystem, patrolling around half of each month, dismantling snares, and collecting wildlife and threat data; partner descriptions emphasize that these teams are structured to work alongside government rangers and connect field evidence to law enforcement and anti-encroachment action.[129] In parallel, external descriptions of FKL's work highlight active intervention against illegal plantations (including illegal oil palm) and forest crime, as well as management of research and monitoring stations and restoration of crucial corridors — the combination that matters in Aceh's steep, fast-responding watersheds where enforcement failures in headwaters quickly become downstream disaster risk.[130] In operational terms, HAKA's monitoring helps identify and prioritize emerging threats, while FKL's patrol capacity is what makes "zero deforestation" credible on the ground; both can plug into IDH's jurisdictional grievance and response architecture when government and companies commit to acting on verified alerts.[131]

The Rimba Collective's work in Aceh is best read as long-term conservation finance deployed through on-the-ground operators in the Gunung Leuser landscape, especially where community forests and buffer zones hold the line between intact forest and conversion pressure. In Leuser Sub-District (Southeast Aceh), it supports an Orangutan Information Center–operated community-forest/buffer-zone footprint of about 14,859 hectares adjacent to Gunung Leuser National Park, explicitly framed around protecting biodiversity while reducing the chronic friction points that drive forest loss (notably human–elephant conflict near settlements and farms).[132] In Meukek District (South Aceh), it supports BITRA Indonesia Foundation's Jambo Papeun Village Forest (about 13,594 hectares), positioned as both a buffer and a wildlife corridor; Rimba's own reporting indicates a defined split between conservation and restoration inside that village forest, paired with livelihood support intended to reduce conversion incentives.[133] This portfolio overlaps geographically and functionally with FKL and HAKA: where Rimba-backed sites sit in Leuser's corridor and buffer belt, HAKA's monitoring and FKL's field protection are the integrity infrastructure that can keep finance from being undermined by leakage (encroachment shifting elsewhere) or by resurgence of illegal clearing.[134]

IDH — The Sustainable Trade Initiative's Aceh work is the "jurisdictional operating system" layer: aligning district and provincial governance, supply-chain actors, and smallholder inclusion so that production landscapes (especially palm oil) can remain deforestation- and conversion-free while staying economically viable. IDH states it has worked since 2017 with the provincial government and with Aceh Tamiang and East Aceh, supporting planning and implementation for a greener growth pathway.[135] It also reports facilitating the Aceh Sustainable Palm Oil Roadmap 2023–2045, formalized under Aceh Governor Decree/Regulation No. 09/2024, with explicit targets including smallholder registration,

[129] "The Leuser Ecosystem," Leuser Conservancy (Forum Konservasi Leuser) https://leuserconservancy.or.id (accessed on December 24, 2025); "Forum Konservasi Leuser," Rainforest Trust. https://www.rainforesttrust.org/get-involved/rainforest-trust-partners/forum-konservasi-leuser/ (accessed on December 24, 2025).
[130] "Rudi Putra," Global Landscapes Forum Events. https://events.globallandscapesforum.org/speaker/rudi-putra/ (accessed on December 24, 2025).
[131] "Forest Monitoring", HAKA, *op cit*.; "Convening a Sustainable Palm Oil Landscape in Aceh, Indonesia," IDH, *op cit*.; "The Leuser Ecosystem", Leuser Conservancy, *op cit*.
[132] "Leuser Subdistrict", Rimba Collective. https://rimbacollective.com/project/leuser-sub-district (accessed on December 24, 2025).
[133] "Meukek District," Rimba Collective. https://rimbacollective.com/project/meukek-district (accessed on December 24, 2025; "Song of the Forest: Restoring Harmony With Nature in Sumatra," Rimba Collective (April 7, 2025). https://rimbacollective.com/updates/song-of-the-forest-restoring-harmony-with-nature (accessed on December 24, 2025).
[134] "Forest Monitoring", HAKA, *op cit*.; "Drones Monitoring", HAKA, *op cit*.; "The Leuser Ecosystem," Leuser Conservancy, *op cit*.
[135] "Aceh, Indonesia," IDH — The Sustainable Trade Initiative. https://www.idhsustainabletrade.com/landscapes/aceh-indonesia/ (accessed on December 24, 2025).

protection of High Conservation Value and High Carbon Stock areas, and establishment of deforestation monitoring and grievance-response mechanisms — and it has convened a pre-competitive working group (launched August 13, 2025) to coordinate corporate participation in implementation.[136] This is where cross-linkages become operational: HAKA's "where is clearing happening" intelligence can feed the monitoring and grievance-response mechanism; FKL's "can we stop it on the ground" capacity can provide rapid verification and deterrence; and Rimba-backed projects can finance protection and restoration in strategic corridor/buffer geographies while IDH works to reduce market incentives for conversion through deforestation-free sourcing and smallholder upgrading.[137]

Supporting these activities in Aceh should be treated as building an integrated pipeline from detection to response to durable livelihood alternatives — and then funding it at the time horizon that flood-risk reduction and forest transition actually require. Concretely: (1) finance a shared, province-level spatial intelligence and alerting platform where HAKA's satellite/ drone signals, FKL patrol data, and IDH's grievance system speak the same language (common geographies, common thresholds, shared case tracking); (2) fund rapid response capacity (field verification, mediation, law enforcement liaison, and ecological repair) so alerts do not die as "reports"; (3) direct restoration and protection spending using the watershed logic you have already developed (moderate-to-high relief basins, 500–2,000 meter headwater belts, and corridor/buffer zones) so interventions reduce peak-flow and sediment risk rather than only increasing tree cover; and (iv) expand smallholder inclusion packages where IDH is working (Aceh Tamiang and East Aceh) so compliance is feasible (farmer registration, legality, productivity, replanting support, and deforestation-free market access), reducing the political economy pressure that otherwise pushes conversion into the remaining forest margins.[138]

4.7 Engineering Solutions Where Necessary

Even under an aggressive landscape-restoration program, Aceh's flood risk cannot be "restored away" because a large share of the province's hydrometeorological hazard is structurally generated by (2) extreme, short-duration rainfall (which will not be "extreme" soon enough); (2) steep, short travel-time catchments; and (3) sediment- and debris-charged flood hydraulics that amplify peak discharge and blockage risk at bridges, bends, and confluences. The correct implication is not to downgrade ecological repair, but to treat it as the load-reduction layer in an integrated flood-risk system that must also include end-to-end early warning and targeted hydraulic control — and, in specific locations, managed retreat from the highest-hazard micro-topographies.[139]

Aceh's relief-ratio structure makes this logic unavoidable. High-relief watersheds (34–45) along the mountain-to-coast west and southwest systems (for example Teunom, Kluet/ Aceh Selatan, and smaller west-coast basins) concentrate relief over short channel lengths, meaning runoff and entrained sediment reach settlements quickly and with high stream power. Moderate-relief "spine-to-plain" watersheds (22–34) such as Peusangan, Jambo Aye, Krueng Tamiang, Woyla, Tripa, and Krueng Aceh combine steep headwaters with extensive middle-to-lower floodplains where inundation becomes spatially broad once channels are exceeded

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[136] HAKA, *op cit*.; "Aceh Sustainable Palm Oil Working Group," IDH (August 28, 2025). https://idh.org/resources/aceh-sustainable-palm-oil-working-group (accessed on December 24, 2025); "Aceh Tamiang," SourceUp. https://sourceup.org/initiatives/aceh-tamiang (accessed on December 24, 2025).

[137] "Convening a Sustainable Palm Oil Landscape in Aceh, Indonesia," IDH, *op cit*.; "The Leuser Ecosystem," Leuser Conservancy, *op cit*.; "Leuser Subdistrict", Rimba Collective, *op cit*.; "Song of the Forest: Restoring Harmony With Nature in Sumatra," Rimba Collective, 2025, *op cit*.;

[138] "Forest Monitoring", HAKA, *op cit*.; "Convening a Sustainable Palm Oil Landscape in Aceh, Indonesia," IDH, 2025, *op cit*.; "Aceh, Indonesia," IDH, *op cit*.

[139] Sari, 2025, *op cit*.; WMO (World Meteorological Organization of the United Nations), 2015. *WMO Guidelines on Multi-hazard Impact-based Forecast and Warning Services*. World Meteorological Organization of the United Nations.

or constricted. Low-relief coastal-plain systems (1–22) such as Singkil have slower onset but longer-duration flooding driven by drainage congestion, backwater effects, and limited conveyance. When mid- and upper-elevation deforestation is layered onto this geomorphic template, the hazard multiplies in two direct ways: faster runoff generation (higher and earlier peaks) and higher sediment/woody-debris loads (reduced channel capacity, rapid aggradation, and blockage-driven overbank flow). In other words, the same relief-ratio class becomes more dangerous after deforestation because the watershed delivers both more water and more material to the same downstream bottlenecks.[140]

For early warning, Aceh needs a genuinely end-to-end, people-centered system — not only better forecasts, but a closed loop from risk knowledge to monitoring, dissemination, and response capability.[141] In practice, this means coupling BMKG's short-lead extreme-weather products (including spatially explicit nowcasting and provincial extreme-weather outlooks) with river-stage/rainfall thresholds on the highest-risk tributaries and confluences, and with village-level evacuation protocols that are drilled, timed, and enforced.[142] The technical step-change is to move from "rain is coming" to impact-based triggers: for each priority sub-basin, define rainfall intensity-duration thresholds and upstream water-level thresholds that translate into expected impacts at named downstream locations (for example, bridge approaches, market areas, school clusters, and settlement strips along the active floodway). This is consistent with WMO guidance that impact-based forecasting requires multi-agency co-production (meteorology, hydrology, local government, and communities) and clear, action-oriented warning messages.[143] BNPB's *InaRISK* platform can be used as the standardized, government-facing baseline for risk zoning and prioritization, while Aceh's BPBD and kabupaten governments refine it with higher-resolution terrain, river cross-sections, and observed flood marks from the recent events.[144]

A people-centered early warning system will still fail if communities cannot see, in plain spatial terms, whether they live in a floodway, an alluvial fan, a landslide corridor, or a low-lying backwater pocket — and whether evacuation routes and safe sites remain safe under extreme rain. Aceh therefore needs a single, authoritative, publicly accessible risk map (web-based and mobile-friendly) that integrates flood inundation pathways, landslide-prone slopes, river setback zones, and critical infrastructure chokepoints (bridges, culverts, embankments), and is updated transparently after each major event with observed flood marks and damage footprints. This is not "nice-to-have communication"; it is the operational backbone of warning and response: it enables households to act on alerts, allows village governments to pre-position shelters and supplies, and forces permitting and land-use decisions to internalize known risk rather than reproduce it. Public-facing mapping platforms already exist nationally (such as BNPB's InaRISK) and should be strengthened with Aceh-specific, higher-resolution watershed and settlement layers so that risk information is accessible as a public good — not a document that circulates only within agencies.[145]

On engineering hydrological control, Aceh should not default to uniform "normalization" everywhere; the design logic has to follow relief ratio and sediment regime. In high-relief watersheds (34–45), the priority is debris and sediment control upstream of settlements: check dams/sabo-type structures, debris basins, grade-control, and targeted slope/channel stabilization on the most failure-prone tributary fans — because the dominant failure mode is not only high

[140] Sari, 2025, *op cit*.
[141] WMO, 2015, *op cit*.
[142] "Nowcasting BMKG (Sistem Peringatan Dini Cuaca Berbasis Spasial)." BMKG. https://nowcasting.bmkg.go.id/nowcast/ (accessed on December 24, 2025); "Potensi Cuaca Ekstrem," BMKG. https://www.bmkg.go.id/cuaca/potensi-cuaca-ekstrem (accessed on December 24, 2025).
[143] WMO, 2015, *op cit*.
[144] Indeks Risiko Bencana Indonesia (InaRISK) — Risiko Banjir, BNPB. https://inarisk.bnpb.go.id/irbi (accessed on December 23, 2025).
[145] "InaRISK — Risiko Banjir," BNPB, *op cit*.; WMO, 2015, *op cit*.

discharge, but channel choking and avulsion triggered by sediment and woody debris. In moderate-relief watersheds (22–34), the priority becomes peak shaving and conveyance management: off-channel detention/retarding basins on middle floodplains, strategic levee set-backs (where feasible), bridge/culvert capacity upgrades at known choke points, and routine sediment management to preserve channel capacity. The operational relevance is already visible in field realities documented by BWS Sumatera I: severe floods can deliver "lumpur dan puing" (mud and debris) that impair infrastructure function and force emergency sediment removal and channel re-opening — as seen at Bendung Jambo Aye (Aceh Utara) and in post-flood normalisasi of Krueng Lingka (Langkahan, Aceh Utara).[146] In low-relief coastal plains (1–22), the priority is drainage and backwater management: retention/poldering where necessary, pump capacity and maintenance, and strict control of encroachment that narrows channels and blocks outfalls.

Large storage can contribute, but it must be treated as one component in a portfolio, not a single "solution." Aceh already has relevant flood-control narratives in the national infrastructure program: Bendungan Keureuto (Aceh Utara) has been publicly projected to reduce floods by around 30 percent, and Bendungan Rukoh (Pidie) is described by the water resources authority as delivering both irrigation and flood-control benefits.[147] These assets should be integrated into basin-specific operating rules that prioritize flood attenuation during high-risk periods (pre-release protocols, spillway management, sediment management, and clear downstream warning linkages), while acknowledging a hard physical constraint: under extreme rainfall and high sediment loads, dams do not eliminate flash flood risk in the steep tributary network above and below the reservoir influence.

Finally, managed retreat and safer rebuilding have to be discussed explicitly, because "rebuild in place" is structurally incompatible with both geomorphology and law in specific strips of Aceh's river corridors. The starting point is Indonesia's own river-setback framework (garis sempadan sungai), which establishes river-border protections and implies that settlement expansion within these functional river spaces is not acceptable risk policy.[148] This is reinforced operationally by BWS field messaging in Aceh Barat that communities should not build in the river setback area, precisely to preserve river function and the durability of bank protection works.[149] Within Aceh's high- and moderate-relief watersheds, the most urgent relocation candidates are (1) alluvial-fan apex settlements below steep tributaries, (2) narrow valley-floor strips with limited lateral escape routes, and (3) active meander belts and confluence zones where avulsion and backwater effects concentrate. A practical Aceh-specific pathway is to use *InaRISK*/ basin hazard overlays to identify the highest-fatality-risk micro-sites, then develop relocation packages that keep people within livelihood catchments (farms, fisheries, local

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[146] "Banjir Parah Rusak Bendung Jambo Aye Aceh Utara, BWS Sumatera I Lakukan Penanganan Darurat," Balai Wilayah Sungai Sumatera I (December 16, 2025). https://sda.pu.go.id/balai/bwssumatera1/article/banjir-parah-rusak-bendung-jambo-aye-aceh-utara-bws-sumatera-i-lakukan-penanganan-darurat (accessed on December 24, 2025); "BWS Sumatera I Lakukan Normalisasi Krueng Lingka Pascabanjir di Langkahan Aceh Utara," BWS Sumatera I (December 22, 2025). https://sda.pu.go.id/balai/bwssumatera1/article/bws-sumatera-i-lakukan-normalisasi-krueng-lingka-pascabanjir-di-langkahan-aceh-utara (accessed on December 24, 2025).

[147] "Pembangunan Bendungan Keureuto Memasuki Tahap Akhir, Diproyeksikan Reduksi Banjir 30%," BWS Sumatera I (October 16, 2024). https://sda.pu.go.id/balai/bwssumatera1/article/pembangunan-bendungan-keureuto-memasuki-tahap-akhir-diproyeksikan-reduksi-banjir-30 (accessed on December 24, 2025); "Enam Bendungan Siap Diresmikan Pada Tahun 2025,"PUPR, Direktorat Jenderal Sumber Daya Air (January 15, 2025). https://sda.pu.go.id/post/detail/enam_bendungan_siap_diresmikan_pada_tahun_2025 (accessed on December 24, 2025).

[148] PUPR (Kementerian Pekerjaan Umum dan Perumahan Rakyat (Ministry of Public Works and Housing), 2015. Peraturan Menteri PUPR No. 28/PRT/M/2015 tentang Penetapan Garis Sempadan Sungai dan Garis Sempadan Danau.

[149] "Perkuatan Tebing Sungai Krueng Meurebo untuk Lindungi Pemukiman dan Irigasi," BWS Sumatera I (October 10, 2025). https://sda.pu.go.id/balai/bwssumatera1/article/perkuatan-tebing-sungai-krueng-meurebo-untuk-lindungi-pemukiman-dan-irigasi (accessed on December 23, 2025).

labor markets) but move housing and critical services to higher terraces/interfluves outside mapped floodways. BNPB's rehabilitation and reconstruction guidance provides the formal planning basis for post-disaster recovery programming by government, and the later RR-planning regulation clarifies that recovery planning should be structured, time-bound, and evidence-based.[150] Where relocation is unavoidable, adopting internationally recognized safeguards helps prevent "risk transfer" into poverty: avoid forced eviction, minimize displacement, and ensure livelihood restoration and adequate services at the new site.[151]

4.8 Sustainable Socio-Economic Recovery

Flood recovery in Aceh has to be treated as an economic geography problem, not just a reconstruction program: the same watershed mechanics that amplified peak flows (high–moderate relief-ratio basins draining steep headwaters into narrow valley floors and lowland floodplains) also determine where livelihoods are concentrated, which assets fail first, and which "recovery" investments accidentally lock communities into repeat losses. In practice, that means short-term measures must restart cashflow in the floodplain economies (rice, oil palm, coastal fisheries, trading and transport), while medium- to long-term measures must re-balance land use in upstream and mid-slope zones so the lowlands are not forced to absorb ever-higher hydrologic volatility. This is the core logic of a landscape approach: protect the ecological infrastructure that regulates water, concentrate intensive production where slope and soil permit it, and re-site (or redesign) settlement and infrastructure where repeated exposure has become structurally uneconomic.[152]

In Aceh, the recovery "economic spine" is the north–east coastal plain and its river mouths — where rice floodplains, oil-palm smallholdings, and coastal fisheries overlap with the main logistics corridor connecting Banda Aceh–Lhokseumawe–Langsa–Aceh Tamiang (and onward to North Sumatera). The vulnerability is not abstract: the same districts that anchor production also show up as structural concentration points in the commodity data. For smallholder oil palm, Aceh Tamiang (68,232 hectares), Aceh Utara (59,127 hectares), and Aceh Timur (44,838 hectares) together account for roughly two-thirds of Aceh's smallholder oil-palm area (258,992 hectares), and they also dominate smallholder production (Aceh Tamiang 122,022 tons; Aceh Utara 83,990 tons; Aceh Timur 90,632 tons).[153] When floods interrupt field access, damage farm roads and bridges, or strand harvested fresh fruit bunches, the economic loss is not only yield loss — it is also a sharp, localized liquidity shock transmitted through mills, transporters, wage labor, kiosks, and village credit. A "fast" recovery package therefore needs (1) rapid repair of secondary farm-to-mill roads and river crossings in the east-coast palm belt (Aceh Timur–Langsa–Aceh Tamiang and parts of Aceh Utara), (2) emergency working-capital facilities for smallholders and cooperatives tied to replanting/rehabilitation standards (to avoid post-flood expansion into steeper mid-slopes), and (3) mill-side resilience measures (drainage, on-site storage protocols, redundancy in transport routing) because logistical disruption is often the binding constraint, not agronomy.

Weather permitting, coastal fisheries are the other immediate cash engine — and the BPS

[150] BNPB (Badan Nasional Penanggulangan Bencana), 2008. Peraturan Kepala BNPB Nomor 11 Tahun 2008 tentang Pedoman Rehabilitasi dan Rekonstruksi Pasca Bencana; BNPB, 2017. *Peraturan BNPB Nomor 5 Tahun 2017 tentang Penyusunan Rencana Rehabilitasi dan Rekonstruksi Pascabencana*.

[151] World Bank, 2017. *Environmental and Social Framework: ESS5 Factsheet — Land Acquisition, Restrictions on Land Use and Involuntary Resettlement*. World Bank, Washington, DC (accessed on December 23, 2025).

[152] "Aceh, North Sumatra and West Sumatra Provinces, Indonesia Flood 2025 - DREF Operation MDRID028," ReliefWeb (December 9, 2025). https://reliefweb.int/report/indonesia/aceh-north-sumatra-and-west-sumatra-provinces-indonesia-flood-2025-dref-operation-mdrid028 (accessed on December 24, 2025).

[153] BPS (Badan Pusat Statistik Provinsi) Aceh, 2024. "Dinas Komunikasi, Informatika dan Persandian Aceh, 2024. "Luas Tanam dan Produksi Kelapa Sawit Perkebunan Rakyat menurut Kabupaten/Kota, 2022," Badan Pusat Statistik Provinsi Aceh, Banda Aceh.

marine-capture table makes the spatial pattern unmistakable. In 2023, Aceh's recorded marine capture volume totals about 291.7 million kilograms with a production value of about Rp 9.77 trillion; within that, Aceh Utara (33.7 million kilograms; Rp 1.79 trillion) and Aceh Jaya (28.8 million kilograms; Rp 1.75 trillion) alone contribute roughly 36 percent of total value, while Aceh Timur (28.2 million kilograms; Rp 0.73 trillion) and several north-coast districts add further mass. This is why recovery should treat fish-landing sites, ice plants, cold-chain logistics, and basic port functionality as "first 100 days" priorities in the north and west coasts — especially where flood debris, siltation, and road damage disconnect landing sites from markets. A practical package is (1) rapid restoration of access to key landing points and market roads, (2) replacement/repair grants for small craft and gear with a bias toward cooperative purchasing (to reduce unit costs), and (2) cold-chain micro-infrastructure (ice, insulated storage, hygienic handling) targeted to the highest-value nodes (Aceh Utara, Aceh Jaya, Aceh Timur, Pidie, Bireuen, and the Banda Aceh–Aceh Besar market area).[154] This is also where North Sumatera and West Sumatera offer an instructive comparison: both provinces have similarly concentrated coastal and lowland production systems, but their "economic recovery" performance tends to hinge on whether district governments can quickly reopen transport and trading arteries after flooding (so prices normalize and labor markets restart), rather than on one-off asset replacement.

Rice-based food security requires a different recovery logic: not just replacing lost inputs, but restoring irrigation and drainage function in floodplain systems that now face more frequent extreme rainfall. BPS's province-level rice statistics for Aceh, North Sumatera, and West Sumatera underscore that these provinces remain meaningful contributors to regional rice supply, so extended irrigation downtime is a macro-risk, not merely a local hardship.[155] In Aceh, the most economically rational short-term interventions are: (1) clearing and rehabilitating tertiary canals and village-scale drainage in the most productive floodplains (notably in the north and northeast where paddy landscapes are extensive), (2) synchronized seed distribution with a replanting calendar that reflects receding-water realities (so replanting does not fail repeatedly), and (3) cash-for-work programs focused on restoring agricultural water control (desilting, repairing sluices, reinstating embankment breaks) — because these programs inject liquidity while repairing the public-good infrastructure that determines yields in the next season. Over the medium term, the same areas need risk-based redesign: drainage capacity that assumes higher short-duration intensities, protected pump and gate infrastructure, and strict control of settlement encroachment on natural flood conveyance corridors.

Long-term sustainable recovery, however, cannot be achieved by making the lowlands "fight water" alone. The relief-ratio analysis you have been using matters economically because it indicates which watersheds will produce flashier runoff and debris-laden flows removed. In Aceh, that translates into a simple economic rule: where high–moderate relief-ratio basins drain steep headwaters to densely settled plains (for example, the spine-to-plain systems such as Peusangan, Jambo Aye, Krueng Tamiang, Krueng Aceh, Woyla, Tripa, and several west-coast basins), protecting and restoring mid-slope forest cover is not an environmental "add-on" — it is an upstream risk-reduction investment that protects downstream fixed capital (roads, bridges, mills, markets) and makes private investment in agriculture and processing financeable at reasonable risk premiums. This is also where commodity strategy and ecology align: Gayo coffee landscapes in Aceh Tengah and Bener Meriah demonstrate

[154] BPS Aceh, 2025. "Volume Produksi dan Nilai Produksi Perikanan Tangkap di Laut Menurut Kabupaten/Kota dan Komoditas Utama di Provinsi Aceh, 2023", last updated January 23, 2025. Badan Pusat Statistik Provinsi Aceh, Banda Aceh.

[155] BPS Aceh, 2024. "Luas Panen dan Produksi Padi di Provinsi Aceh 2023," Berita Resmi Statistik, Badan Pusat Statistik Provinsi Aceh (November 29, 2024); BPS Sumatera Utara, 2024. "Luas Panen dan Produksi Padi di Provinsi Sumatera Utara 2023," Berita Resmi Statistik, Badan Pusat Statistik Provinsi Sumatera Utara, Medan; BPS Sumatera Barat, 2024. "Luas Panen dan Produksi Padi di Provinsi Sumatera Barat 2023," Berita Resmi Statistik, Badan Pusat Statistik Provinsi Sumatera Barat, Padang.

the production benefits of maintaining tree cover and microclimate regulation; scaling similar agroforestry logic (shade, contour planting, riparian buffers) into mid-slope commodity mosaics is one of the few ways to raise incomes without increasing hydrologic hazard.[156]

On investment opportunities, there are credible pathways in both commodity production and ecosystem services — but only if risk, legality, and land-use integrity are managed explicitly. On the commodity side, the bankable opportunities are largely "intensification and value addition" rather than expansion: (1) deforestation-free oil palm upgrading in the east-coast belt (replanting with higher-yield material, better farm management, traceability, and mill efficiency) paired with mandatory riparian restoration and no-go zones on steeper slopes; (2) fisheries processing, quality assurance) focused on the highest-value capture districts identified above; and (3) coffee and horticulture value addition in the highlands (processing, grading, logistics) coupled with enforceable forest protection in the watershed headwaters.value-chain upgrading (cold chain,

On the ecosystem-services side, carbon and related environmental markets can provide blended-finance leverage, but they require compliance with Indonesia's emerging carbon-trading governance. The practical implication for Aceh is that the most investable "ecosystem service" pipelines will be those that combine (1) measurable emission reductions or removals (forest protection, peat and mangrove restoration where relevant), (2) robust social safeguards and tenure clarity, and (3) strong monitoring, reporting, and verification and registry alignment — so that ecosystem interventions can be financed without creating future legal or reputational liabilities.

The ecosystem-service opportunity is most credible when it is mapped to where flood regulation and sediment control are physically generated. Conservation finance should prioritize the remaining intact upland blocks that still function as provincial "water towers" — especially the Leuser-facing headwaters and the Ulu Masen landscape (Aceh Besar, Aceh Jaya, Aceh Barat, Pidie, and Pidie Jaya) — because avoided degradation there protects downstream rice, palm, roads, and settlements in the north and east lowlands.[157] Rehabilitation should concentrate in the mid-slope disturbance belt (roughly 500–2,000 meters) of the main spine-to-plain watersheds (Peusangan, Jambo Aye, Krueng Tamiang, Krueng Aceh, Woyla, and Tripa), where assisted natural regeneration, riparian recovery, and slope stabilization most directly reduce peak inflows and sediment pulses that widen flood footprints downstream. Restoration should target (1) floodplain corridors in the displacement belt (Aceh Utara–Aceh Timur–Aceh Tamiang), (2) peat hydrological units that only recover with rewetting first (Tripa in Nagan Raya and Aceh Barat Daya; Singkil in Aceh Singkil), and (3) the thinned east-coast mangrove belt (Aceh Timur, Aceh Tamiang, and Kota Langsa) where additional loss directly increases compound coastal risk.[158] Any investable pipeline (including carbon) should be designed from the outset to meet Indonesia's carbon trading and registry requirements, so ecosystem-service revenue strengthens protection and restoration rather than creating future compliance risk.

[156] Hanifah, M., B. Nathania, and A.A. Nasution, 2024. "The Forest Monitoring Story Behind a Cup of Gayo Coffee," World Resources Institute Indonesia (May 14, 2024).

[157] The Government of Aceh, *et al.*, 2007, op cit.
[158] Ramsar Convention on Wetlands, 2021, *op cit*.

District/city (Kabupaten/Kota)	Priority sectors to restart quickly (0–24 months)	Priority sectors to build long-term (3–10 years), including investable themes
Aceh Utara	Food-crop recovery (paddy irrigation/drainage repair; post-flood seed and input packages); coastal capture fisheries cold-chain and landing-site repairs; logistics for Lhokseumawe industrial/port-adjacent economy.	Climate-resilient rice intensification (drainage upgrades, flood-tolerant calendars); fisheries value-chain (ice, handling, processing); riparian corridor restoration as "risk-reduction infrastructure" to protect the province's largest paddy base.
Aceh Timur	Rapid rehabilitation of smallholder oil palm supply chain (farm access roads, bridges, collection logistics); paddy recovery in floodplain blocks; coastal fisheries landing and market connectivity.	Deforestation- and conversion-free palm upgrading (replanting, traceability, mill efficiency) aligned with Aceh's jurisdictional palm roadmap; integrated floodplain management (setbacks, flood-compatible land uses); investable smallholder upgrading packages and verification systems.
Aceh Tamiang	Same east-coast bundle: smallholder oil palm logistics and working capital; paddy recovery and canal repair; market access to Medan corridor.	Jurisdictional sustainable palm platform (smallholders, mills, grievance response) and flood-risk–aware land-use control in upper catchment; investable "deforestation-free" commodity upgrading tied to compliance and monitoring.
Bireuen	Paddy recovery (tertiary irrigation/drainage, field access); trading and transport restoration along the north corridor.	Climate-smart rice intensification and irrigation modernization; agro-processing and storage (rice milling, drying) placed outside floodways; riparian buffers to reduce bank erosion and overtopping.
Pidie	Paddy recovery and irrigation/drainage repair; rebuilding local market connectivity.	Modernized irrigation operations and flood-compatible floodplain zoning; rice value chain upgrading (post-harvest, storage) to reduce seasonal income volatility.
Pidie Jaya	Paddy recovery (high-yield systems depend on fast drainage restoration); small-scale coastal economy and services.	Flood-resilient paddy systems and drainage pumping where required; coastal fisheries and small port/landing improvements; settlement planning aligned with river-setback compliance.
Aceh Besar	Paddy and peri-urban food systems recovery; restoring road connectivity to Banda Aceh markets.	Flood-resilient peri-urban agriculture and water management; eco-tourism and services that rely on watershed protection of Krueng Aceh headwaters; investable "green infrastructure" for urban flood mitigation.
Banda Aceh	Services, trade, and reconstruction supply chain; strengthening market systems and logistics during recovery.	Disaster-resilient urban services economy; construction-material supply chain modernization; investable resilience infrastructure (drainage, retention, safe evacuation corridors) that protects regional trade.
Lhokseumawe	Industrial and port-linked services recovery; transport and energy reliability.	Resilient industrial services and logistics; investable adaptation upgrades around critical infrastructure corridors (ports, access roads) to reduce downtime during flood events.
Langsa	Trading and logistics node on the east coast; fisheries and smallholder market services.	Coastal fisheries value chain and resilient logistics; integration into deforestation-free sourcing and smallholder support systems serving the Aceh Timur–Aceh Tamiang belt.
Aceh Jaya	Coastal capture fisheries restart (landing sites, ice/cold chain) and road access; restoring local trading.	Fisheries value-chain upgrading and coastal resilience; watershed-to-coast planning for short west-coast basins; investable "blue economy" upgrades tied to water quality and mangrove/coastal protection where relevant.
Aceh Barat	Paddy recovery (selected floodplains) plus coastal capture fisheries and services; restoring market access.	Integrated basin management (Woyla and connected systems): floodplain storage corridors, riparian restoration; fisheries value addition and coastal infrastructure designed for sediment pulses.
Nagan Raya	Plantation and paddy recovery where floodplain blocks were hit; restoring district road access and irrigation/drainage.	High-priority peat hydrology restoration and rewetting (Tripa peat unit) as both risk-reduction and carbon investment pipeline; enforce canal controls and peat-compatible livelihoods.
Aceh Barat Daya	Coastal fisheries restart; agriculture recovery; reconnect rural roads.	Tripa-linked peat and swamp restoration where conversion has degraded hydrological storage; eco-friendly coastal/fisheries upgrading; carbon-finance pipeline tied to verified peat rewetting outcomes.
Aceh Selatan	Coastal fisheries and local agriculture recovery; restoring connectivity across west–southwest corridors.	High-relief basin management (flash-flood risk): slope stabilization and riparian restoration paired with flood-compatible settlement and road placement; sustainable coastal fisheries and processing.

District/city (Kabupaten/Kota)	Priority sectors to restart quickly (0–24 months)	Priority sectors to build long-term (3–10 years), including investable themes
Aceh Singkil	Restoring drainage and access in low-relief coastal plain; fisheries restart and market access.	Peat-swamp hydrological restoration and protection in the Singkil landscape (canal management, rewetting) as a long-duration flood-risk reducer and ecosystem-services investment (carbon, biodiversity); strengthen peatland governance and enforcement.
Subulussalam	Agricultural recovery and road access; restoring basic services and market links.	Upper-watershed protection and agroforestry-compatible development; targeted restoration to reduce sediment delivery into downstream corridors; investable agroforestry systems where tenure is clear.
Aceh Tengah	Highland cash economy stabilization (coffee processing and logistics); maintain road access to markets.	Coffee-led agroforestry intensification (quality, processing, traceability) that maintains tree cover and reduces runoff/sediment risks; investable value-add (washing stations, grading, branding) built around Gayo coffee.
Bener Meriah	Same Gayo highland package: coffee logistics, processing, and rural access.	Coffee agroforestry and watershed protection as a dual economic–hydrological strategy; investable processing and quality upgrades anchored in farmer organizations.
Gayo Lues	Rural connectivity and basic services; diversified smallholder recovery.	Forest-friendly livelihood diversification and eco-tourism potential where feasible; upstream watershed protection as the foundation for downstream risk reduction.
Simeulue	Coastal fisheries restart and market connectivity (island logistics); restoring basic services.	Fisheries value chain (cold chain, processing) and climate-resilient coastal infrastructure; investable small-scale blue economy with strong resource management.
Sabang	Services and tourism restart; small-scale fisheries and port services.	Sustainable tourism and port-linked services, coupled with marine protection; resilience upgrades to reduce downtime during extreme weather.

Table 4.1. Post-disaster short- and long-term potential economic opportunities in Aceh. Source: various statistical notes by BPS.
Notes on "investment opportunity" framing (used across districts):

- Commodity-side investments are most bankable where they are intensification and value addition (not area expansion): deforestation-free palm upgrading in the east-coast belt; fisheries cold-chain and processing on high-volume coasts; coffee processing and quality upgrades in the Gayo highlands.
- Ecosystem-services investments are most credible where hydrological function is high and monitoring is feasible: peat rewetting and protection in Tripa (Nagan Raya/Aceh Barat Daya) and Singkil; watershed and riparian restoration in the major moderate-relief basins that anchor Aceh's rice and palm economies.
- If carbon finance is pursued, it should be structured to comply with Indonesia's carbon trading governance under the Financial Services Authority (Otoritas Jasa Keuangan) carbon-exchange framework.

4.9 Governance Reform

Reducing Aceh's flood risk to a fundamentally lower level requires governance, legal, and permitting reform that matches how risk is actually produced: upstream land-use decisions in specific watersheds propagate into downstream exposure along the north and east floodplains (especially the Aceh Utara–Aceh Timur–Aceh Tamiang belt) and the short, steep west-coast basins (including Teunom- and Kluet-facing systems). The core shift is to move from "project-by-project" and "district-by-district" management to enforceable, watershed-based rules that (1) stop new high-risk conversion in headwaters and mid-slopes, (2) restore river corridor function where it has been occupied, and (3) make every permit conditional on risk and hydrology, not only on administrative completeness.[159]

Watershed-based governance with binding authority. Aceh should institutionalize a watershed governance mechanism that is legally anchored, cross-district, and operational — not a coordination

[159] RI, 2012. Government Regulation (Peraturan Pemerintah) No. 37/2012 on Watershed Management (Pengelolaan Daerah Aliran Sungai).

forum. Practically, this means designating priority watersheds for recovery and risk reduction (for example, Peusangan, Jambo Aye, Krueng Tamiang, Krueng Aceh, Woyla, Tripa, and the high-relief west-coast basins), then requiring an integrated watershed plan under the national watershed management framework — with explicit land-use controls, restoration targets, and enforcement protocols that kabupaten and sector agencies must follow.[160] To make this work in Aceh's autonomy setting, the Governor should bind kabupaten plans and permitting practice to those watershed controls through the province's special-governance mandate, and hardwire the basin plans into budgeting and performance evaluation for district heads and agencies.[161]

Spatial planning reform that treats floodways and river corridors as non-negotiable "risk space". Risk reduction will fail if spatial plans continue to legalize exposure. Aceh's provincial spatial plan and detailed spatial plans must explicitly incorporate flood hazard, landslide susceptibility, and river corridor function, then translate them into enforceable zoning and the Spatial Utilization Conformity (Kesesuaian Kegiatan Pemanfaatan Ruang, KKPR) gate for every new activity.[162] The key "no-regret" legal move is strict implementation of river setback rules (garis sempadan sungai) and prohibition of new settlement and permanent structures inside functional river space — especially along the lowland corridors where displacement concentrates and where aggradation and blockage drive widening inundation.[163] Where settlements already occupy setbacks and repeatedly flood, the spatial plan should explicitly designate relocation zones on safer terraces and interfluves, and treat relocation as compliance with spatial law rather than as discretionary humanitarian assistance.[164]

Environmental approval reform: make hydrology, sediment, and cumulative impact mandatory in Environmental Impact Assessment. Many destructive outcomes persist because environmental approvals are treated as paperwork, not as a risk filter. Aceh should tighten the conditions under which Environmental Impact Assessment (Analisis Mengenai Dampak Lingkungan, AMDAL) is required and ensure that, in priority watersheds, AMDAL must include hydrological modeling (peak flow and travel time), sediment and debris risk, and cumulative impacts across the basin — not only site-level impacts. The legal basis already exists: Indonesia's environmental law mandates systematic protection and management and provides for Strategic Environmental Assessment (Kajian Lingkungan Hidup Strategis, KLHS) to ensure that plans and policies reflect environmental carrying capacity, while the implementing government regulation governs environmental approval instruments and administrative sanctions.[165] In Aceh's context, KLHS should be used as the "upstream" filter for spatial plans and sector development strategies in flood-prone watersheds, and AMDAL should become the "downstream" gate that can legally deny or redesign high-risk projects (for example, new roads that cut unstable slopes, new estates on steep mid-slopes feeding spine-to-plain basins, or drainage in peat hydrological units).

Permitting reform under Risk-Based Business Licensing: tighten the gates, then audit and clean the legacy stock. Indonesia's Risk-Based Business Licensing (Perizinan Berusaha Berbasis Risiko) system through Online Single Submission (OSS) can either dilute safeguards or strengthen them —

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[160] *ibid*.
[161] RI, 2006, *op cit*.
[162] RI, 2007. Law (Undang-Undang) No 26/2007 on Spatial Planning (Penataan Ruang); RI, 2021a. Government Regulation (Peraturan Pemerintah) No. 21/2021 on Spatial Planning Implementation (Penyelenggaraan Penataan Ruang).
[163] Ministry of Public Works and Housing, 2015. Ministerial Regulation (Peraturan Menteri) of Public Works and Housing No. 28/PRT/M/2015 on River Setback Lines and Lake Setback Lines (Penetapan Garis Sempadan Sungai dan Garis Sempadan Danau).
[164] RI, 2007, *op cit*.; RI, 2021, *op cit*.; Ministry of Public Works and Housing, 2015, *op cit*.
[165] RI, 2009. Law (Undang-Undang) No. 32/2009 on Environmental Protection and Management (Perlindungan dan Pengelolaan Lingkungan Hidup); RI, 2021b. Government Regulation (Peraturan Pemerintah) No. 22/2021 on the Implementation of Environmental Protection and Management (Penyelenggaraan Perlindungan dan Pengelolaan Lingkungan Hidup).

depending on whether the "basic approvals" are rigorous. Aceh should treat KKPR and environmental approval as non-waivable risk filters within OSS for all new permits in priority DAS, and require a "watershed-risk clearance" step for high-risk locations (mid-slope conversion, riparian zones, peat, and coastal buffers).[166] The second half is legacy reform: implement a time-bound permit audit across priority watersheds to identify illegal overlaps, non-compliance with spatial designation, encroachment into protected forests/riparian setbacks, and non-performance of rehabilitation obligations — followed by corrective actions, suspension, or revocation.[167] This is the single fastest way to reduce future disaster probability because it stops the next wave of risk accumulation while restoration proceeds.

Special regimes where the law is already explicit: peat, mangroves, and "One Map" enforcement. In peat landscapes (Tripa in Nagan Raya and Aceh Barat Daya; Singkil in Aceh Singkil), risk reduction is hydrology-first: drainage-dependent land uses in peat domes and key peat hydrological units are structurally incompatible with flood buffering and fire prevention. The peat ecosystem protection regulation provides the legal basis to enforce water-table protection and restoration (rewetting) and should be used to prevent new drainage and to compel correction where canals and land management have undermined peat function.[168] Likewise, along the east-coast mangrove belt (Aceh Timur, Aceh Tamiang, and Langsa), permitting should explicitly treat remaining mangroves as protective infrastructure (coastal flooding and storm surge buffering) and lock them into spatial zoning and permit denial for conversion where ecosystem function is already thin. Finally, to make enforcement credible, Aceh must operationalize the One Map Policy so that concession boundaries, forest area status, peat extents, and spatial designations align and are publicly auditable — reducing "administrative ambiguity" that often becomes a de facto amnesty for illegal occupation[169]

Enforcement, transparency, and accountability as routine practice
Risk is not reduced by plans alone; it is reduced by predictable enforcement. Aceh should publish an integrated permit registry for priority watersheds (concession boundaries, permit conditions, environmental approval status, and compliance findings) and run routine basin-scale monitoring with escalation protocols — administrative sanctions first, then license suspension and revocation where non-compliance persists. The legal foundation for administrative sanctions and supervision exists in the environmental implementing regulation and the risk-based licensing regulation; what is missing is consistent application and public visibility that changes behavior.[89]

Embed disaster risk reduction into development and budgeting. The disaster management law already frames government responsibility to integrate disaster risk reduction into development programs and planning. Aceh should translate this into budget rules: prioritize funding for permit audit and enforcement, basin restoration, river corridor recovery, and risk-informed infrastructure upgrades in the specific DAS that drive repeated impacts; and condition kabupaten transfers and program approvals on measurable compliance (setback enforcement, halted expansion into protected headwaters, and verified restoration in priority sub-basins).[170] This is the fiscal mechanism that turns "tobat ekologis" into durable governance rather than a one-off post-disaster narrative.

Eradicate corruption. Corruption, especially in licensing and legal enforcement, is not a side issue in disaster-risk reduction in Aceh; it is a direct "risk multiplier" because it converts high-hazard land-use change (clearing steep

[166] RI, 2021a. Government Regulation (Peraturan Pemerintah) No 5/2021 on Risk-Based Business Licensing (Penyelenggaraan Perizinan Berusaha Berbasis Risiko); RI, 2007, *op cit*.; RI, 2021, *op cit*.
[167] RI, 2021b. Presidential Regulation (Peraturan Presiden) No. 23/2021 amending Presidential Regulation No. 9/2016 on Accelerating the One Map Policy at 1:50,000 Scale Accuracy.
[168] RI, 2016a. Government Regulation (Peraturan Pemerintah) No. 57/2016 amending Government Regulation No. 71/2014 on Peat Ecosystem Protection and Management (Perlindungan dan Pengelolaan Ekosistem Gambut).
[169] RI, 2016b, *op cit*.; RI, 2021b., *op cit*.
[170] RI, 2007. Law (Undang-Undang) No. 24/2007 on Disaster Management (Penanggulangan Bencana).

headwaters, opening road-access, or normalizing plantations and mines inside sensitive forest blocks) into administratively "legal" outcomes, while simultaneously weakening the state's ability to stop illegal clearing once it starts.[171] In practice, this often takes the form of rent-seeking around the issuance, recommendation, and extension of permits, and selective enforcement that turns sanctions into a negotiable cost. Indonesia has repeatedly documented this pattern in real cases. For example, the Buol oil-palm bribery case showed how a concession and subsequent forest-conversion decisions can remain on the table even after the underlying permit pathway was tainted by bribery — creating perverse incentives for companies to treat bribery as an "investment" in land access.[172] More recently, the Corruption Eradication Commission (Komisi Pemberantasan Korupsi — KPK) has pursued cases where "fees" and in-kind benefits were allegedly paid to smooth forest-area management cooperation and where "redemption money" was allegedly solicited to condition the extension of Mining Business Licenses (Izin Usaha Pertambangan — IUP).[173].[3 4] Aceh itself has also experienced high-profile prosecution around "commitment fees" in government decisions (including special autonomy–funded projects), underscoring how patronage systems can become institutionalized and then spill over into spatial decisions and enforcement bargains.[174] For Aceh's flood-risk governance, the implication is concrete: permit audits and watershed-based zoning reforms must be paired with anti-corruption design — full public disclosure of permit chains and maps; conflict-of-interest controls in recommendations; traceable e-licensing; independent monitoring; corporate liability (not only individual officials); and automatic administrative consequences (revocation, restoration liabilities) when permits are proven to be obtained through bribery — otherwise, the steep, high-runoff parts of the landscape will remain "open" to politically financed conversion, regardless of what is written in plans.

Governance reform must be designed explicitly to safeguard Politics "with a capital P" — a politics of dignity, humanity, and civility — as the operating logic of recovery, not merely its rhetoric. Practically, this means building a legitimacy architecture that makes Acehnese communities and local institutions co-owners of both decisions and outcomes: a formal co-decision platform at watershed scale that brings together district governments, customary leadership where relevant, village representatives, women's and youth groups, and affected livelihood sectors; a transparent rulebook for prioritizing investments and trade-offs (including who bears restrictions and who receives compensation or livelihood support); and a time-bound grievance and dispute-resolution mechanism with published service standards, escalation routes, and publicly reported outcomes. To keep the reform agenda credible when it collides with entrenched interests, the program should also hardwire transparency into the political economy of permits and enforcement — through routine public disclosure of licensing status, compliance findings, and sanction actions — and use independent monitoring (academia, civil society, and professional associations) to verify progress. In Aceh's context, these mechanisms are not "participation extras"; they are the practical instruments that convert permit audits, spatial discipline, restoration targets, and enforcement into durable commitments — and that prevent governance reform from being gradually hollowed out by transactional small-p politics.

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[171] Schütte and Syarif, 2020, *op cit*.

[172] Jong, H.N., 2019. "Indonesian minister blasted over palm permit for graft-tainted concession," *Eco-Business* (February 25, 2019). https://www.eco-business.com/news/indonesian-minister-blasted-over-palm-permit-for-graft-tainted-concession/ (accessed on December 25, 2025).

[173] "KPK Tangkap Tangan Suap Izin Pengelolaan Kawasan Hutan," Siaran Pers, Komisi Pemberantasan Korupsi (August 14, 2025). https://kpk.go.id/id/ruang-informasi/berita/kpk-tangkap-tangan-suap-izin-pengelolaan-kawasan-hutan (accessed on December 25, 2025); "KPK Tahan Tersangka Penerima Suap Izin Pertambangan di Kalimantan Timur TA 2013–2018," Komisi Pemberantasan Korupsi (September 11, 2025). https://kpk.go.id/id/ruang-informasi/berita/kpk-tahan-tersangka-penerima-suap-izin-pertambangan-di-kalimantan-timur-ta-2013-2018 (accessed on December 25, 2025).

[174] Natalia, D.L., 2019, *op cit*.

5
Concluding Note: We Need a Fundamental and Comprehensive Landscape Management Reform

This rapid assessment reaches a clear conclusion: Aceh's November 2025 floods were not only an extreme weather event, but the predictable outcome of extreme rainfall interacting with degraded watersheds, exposed settlement patterns, and governance systems that have not consistently treated ecological function as public safety infrastructure. In Aceh's ridge-to-reef geography, risk is generated upstream and paid for downstream — through damaged homes, disrupted markets, failed bridges, lost harvests, and repeated displacement. Recovery, therefore, cannot be defined as rebuilding what was lost in the same places, under the same rules. It must be a deliberate transition toward a watershed-based development model that internalizes hydrological reality in land use, permitting, infrastructure, and public finance.

A landscape approach provides the operational pathway for that transition. It requires tightening protection in intact headwaters and high-function ecosystems, concentrating rehabilitation where degraded mid-slopes most influence peak flows and sediment pulses, and restoring converted river corridors, floodplains, peat hydrological units, and coastal buffers where the landscape has lost its "room for water." But the assessment also affirms a hard constraint: even the best ecological restoration will not eliminate flooding under torrential rainfall in steep and moderate-relief basins. Aceh therefore needs an integrated risk-management system that combines nature-based measures with end-to-end early warning that reaches villages with actionable triggers, engineering solutions designed for sediment-rich hydrology, and safer settlement choices — including planned relocation where exposure is structurally indefensible and rebuilding in place locks communities into recurrent loss.

Long-term recovery must also be economic, not only ecological. The affected areas cannot wait for forests to regrow before livelihoods restart. Short-term priorities are to restore access and market connectivity, restart production safely, and stabilize household cashflow, while the medium- to long-term agenda is to shift growth toward deforestation- and conversion-free commodity systems, resilient supply chains, and diversified rural incomes compatible with watershed protection. This is not an "environment versus economy" debate. Recurrent floods are an economic constraint that raises risk premiums, discourages investment, and repeatedly wipes out household assets. A credible pathway exists to mobilize investment in both sustainable commodity upgrading and ecosystem services, but only if it is grounded in spatial priorities, legality, safeguards, and measurable risk reduction.

Finally, none of these measures will hold if licensing and enforcement remain vulnerable to corruption. Corruption in permitting and legal enforcement functions as a direct risk multiplier: it can transform high-hazard land conversion into administratively "legal" outcomes, weaken supervision, and turn sanctions into a negotiable cost. This is why watershed-based governance and permit audits must be paired with corruption-proofing: public disclosure of permit chains and maps, enforceable conflict-of-interest controls, traceable e-licensing, independent monitoring, and automatic administrative consequences when permitting is tainted or conditions are violated, including suspension or revocation and restoration liabilities. In practical terms, Aceh's commitment to building back better is ultimately a commitment to restoring the authority of the state to protect high-function landscapes, enforce risk-based rules fairly, and align budgets and incentives so that protection and restoration are rewarded rather than undermined.

If Aceh succeeds, it will not mean floods never occur again. It will mean floods no longer become recurring catastrophe — because exposure is reduced, warnings are trusted and acted upon, infrastructure is designed for real hydrological conditions, ecosystems regain function where it matters most, and governance has the integrity to keep risk from being rebuilt back into the landscape.

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