Analyzing Spatial Co-benefits of Carbon and Structural Diversity in South-East Asia with GEDI

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Objectives

Leveraging NASA GEDI derived wall to wall products, this study aims to identify high carbon and structurally diverse co-benefit areas in South-East Asia (SEA). The study is guided by three key objectives:

1. *Identify high priority co-benefit areas using GEDI products.*
2. *Quantify the protection status of co-benefit areas within the target countries of each SEA ecoregion.*
3. *Assess the anthropogenic pressure and biomass disturbance in and around the identified areas.*

Introduction:

- **Tropical forests** store most global plant biomass and absorb ~30% of annual fossil fuel emissions [1].
- Rapid deforestation and habitat loss **threaten >40% of regional biodiversity by 2100** [2].
- **South-East Asia (SEA)** holds ~15% of tropical forests and multiple biodiversity hotspots and are committed to **protecting 30% of land/sea by 2030** [3], but **PA effectiveness remains uncertain** [4].
- PAs preserve **older, carbon-rich forests** and buffer local climate extremes [5] GEDI estimates show **PAs store 26% of woody carbon; 9.65 Gt C linked to avoided degradation** [6].
- In the early 2000s, **>90%** of SEA forests were **unprotected**; many PAs showed little additional impact [7].
- **Indonesia** lost **~28.4 Mha** of primary forest (1991–2020); only 48.6 Mha remained by 2020 [8].

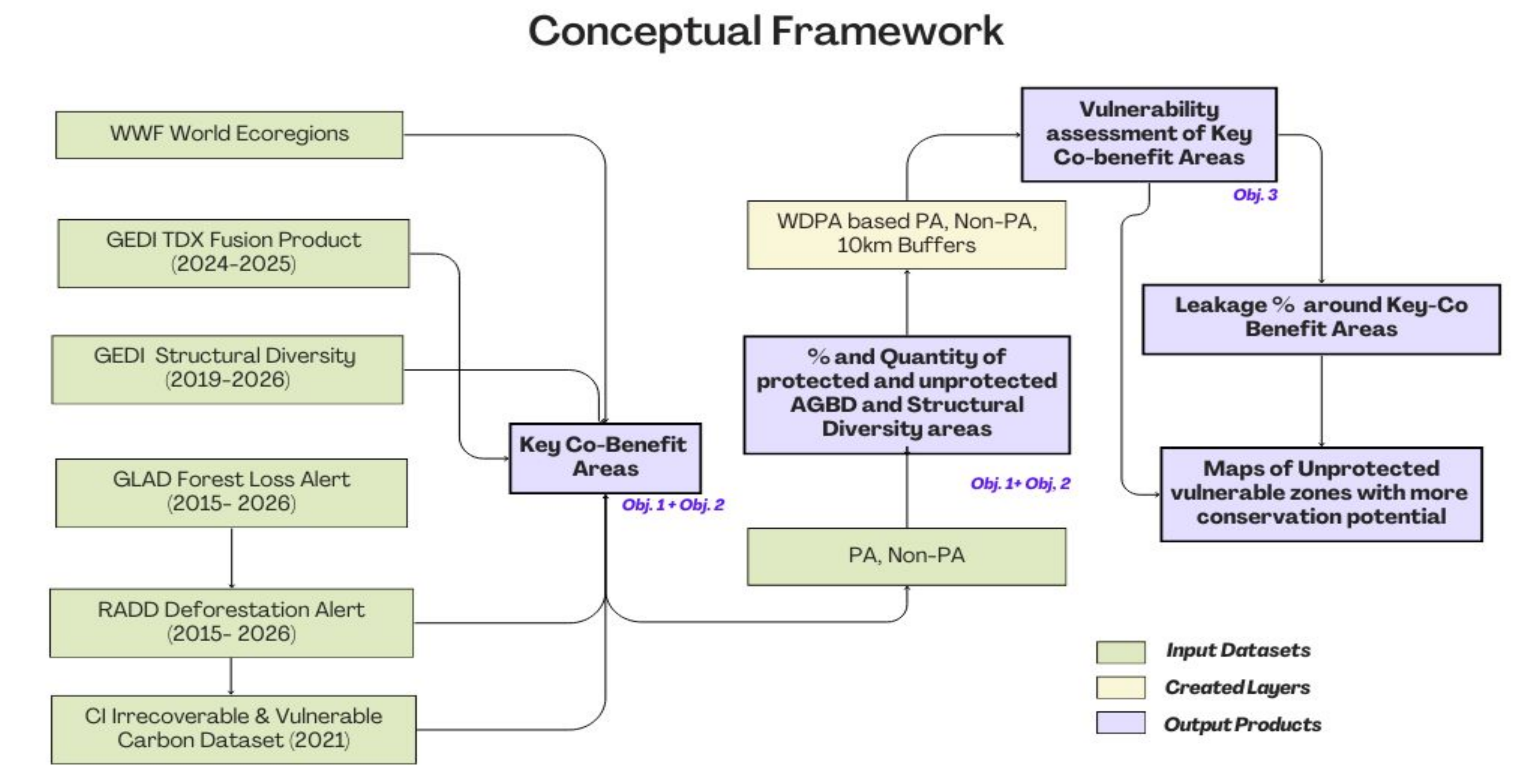

Figure 1: Conceptual Framework of the research describing the input datasets, steps and anticipated products.

Methods:

Co-benefit identification:

- Use NASA GEDI wall-to-wall AGBD and WSCI data.
- Select top 10% (90th percentile) hotspots cells per ecoregion.

Protection status analysis:

- Overlay selected cells with WDPA layers.
- Calculate % area and biomass inside vs. outside PAs.

Vulnerability assessment:

- Compare GEDI data from 2020–2023 and 2024–2026.
- Use GLAD and RADD alerts to detect forest loss.
- Analyze within co-benefit areas and 10 km buffers.
- Overlay with CI's irrecoverable/vulnerable carbon datasets.
- Generate country-level disturbance and risk maps.

Preliminary Results:

- **GEDI–TanDEM-X fusion** reveals that only **~27%** of Indonesia's **AGB (Aboveground Biomass) hotspots** are currently captured.
- **GEDI L4C-derived hotspots** exhibit **WSCI** (Waveform Structural Complexity Index) values between **10.40–11.36**, indicating the **highest structural diversity** is observed in tropical forests.
- Only **27.5%** of **carbon-rich areas** and **37.6%** of **structurally diverse zones** fall within **Protected Areas (PAs)**.
- **Threshold-based hotspot delineations** at the **ecoregion level** reveal **spatial disparities in protection coverage**, with the majority of high-value areas lying **outside PA boundaries**.
- **Ecoregion-level analyses** identify which regions contain greater **AGB** or **structural diversity** within PAs-providing a framework for guiding **future conservation strategies.**

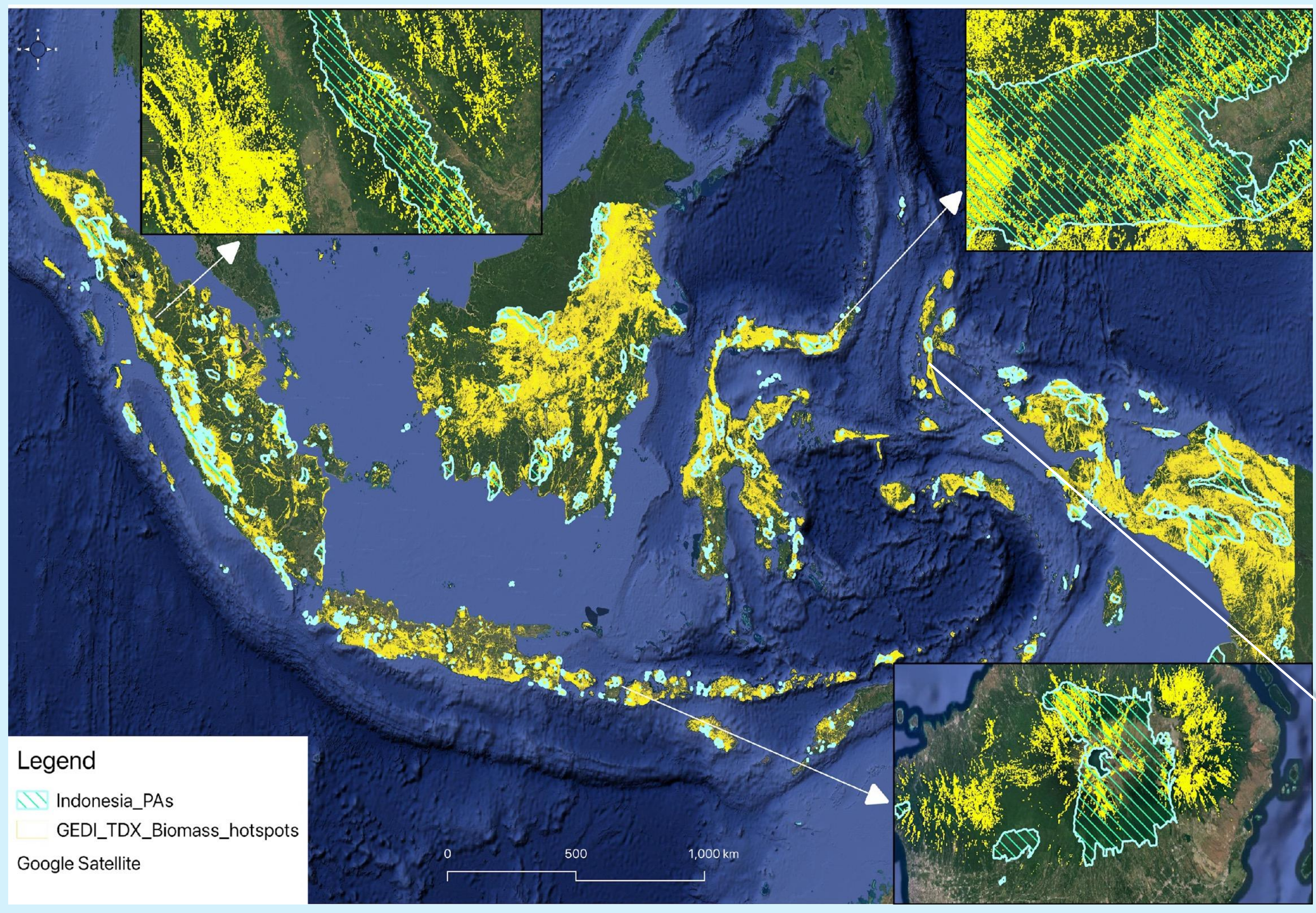

Figure 2: GEDI-TDX based Ecoregion Biomass Hotspots(2013-2018) Map with Protected Areas in Indonesia.

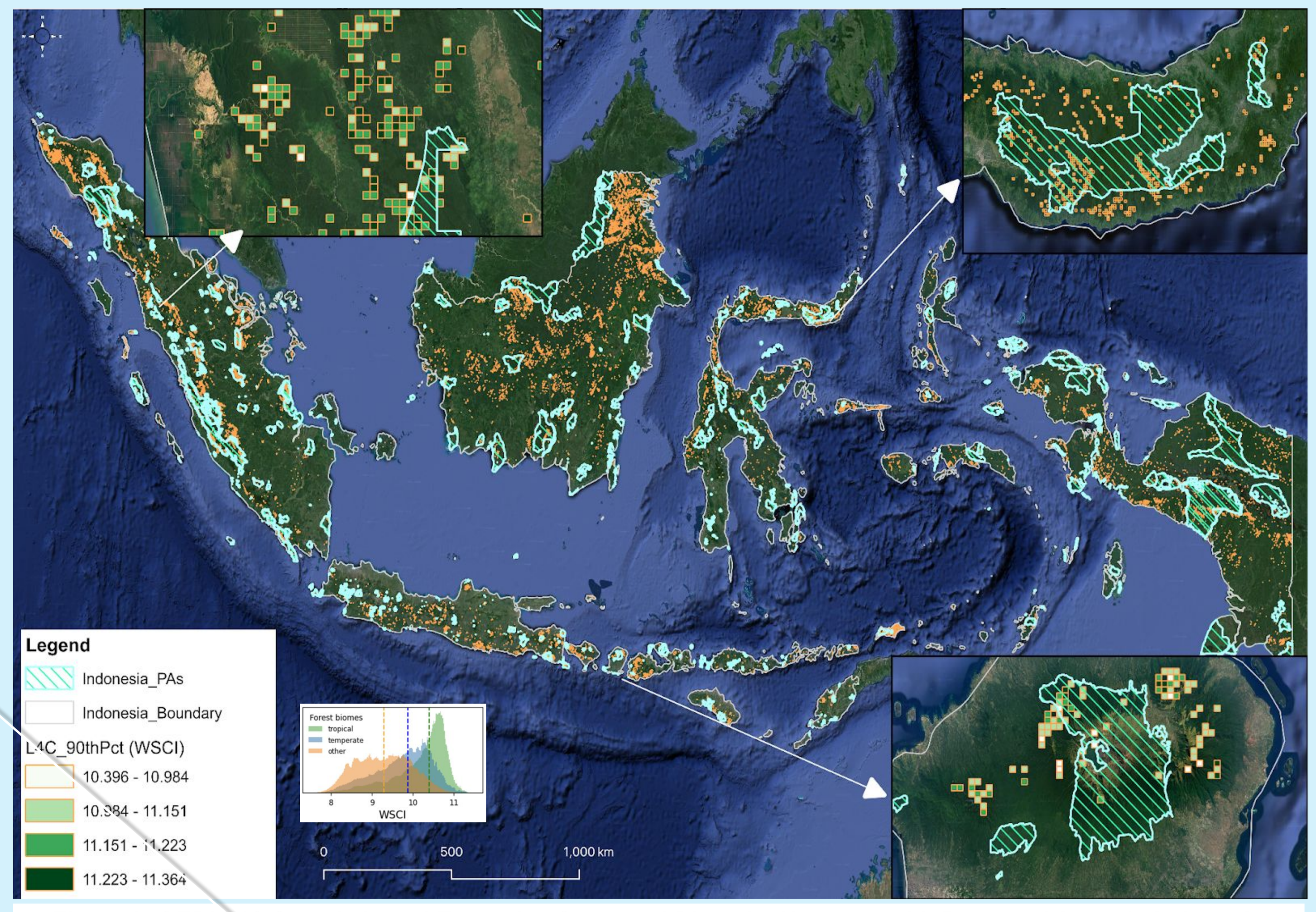

Figure 3: GEDI L4C Sample based Ecoregion Structural Diversity Hotspots with Protected Areas in Indonesia.

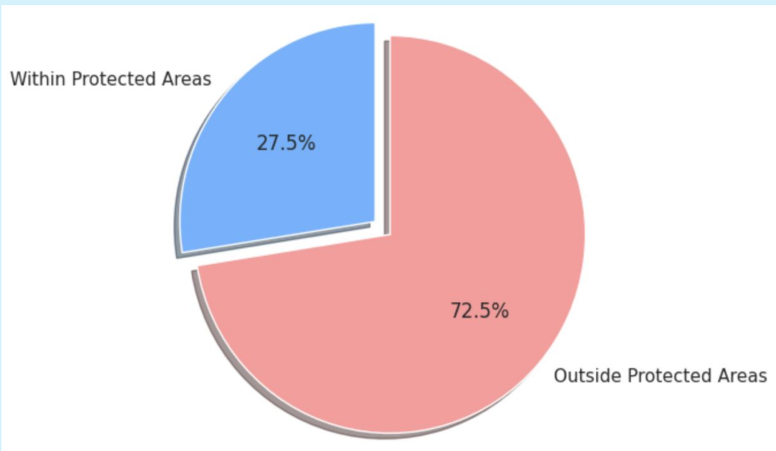

Figure 4: AGB hotspots Coverage in Indonesian Protected Areas

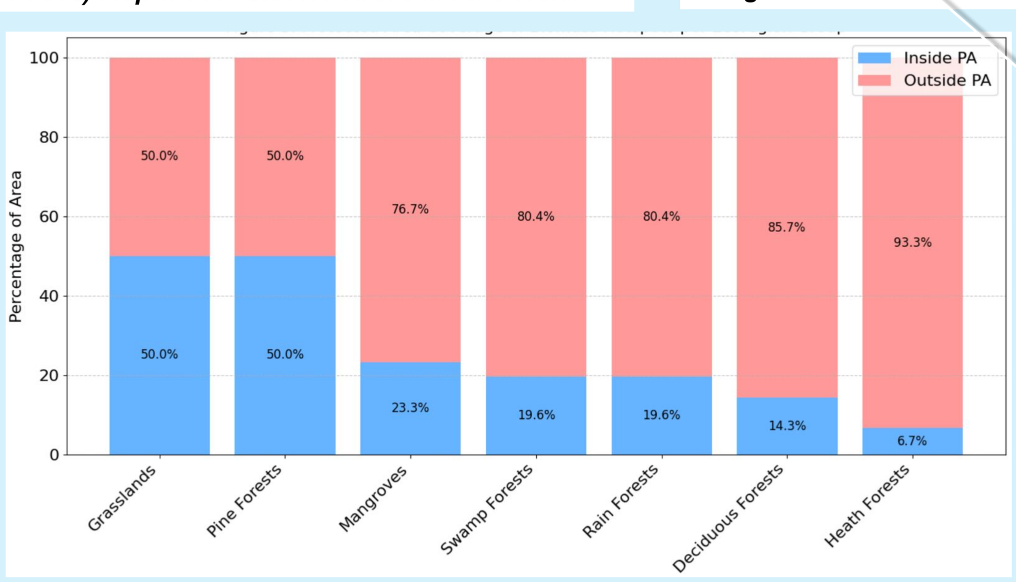

Figure 5: Protected Area Coverage of AGB hotspots per Ecoregion Group

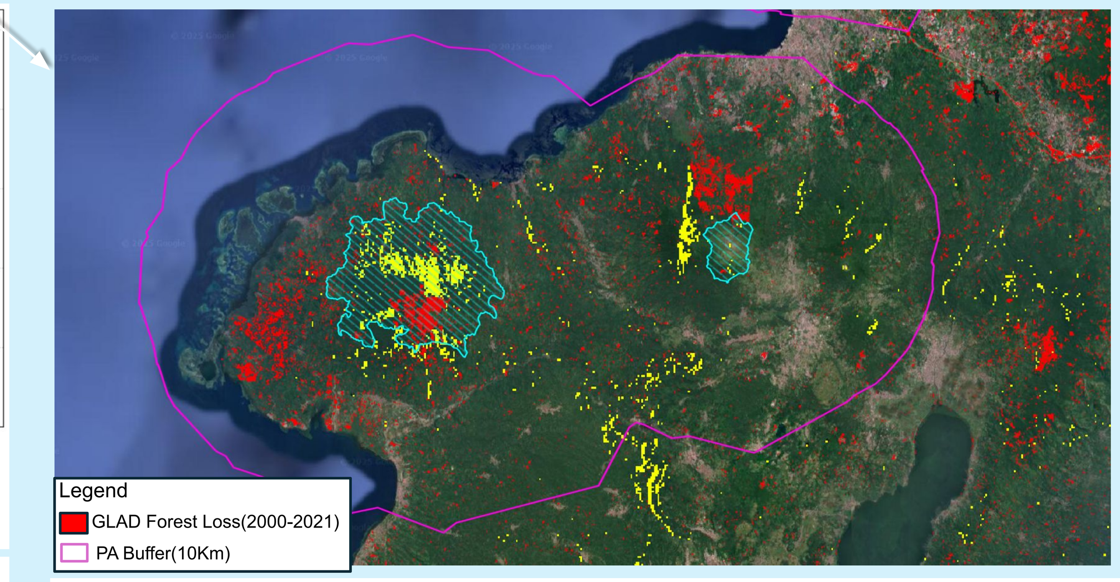

Figure 6: Forest disturbance near AGB hotspots and 10 km buffer zones of two Indonesian PAs.

Anticipated Results:

- This research will highlight **regions of high-carbon, structurally complex forests** across SEA, vital for **climate mitigation** and **biodiversity conservation**.
- A significant proportion of these **co-benefit areas** are expected to **fall outside existing PAs**.
- **Higher biomass disturbance** rates are expected in **unprotected and edge zones**, potentially indicating **leakage effects** and **anthropogenic pressure.**
- Results will offer **spatial guidance** to inform **conservation prioritization** and **policy planning**, in alignment with the **30x30 global biodiversity target** [3].
- Findings aim to **fill a major data gap** in SEA forest conservation by leveraging **GEDI** and other **remote sensing data**.

Summary and Conclusion:

- Preliminary results show that biomass hotspots are primarily found outside of protected areas, particularly in forests and mangroves
- Future work will focus on mapping and analyzing **co-benefit areas** (high **carbon** + **structural diversity**) across **South-East Asia.**
- Analysis of disturbance rates inside protected areas and co-benefit areas will inform **conservation priorities** and **policy actions.**
- Open science activity conducted on the NASA MAAP Platform
- Contributes to **NASA ESD's Earth Action** strategy by:
  - Identifying **high-priority conservation areas.**
  - Assessing **vulnerability** to improve protection of **carbon** and **biodiversity**

Acknowledgements:

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- All data processing and analyses are conducted, and will continue to be conducted, using the **NASA Multi-Mission Algorithm and Analysis Platform (MAAP)** to promote transparency and open science practices.

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