# ENHANCING COASTAL RISK REDUCTION SCIENCE AND PRACTICE BY CONSIDERING CLIMATE, ECOSYSTEMS AND COMMUNITIES IN THE TROPICAL REGION


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With: BRIN Indonesia | UNU-IAS Japan | Vidyasagar University India


Context: ISAP 2026 — International Forum for Sustainable Asia and the Pacific.


APN Project CRRP2022-06MY-Muslim | 2022–2024 | USD 85,000


Eco-DRR · Coastal Resilience · Geospatial Risk Assessment
Mangrove · Coral Reef · Seagrass · Small Islands · Science-Policy Interface · SDGs

# The Consequence of Coastal Vulnerability

# 600 million

## people live within 10 m of sea level.

Sea-level rise, coastal erosion, and intensifying storms are reshaping shorelines that communities depend on for food, shelter, and income.

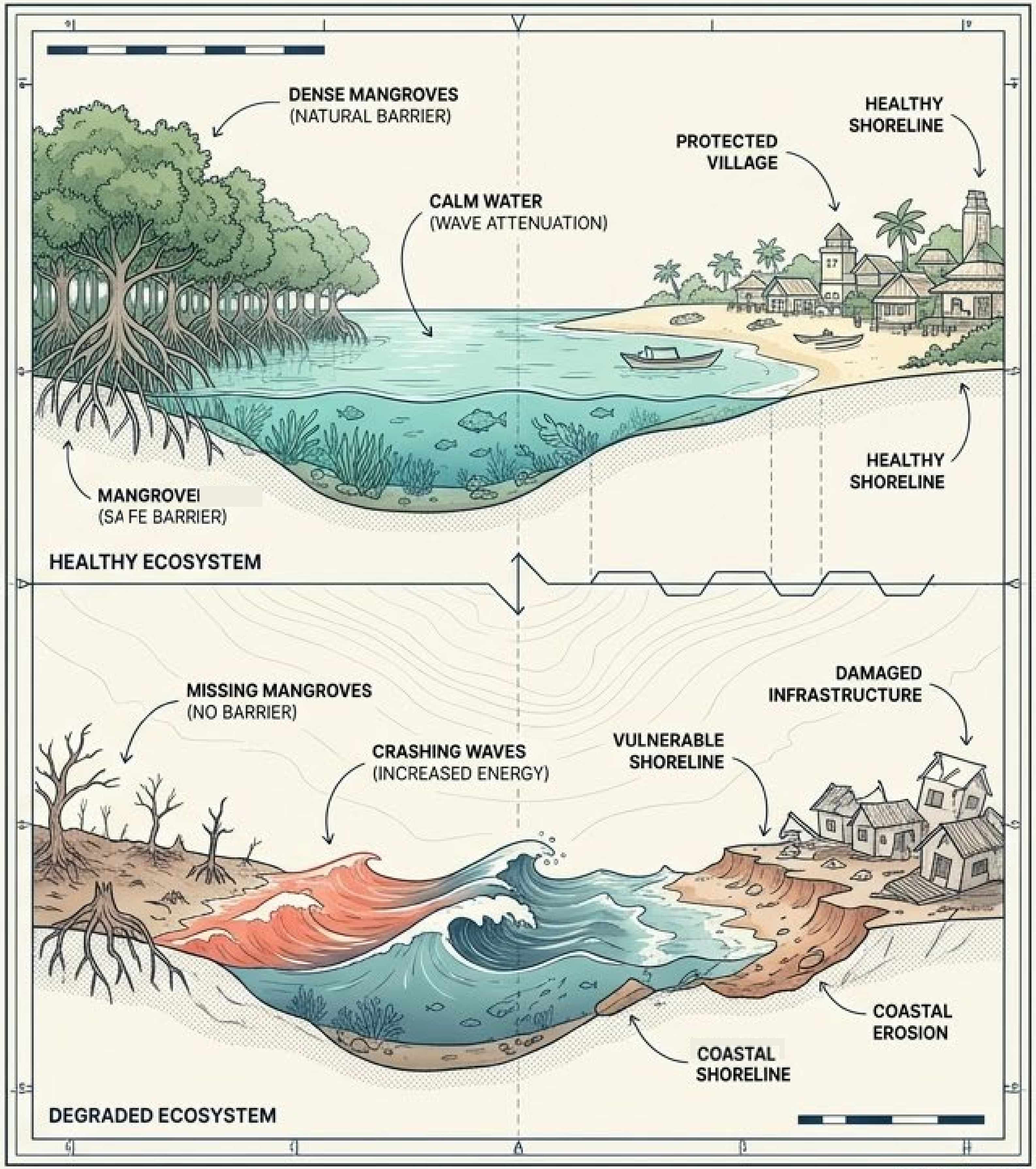
**What's missing from most risk assessments:**
Physical hazard data alone — no ecosystem health, no social vulnerability, no future scenarios integrated.

**The consequence if coastal habitats are lost**

**96%** **of Bintan Island residents** → high hazard exposure.

**63%** **of Seribu Islands residents** → high hazard exposure.

**Today, with ecosystems intact, those numbers are a fraction of this.** (Setiawati et al., 2024)




NotebookLM

# Defining Ecosystem-based Disaster Risk Reduction

**Eco-DRR is the sustainable management and conservation of natural ecosystems to reduce disaster risk, while delivering co-co-benefits for livelihoods, biodiversity, and climate adaptation.**

## What it does

- Quantifies how ecosystems reduce hazard exposure.
- Integrates ecology, climate, and community into risk planning.
- Provides evidence for where to protect habitat first.

## What it is not

- A substitute for all engineered structures.
- Going green without spatial evidence.
- A one-size-fits-all solution.

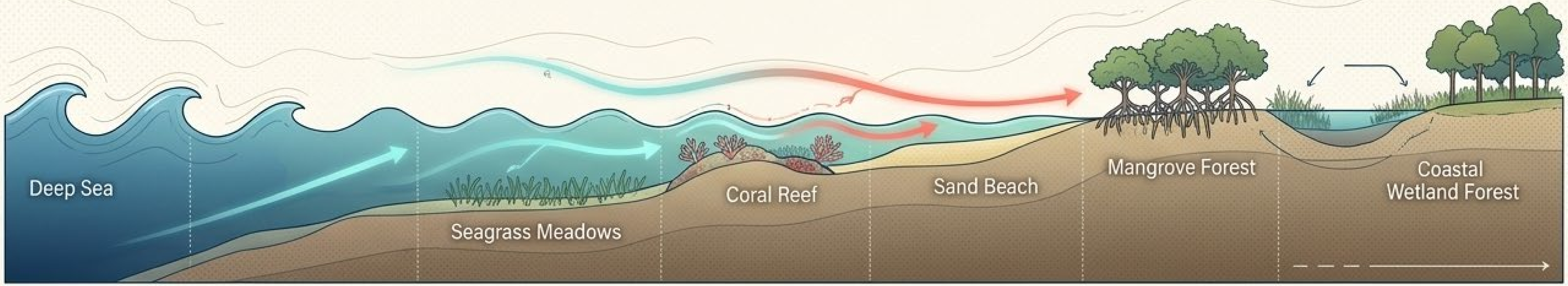
Sendai Framework → Paris Agreement → Kunming-Montreal GBF → SDG 13, 14, 15

# Seawalls are expensive, static, and they do not adapt.

| | Grey Infrastructure | Coastal Ecosystem |
|---|---|---|
| Cost | High build + maintenance | Low (especially mangrove restoration) |
| Adaptability | Fixed height/overtops as seas rise | Grows, migrates, self-repairs |
| Ecology | Destroys intertidal habitat | Supports fisheries, biodiversity |
| Co-benefits | None | Carbon, tourism, fisheries, water quality |
| Long-term | Increasingly inadequate | Potentially more effective over time |

Conservation and habitat restoration are less expensive than engineered protection and far more cost-effective when co-benefits are included.
(Narayan et al., 2016; Temmerman et al., 2013)

# Three Lines of Natural Defense




## Mangrove (Rank 1)

- Absorbs **50–70%** of wave energy across a **500m** fringe.
- **Highest protection** (InVEST Hazard Index).
- Nursery for fish. Carbon store. Erosion shield.

## Coral Reef (Rank 1)

- Dissipates **70–97%** of incoming wave energy.
- **Natural breakwater** that also feeds communities.
- At risk from **bleaching** — its loss raises hazard levels immediately.

## Seagrass (Rank 3)

- Reduces **current velocity** in shallow coastal zones.
- **Filters water**, feeds turtles and dugongs.
- Being **destroyed** by self-reclamation in Seribu Islands MPA.

**Hazard Rank Scale:** Coral/Mangrove = 1 (lowest risk) → Seagrass = 3 → **No habitat** = 5 (highest risk).

| 1 | 3 | 5 |
|---|---|---|
| lowest risk | Seagrass | highest risk |

# The Missing Spatial Framework

> “If the mangroves, reefs, and seagrass disappear — how many more people face hazard, and where exactly are they?

## Before this project

- Risk maps used physical data only.
- No integrated framework for tropical small islands.
- Conservation arguments were qualitative.
- Policymakers could not see where habitat loss would hurt most.

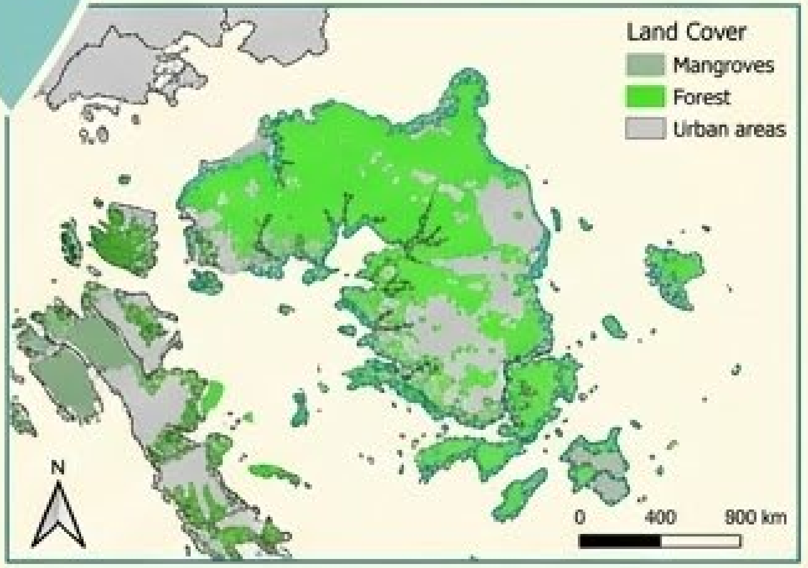
## After this project

- Reproducible spatial framework — 7 physical + 5 social variables.
- Hazard index under 4 scenarios: present/future, with/without ecosystem.
- First published CVI for Bintan and Seribu Islands grounded in natural capital data.
- Open-access maps, datasets, and training materials.

# Three High-Stakes Pilot Sites

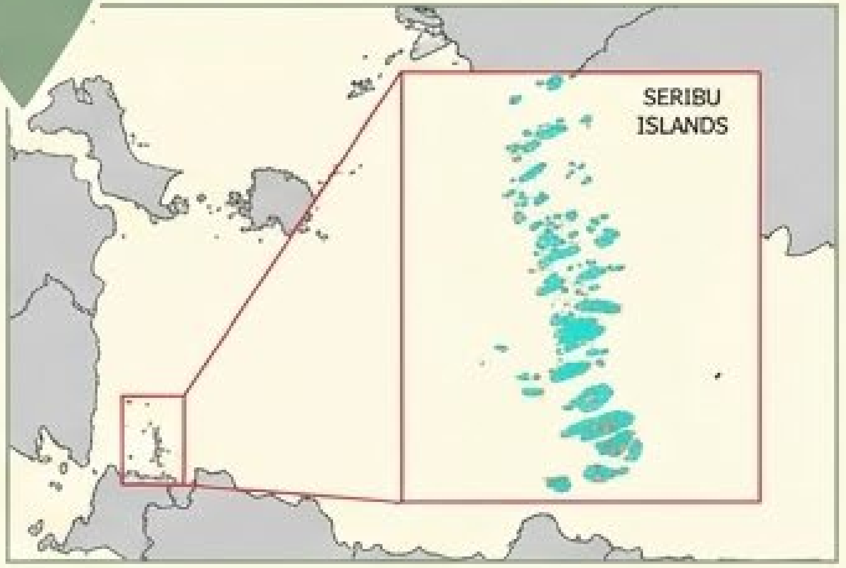
## Three sites. Two countries. One framework. A representative cross-section of tropical coastal risk in South-East Asia.

### Bintan Island, Indonesia



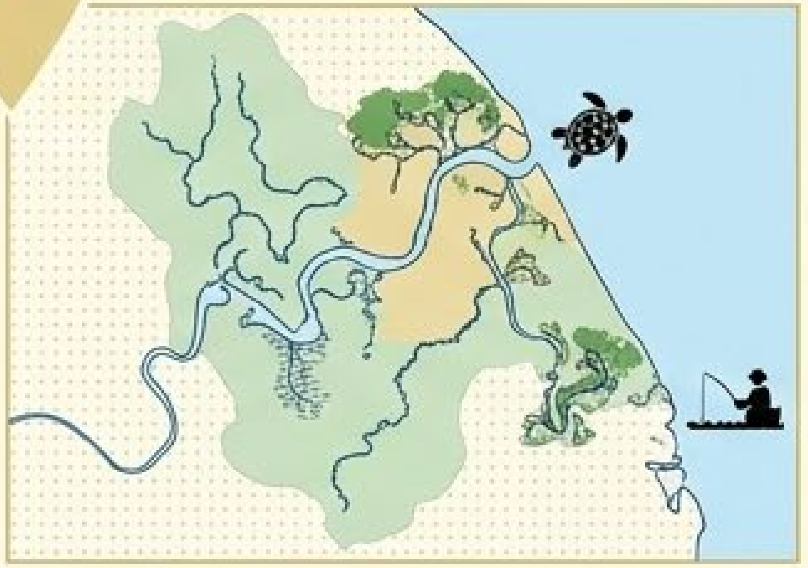

- Maritime crossroads (Indonesia, Malaysia, Singapore).
- Transboundary oil spills + bauxite mining + resort development.
- Mangrove cover fell 15% between 1990 and 2020.

### Seribu Islands, Indonesia




- Small islands in Jakarta Bay | Marine Protected Area.
- Self-land reclamation destroying seagrass and coral inside MPA.
- 40% of residents in poverty | 18% are children under 5.

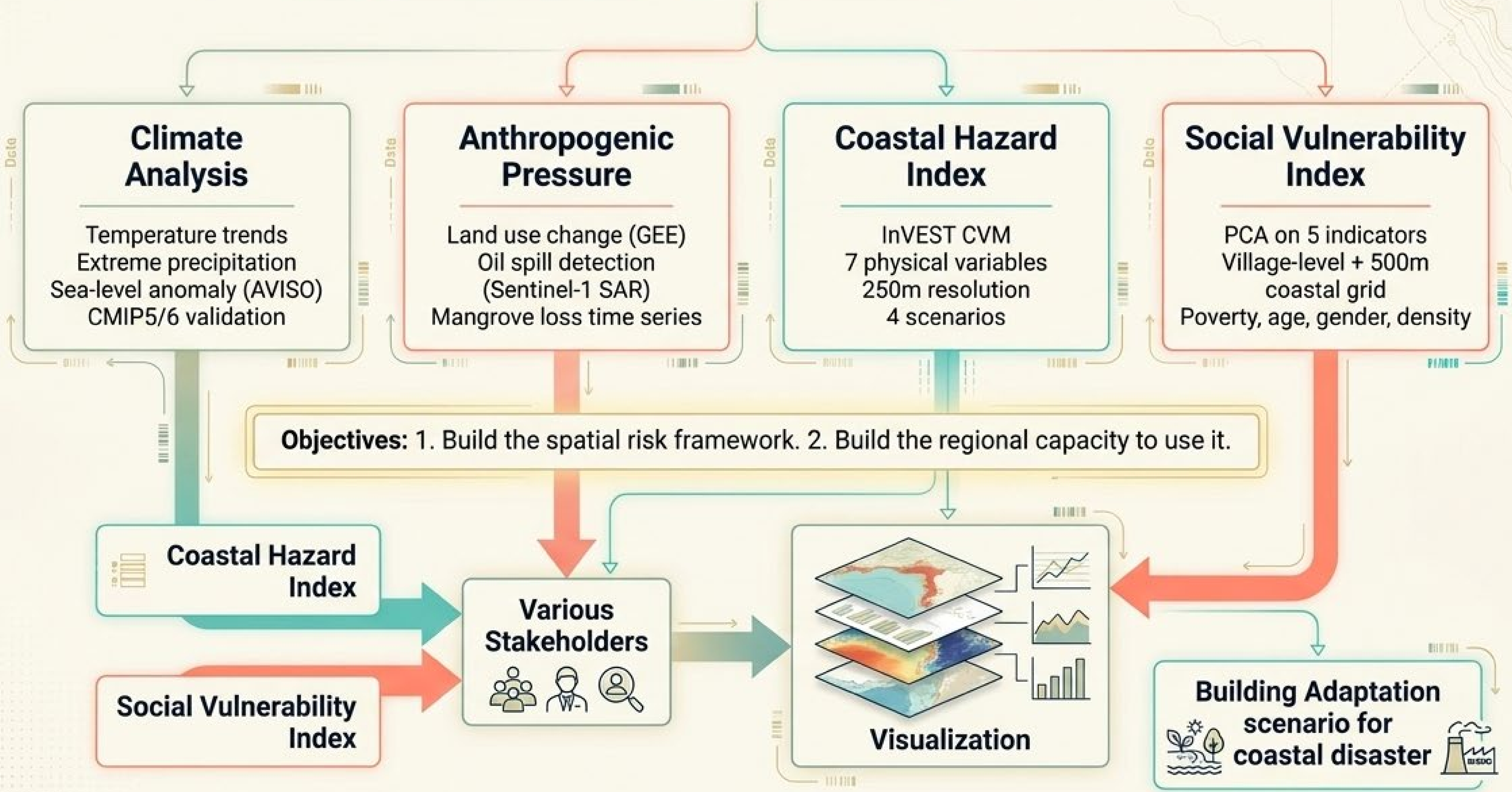
### Setiu Wetland, Malaysia



- Only 9-ecosystem interconnected wetland in Malaysia.
- IUCN Red List turtle nesting site.
- 645 licensed fishermen | National Eco-Tourism Plan designation.

# The Architecture of Proof

**The Core Equation: Risk = Hazard Exposure + Social Vulnerability** (Neither dimension alone tells the full story).



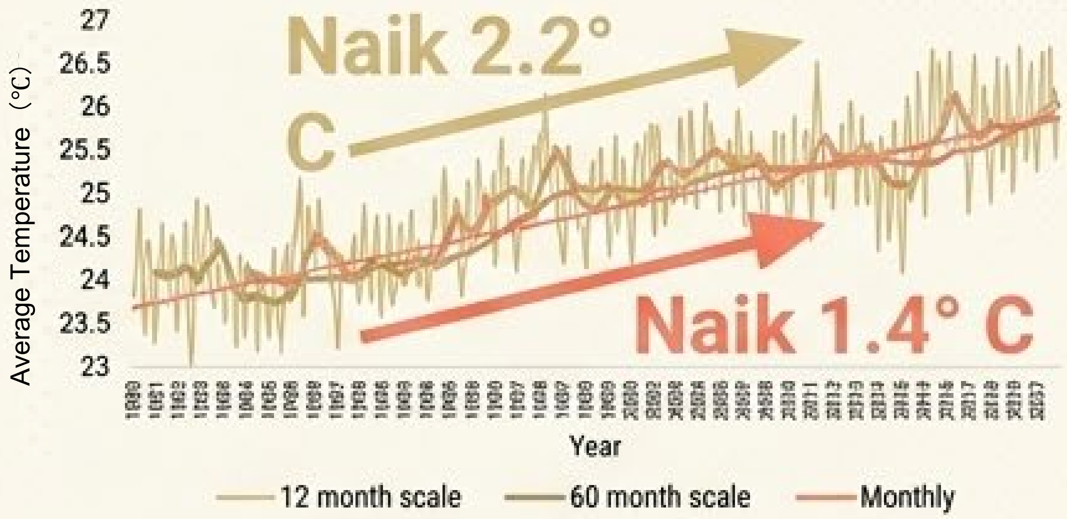
# The InVEST Coastal Vulnerability Model

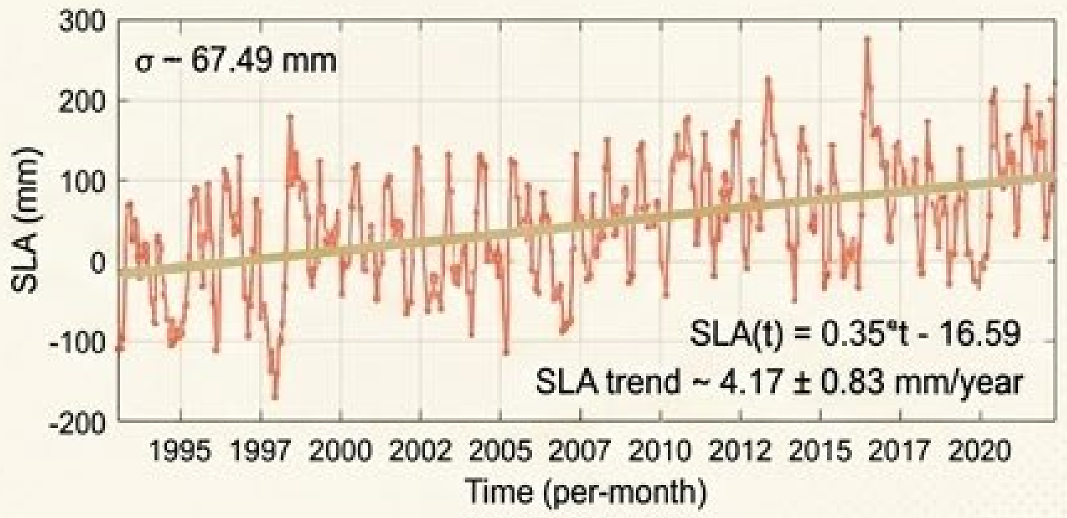
**Open-source** | Natural Capital Project | 250m coastline resolution.

$$HI = \sqrt[7]{\mathbf{Habitat} \times \mathbf{Shoreline} \times \mathbf{Winds} \times \mathbf{SLR} \times \mathbf{Surge} \times \mathbf{Relief} \times \mathbf{Waves}}$$

| Variable | Rank 1 | Rank 5 |
|---|---|---|
| Natural Habitat | Coral reef / Mangrove | No habitat |
| Shoreline Type | Rock / Seawall | Sand |
| Sea Level Rise | 0–20 cm | 80–100 cm |

Data sources: AVISO SLR 1993–2022 | BIG DEM 0.27 arcsec | CMIP5/6 ensemble | Google Open Buildings V3.



# Social Vulnerability Must Be Co-Designed

The SoVI was co-designed, not assumed. (Scoping Workshop, Terengganu — May 2023. 8 scholars, 3 countries).

**SoVI**

- Population density — who is exposed?
- Elderly (>65 yrs) — who cannot flee?
- Children (<5 yrs) — who is most physiologically at risk?
- Women (share) — who faces differential impact?
- Poverty rate — who cannot recover?

Workshop → Variables → PCA Scoring

Rationale Box 1: Why 500m coastal grid?
Village boundaries extend inland.
The grid captures only people at the water's edge.

Rationale Box 2: Why PCA?
Objective.
Reduces redundancy.
Widely validated.

Authentic photo grid





# Bintan Island Hazard Exposure

| Scenario Comparison | | |
|---|---|---|
| **Present + Ecosystem** | 18.24% high-hazard / | ~15,000 people. |
| **Present, No Ecosystem** | Expands ~4x / | Rises to ~11% of total. |
| **2040 + Ecosystem** | Doubles to ~33–42% / | 96% protected by habitat. |
| **2040, No Ecosystem** | Near-total exposure / | Two-thirds of communities at risk. |

**Kawal Village Case:** Dense mangrove in 2011. Open land by 2022. Now sits in the highest hazard class. (Mangrove fell 15%, 1990–2020).

104 km

**Key Finding:** Coastal habitat by 2040 could protect **104 km** of Bintan's shoreline.

# Seribu Islands: High Poverty, High Exposure

High dependency on ecosystems.
40% of residents live in poverty.
18% are children under 5.

40%

18%

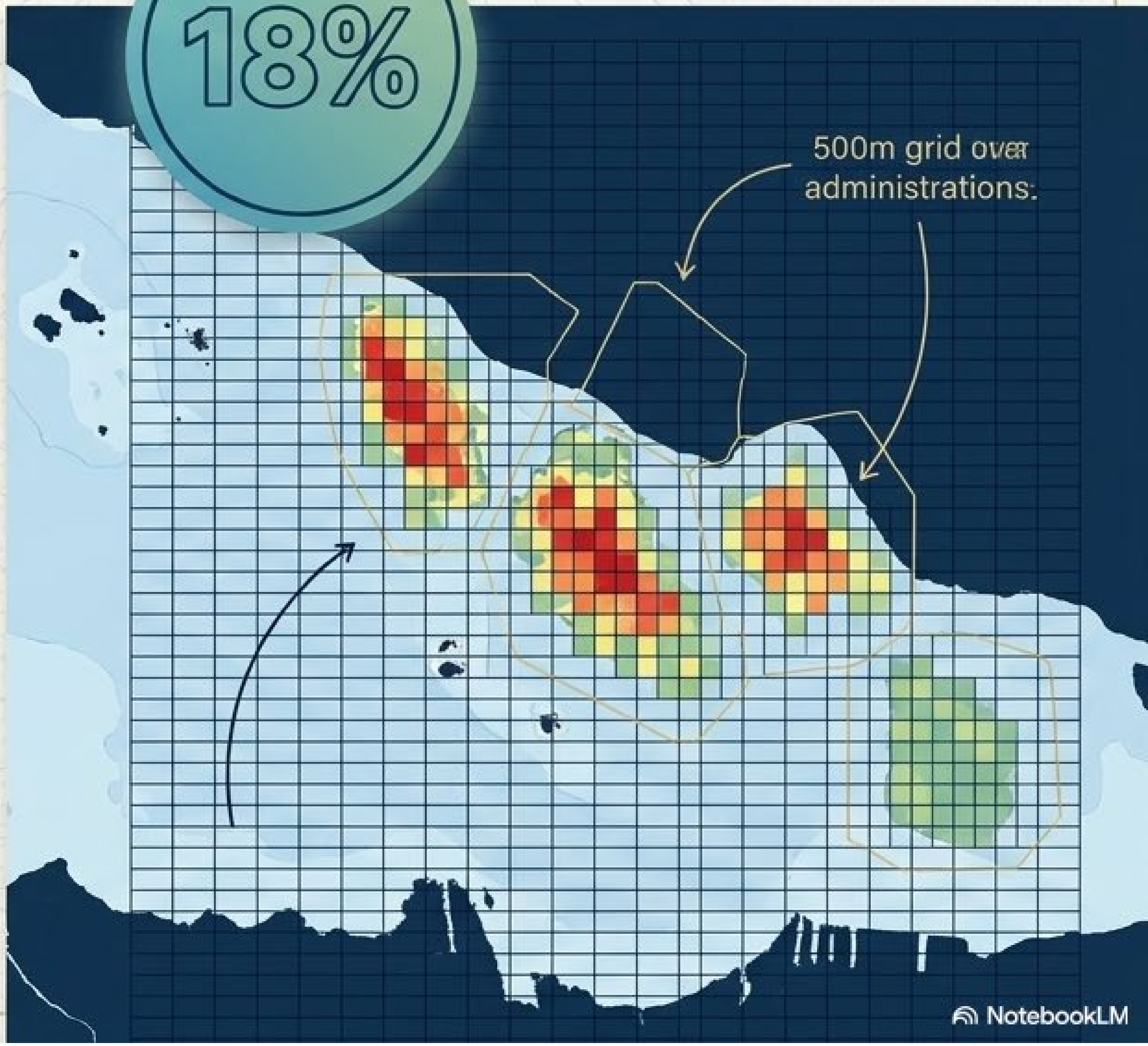
| | |
|---|---|
| Present + Ecosystem: 21.8% | Pari Island well-protected. |
| Present, No Ecosystem: Triples | Kelapa + Tidung most exposed. |
| 2040, No Ecosystem: 3x expansion | 40% of residents at risk. |
| 2040 + Ecosystem: Managed | 50% of exposed areas protected. |

**Kelapa:**
Highest combined risk.

**Panggang:**
High social vulnerability; self-reclamation destroying habitat.

**Tidung:**
High physical hazard.

**Pari:**
Protected now, fully exposed under 2040 no-ecosystem scenario.



# The True Cost of Habitat Loss

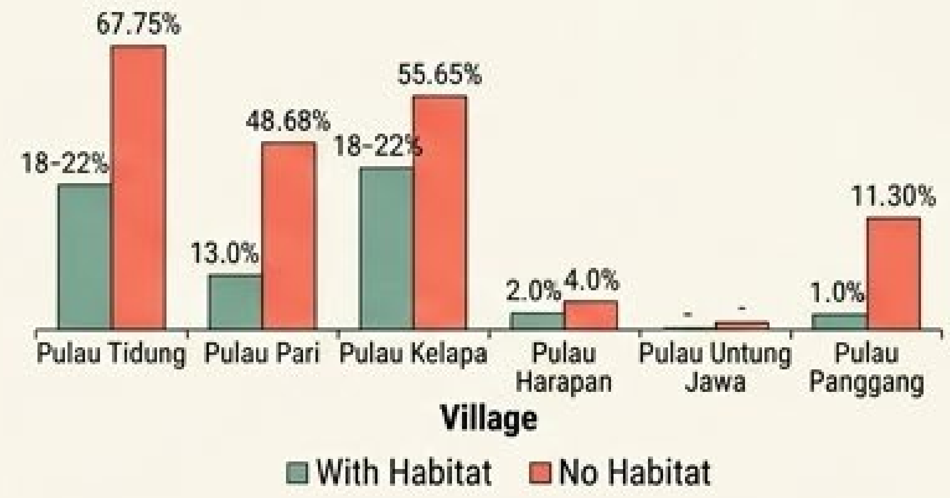
### What the ecosystem buys

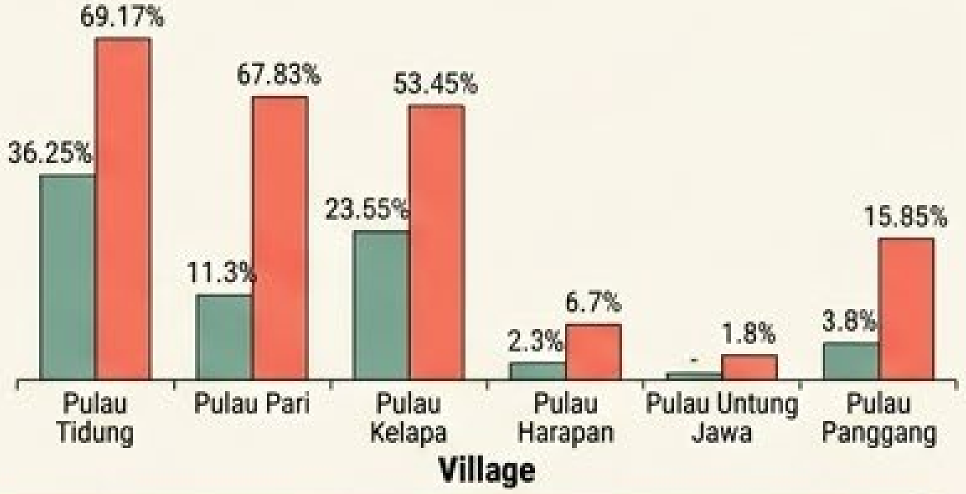
- **104 km** of protected coastline in Bintan.
- **17 km** of protected coastline in Seribu Islands.
- **Two-thirds** of the most vulnerable communities sheltered.

### Scenario Matrix

| | With Ecosystem | Without Ecosystem |
|---|---|---|
| **Present** | **18–22%** high hazard | **Triples or quadruples** |
| **2040** | **50–96%** of exposed areas protected | **63–96%** of residents at risk |

### Coastline Exposure: With vs. No Habitat

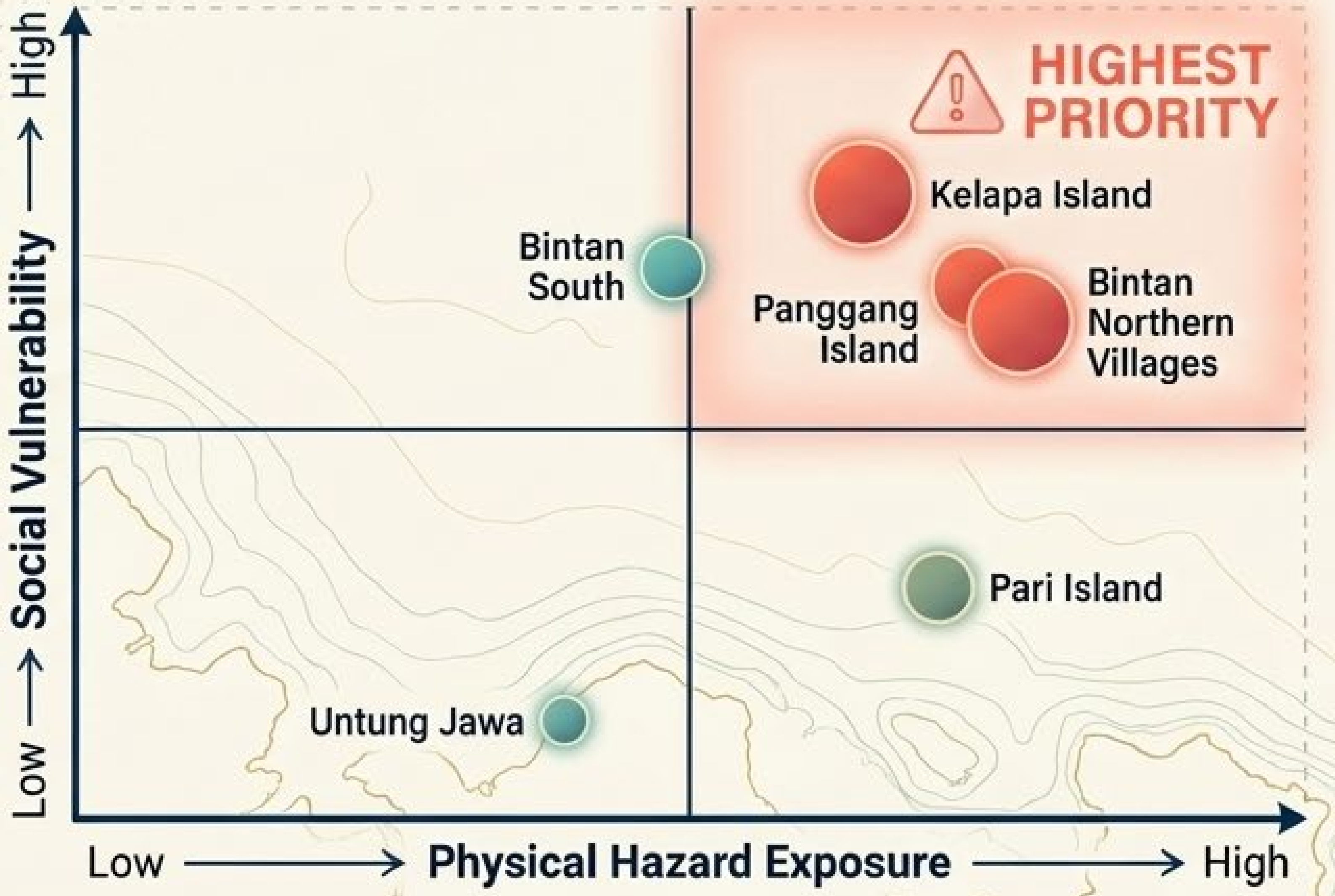



**The Bottom Line:** Preserving natural coastal habitats by 2040 could **protect 104 km and 17 km of coastline and shield two-thirds of the most vulnerable communities** from **rising seas**. (Setiawati et al., 2024).

# Priority Investment: Hazard vs. Vulnerability

Concept: Hazard tells us where. SoVI tells us who.




## Seribu Islands Focus:

- **Kelapa Island** — highest SoVI + high hazard = greatest combined risk.
- **Panggang Island** — very high population density drives SoVI.
- Demographic Reality: **40%** poverty, **18%** <5 yrs.

## Bintan Island Focus:

- Highest risk in northern villages where mangrove loss is concentrated.
- Vulnerability is within walking distance of the water — not spread evenly across the district.
- **Demographic Reality:** **25%** poverty, **6.5%** <5 yrs.

**The Priority Rule: High SoVI + High Hazard = where investment must go first.**
**That is precisely where ecosystem protection delivers the greatest human dividend.**

# Human Pressures Outpace Climate Threats

Climate is not the only threat. Human pressure is faster — and more controllable.

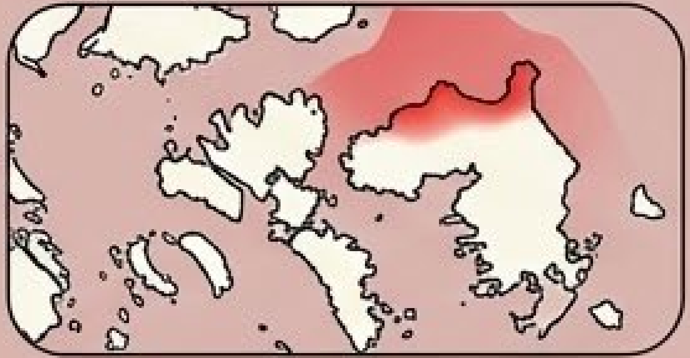
## Bintan: Transboundary Oil Spills

MISSION-CONTROL DASHBOARD

**HIGH**

**HAZARD ZONE**

Detected via Sentinel-1 SAR. Northern coast = highest hazard zone = oil spill hotspot.



## Bintan: Land Clearing

**15% ↓**

Mangrove fell. Open land doubled between 2011-2022.

2011 → 2022

**Driver:** Bauxite mining + resort development. Kawal Village lost dense mangrove.

## Seribu: Self-Reclamation

**↑165%**

Area increase around Panggang Island.

Residents extending land into the sea inside the MPA, destroying protective seagrass/coral.
**Driver:** overcrowding + weak enforcement.

**Synthesis:** These pressures do not exist in isolation from poverty and governance gaps.

# Science That Reaches Policy

Paradigm Statement: Science that does not reach policy is incomplete. This project was designed as a science-policy dialogue from Day 1.

## Involvement

Policymaker embedded from start.

MMAF collaborator (Directorate of Small Islands).

Research questions shaped by ministry mandates.

## Co-Production

**May 2023** Scoping workshop (SoVI co-design).

**June–July 2024** FGDs with Bintan/Seribu authorities.

**May 2024** International participatory workshop.

## Dissemination

**Sep 2024**
Bappenas/BIG/MMAF engagement on RPJMN alignment.

**May 2025** National workshop — CVI endorsed for One Map Policy.

# Co-Production Drives Alignment

**Six engagements.** Each one served a different function. Participants spanned national authorities, local government, village communities, and parliament.

| | | |
|---|---|---|
| **May 2023** | Scoping Workshop, Terengganu → | **SoVI variables co-designed** |
| **Jun 2024** | FGD, Bintan (BPBD + BRIN) → | **Hazard zones field-validated** |
| **Jul 2024** | FGD, Seribu (Local authorities) → | **MPA governance gaps confirmed** |
| **May 2024** | International Participatory Workshop → | **4-point adaptation framework aligned with Sendai** |
| **Aug–Sep 2024** | FGDs with MMAF, Bappenas, BIG → | **CVI alignment with RPJMN confirmed** |
| **May 2025** | National Govt Workshop → | **CVI endorsed for One Map Policy** |

Integration into National Planning Instruments

# The Verdict: This research is already shaping national policy.

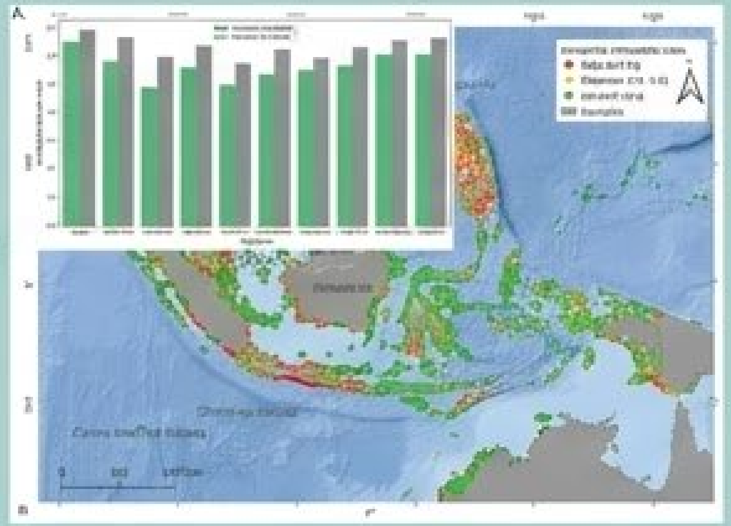
## Indonesia: RPJMN 2025–2029

- CVI listed as indicator under Climate Resilient Development Program (PBI).
- Bappenas adding coastal habitat and SLR scenarios to national CVI.
- Presidential Instruction (Inpres PBI) under discussion.


Bappenas (RPJMN 2025-2029): Coastal vulnerability in Indonesia by considering the role of natural habitat and CC scenarios

## Indonesia: One Map Policy

- BIG Decision No. 16/2023 mandates MMAF as data handler.
- This project's CVI confirmed compatible with 1:50,000 national requirements.
- BRIN Dataverse providing open-access dataset.



## Malaysia: Setiu Wetland

- Climate vulnerability data integrated into local planning.
- Nine-ecosystem designation under National Eco-Tourism Plan.

"This research has the potential to be scaled up to the national level… (Head of Research Center for Oceanography, BRIN).

# Translating Protection into Global Goals

Eco-DRR is inherently multi-SDG.

### SDG 13 — Climate Action

- Replicable spatial risk framework for climate-exposed coastal communities.
- Methodology feeding into RPJMN 2025–2029.
- Adaptation validated under 2040 scenarios.

### SDG 14 — Life Below Water

- Hazard-reduction of coral/mangrove/seagrass quantified.
- Threats (oil spills, reclamation) documented inside MPAs.
- MPA governance evidence base strengthened.

### SDG 15 — Life on Land

- 15% mangrove loss on Bintan mapped.
- Spatial evidence for land-use planning.
- Setiu Wetland 9-ecosystem conservation.

**One mangrove stand = SDG 1 + 2 + 11 + 13 + 14 + 15.**

# Protecting Those Who Cannot Protect Themselves

40%

## SDG 1 — No Poverty

40% poverty (Seribu) | 25% poverty (Bintan).

Ecosystem loss = fishery loss = deeper poverty.

Eco-DRR is a poverty prevention strategy, not only an environmental one.

18%

## SDG 3 — Good Health

18% of Seribu residents are children under 5 (vulnerable to flood illness).

Mangroves/seagrass filter water, reducing disease burden.

## SDG 11 — Sustainable Cities

Seribu Islands are part of megacity Jakarta.

Hazard maps = spatial planning tools for safe development zones.

Self-reclamation is informal urbanisation requiring governance.

**When coastal ecosystems protect the shoreline, they are protecting the people who can least afford the consequences of disaster.**

# Eco-DRR is a development strategy, not just a conservation one.

## Fisheries

- **645 licensed fishermen** in Setiu depend on wetland productivity
- **88.4% have no secondary income** — ecosystem loss = immediate poverty
- **Fish habitat destruction** already observed: declining catch, seasonal disruption

## Ecotourism

- **Setiu** designated under Malaysia's National Eco-Tourism Plan
- **Pulau Redang + Pulau Lang Tengah**: premier dive sites, reef-dependent
- **Seribu Islands**: marine tourism revenue collapses if reef degrades

## Aquaculture

- **1,000 ha shrimp operation** in Setiu (Penarik / Chalok)
- Dependent on clean water quality maintained by surrounding wetland
- **Saltwater intrusion** from SLR would **destroy** production

**Every dollar in ecosystem protection = reduced disaster costs + sustained livelihoods.**



# The only nine-ecosystem coastal wetland of its kind in Malaysia.

Sea → Beach → Mudflat → Lagoon → Estuary → River → Islands → Coastal Forest → Mangrove

*Disrupt one — the rest follow.*


## Why it matters:

(1) IUCN Red List turtle nesting site

(2) 645+ licensed fishermen | 1,000 ha shrimp aquaculture

(3) National Eco-Tourism Plan designation

(4) Only Malaysia site with full nine-ecosystem connectivity

## Threats documented:

(1) Saltwater intrusion contaminating aquaculture and agriculture

(2) Sea-level rise threatening mudflat and mangrove fringe

(3) Altered monsoon disrupting fish migration and production

(4) Flooding of lagoon settlements from extreme precipitation

**Project activities:** Socio-economic survey | Drone mapping | Community engagement on climate adaptation

# From 2 pilots to 54,700 km of Indonesian coastline.


Seribu Islands, Jakarta a workshop

## Four things scaling requires:

### ① Data Infrastructure

Long-term SLR from BIG tide gauge network

National shoreline change map (MMAF — in progress)

Benthic habitat maps at 1:50,000 | Village-level demography from BPS

### ② Institutional Capacity

Train BPBD, MMAF, BIG in InVEST CVM

Short-course materials: inos.umt.edu.my/apn/ (public, now)

Embed CVI in university marine science curricula

### ③ Governance Alignment

CVI into RPJMN reporting indicators

Inpres PBI to mandate CVI across ministries

One Map Policy: add CVI layer to BIG national repository

### ④ Community Inclusion

Village DRM units per MoHA Reg. 46/2008

Community habitat monitoring

Diversify income to reduce ecosystem extraction pressure

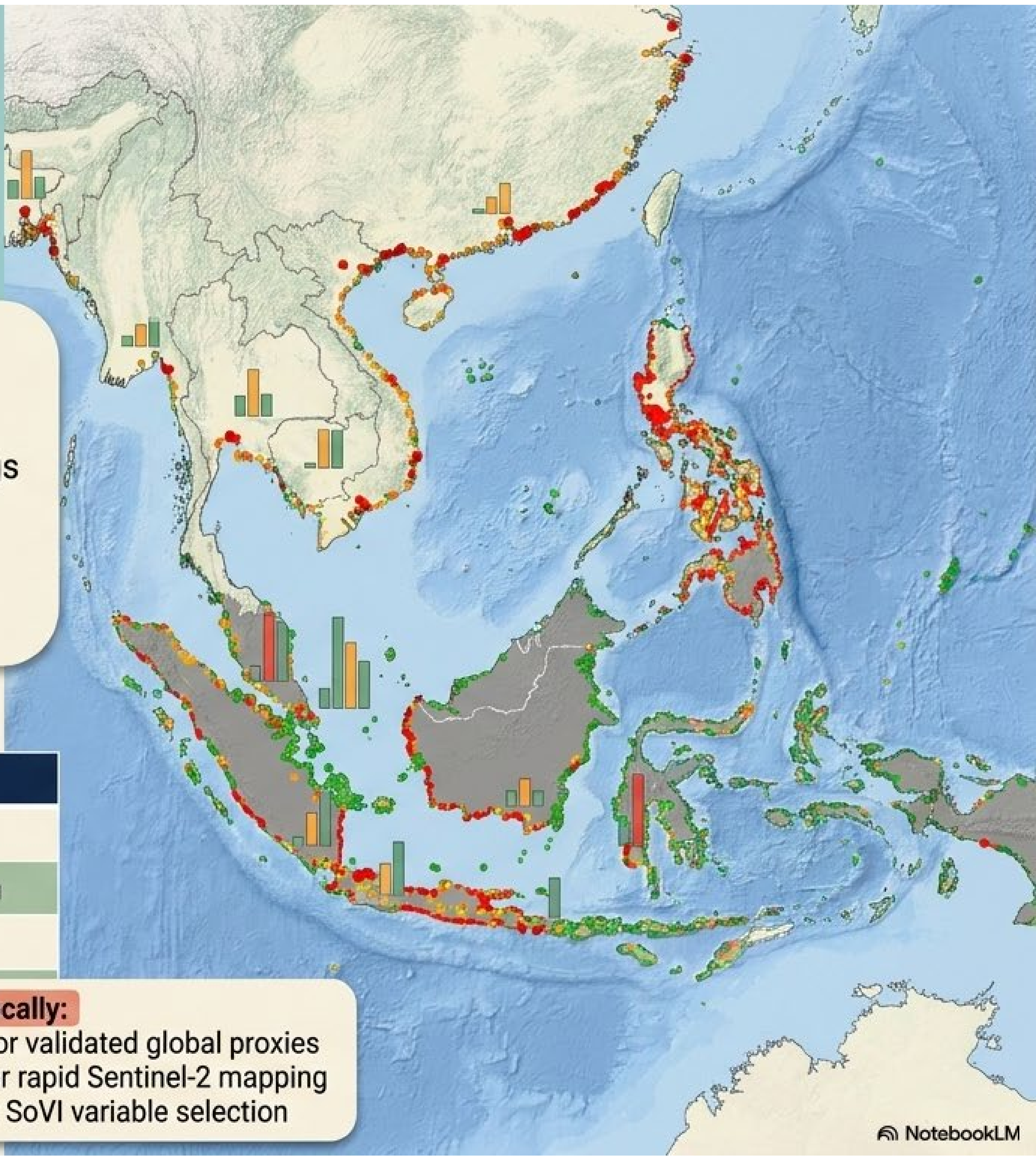
# This framework is ready to travel.

### Why it works anywhere in the tropics:

Open-source tools throughout (InVEST, GEE, SNAP ESA)
Global datasets: AVISO SLR | CMIP5/6 | Google Open Buildings
SoVI variables adapt to local data and stakeholder priorities
Training materials and database publicly available
4-country team = ready-made regional transfer network

**Priority candidates:**

| Country / Region | Key Risk Factor |
|---|---|
| Philippines | Cyclone exposure + Coral Triangle overlap |
| Vietnam | Mangrove loss from aquaculture conversion |
| Bangladesh | Sundarbans + delta SLR + poverty |
| Pacific Island States | Existential SLR |



**What replication needs locally:**

- Local wave/surge data or validated global proxies
- National habitat maps or rapid Sentinel-2 mapping
- Co-design workshop for SoVI variable selection

# What this project opened up.

## Acknowledged Limits:

**Global wind/surge/wave data used** — local observational data would sharpen precision

**SoVI limited to social indicators** — infrastructure and economic resilience not yet included

**2022 population baseline only** — no village-level demographic projections for 2040

**Two pilot sites** — insufficient for direct national rollout without additional validation

## Next Research Priorities:

**National-scale CVI** using BIG tide gauge data + MMAF shoreline change map

**Add infrastructure variables:** hospitals, roads, evacuation routes to SoVI

**Shoreline change validation:** satellite-derived positions over 10–20 years

**Blue carbon accounting module:** link ecosystem protection to carbon/biodiversity credit markets

Extend to Malaysia's Peninsular coast, Sabah, and Sarawak

**Integrate hazard maps** with **real-time meteorological alert systems**

Project Website:
https://inos.umt.edu.my/apn/


https://www.instagram.com/apn.coastalresilience/

**Emerging Opportunity:** Blue carbon and biodiversity credits could fund Eco-DRR at the scale the problem demands. The spatial data from this project is exactly the evidence those markets require.

# What this project proved:

1. **Ecosystems work — measurably.**
   Habitat loss would triple or quadruple high-hazard coastline extent at both sites.

2. **The 2040 window is narrowing.**
   SLR doubles exposure by 2040. Conserving habitat now is the cheapest insurance.

3. **Poverty and hazard always overlap.**
   The most exposed communities are also the poorest. Eco-DRR is poverty reduction.

4. **Science reaches policy when you design for it.**
   CVI aligned with RPJMN 2025–2029 and One Map Policy — because policymakers were partners from Day 1.

5. **Regional teams produce regional results.**
   4 countries | 5 publications | 1 open database | 8 early-career scientists

6. **The framework is ready to travel.**
   Open-source. Documented. Replicable. The region needs it.

# Keywords in focus:

**Eco-DRR** — Using natural ecosystem conservation to reduce disaster risk. Quantified here using the InVEST Coastal Vulnerability Model across 4 scenarios.

**Coastal Resilience** — The capacity of a coastal social-ecological system to absorb and adapt to hazards. Measured through hazard index + SoVI.

**Coastal Vulnerability Index (CVI)** — 7 physical variables + 5 social variables. 250m resolution. Now feeding into Indonesia's RPJMN and One Map Policy.

**Nature-Based Solutions (NbS)** — Eco-DRR is the coastal disaster-risk application of NbS. Conservation replaces or complements engineered structures.

**Science-Policy Interface** — Embedded policymakers, co-design workshops, national dissemination. Not an afterthought. Built in from Day 1.

**Natural Capital** — The stock of ecosystems that provides protective services. Treated here as a quantifiable risk reduction variable.

**Transdisciplinary Research** — Oceanography + remote sensing + geography + governance + community. One framework, one output set, one usable result.


Setiawati, M. D., Chatterjee, U., Djamil, Y. S., Nandika, M. R., Rachman, H. A., Supriyadi, I. H., … & Islam, K. (2023). **Seribu islands in the megacities of Jakarta on the frontlines of the climate crisis.** *Frontiers in Environmental Science*, 11, 1280268. https://doi.org/10.3389/fenvs.2023.1280268

Setiawati, M. D., Nandika, M. R., Supriyadi, I. H., Iswari, M. Y., Prayudha, B., Wouthuyzen, S., Adi, N. S., Djamil, Y. S., Hanifa, N. R., Chatterjee, U., Muslim, A. M., & Eguchi, T. (2023). **Climate change and anthropogenic pressure on Bintan Islands, Indonesia: An assessment of the policies proposed by local authorities.** *Regional Studies in Marine Science*, 66, 103123. https://doi.org/10.1016/j.rsma.2023.103123

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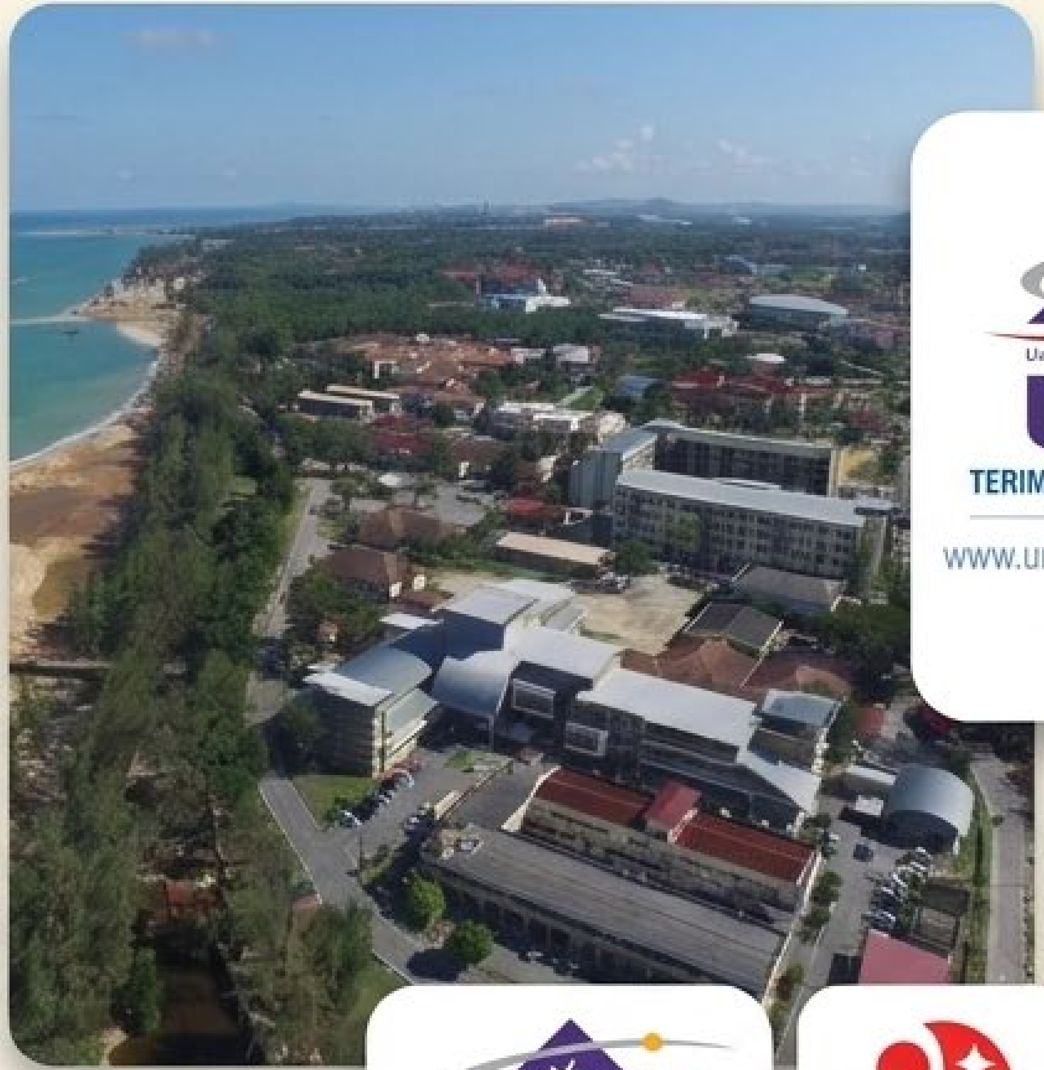
NotebookLM

# Thank you.

**This project was built across four countries, eight institutions, and three time zones — by people who went into the field through monsoon seasons and sat in workshops until the maps made sense to both scientists and village leaders.**



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**Uday Chatterjee** — Vidyasagar University, India
**Novi Susetyo Adi** — MMAF, Indonesia
**Yudha Setiawan Djamil** — BRIN, Indonesia
**Tsuyoshi Eguchi** — Yamaguchi University, Japan

**Five Publications:**

**Setiawati et al. (2023) —**
Frontiers in Environmental Science

**Setiawati et al. (2023) —**
Regional Studies in Marine Science

**Setiawati et al. (2024) —**
Discov Appl Sci **6**, 462

**Djamil et al. (2024) —**
IOP Conf. Series EES

**Nandika et al. (2023) —**
APSAR Conference, Bali

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