Global Hotspots of Change in Mangrove Forests

Marc Simard[1], Lola Fatoyinbo[2], David Lagomasino[3], Nathan Thomas[2], Kyle Kavanaugh[4], Priscilla Baltezar[4], Cheryl Doughty[2], Atticus Stovall[2], Adriana Parra[1], Paulo Murillo-Sandoval[2,5]

[1]Jet Propulsion Laboratory, California Institute of Technology, Pasadena, California
[2]NASA Goddard Space Flight Center, Greenbelt, MD
[3]East Carolina University, North Carolina
[4]University of California, Los Angeles (UCLA)
[5]Universidad del Tolima, Colombia

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Global Distribution of Blue Carbon Ecosystems

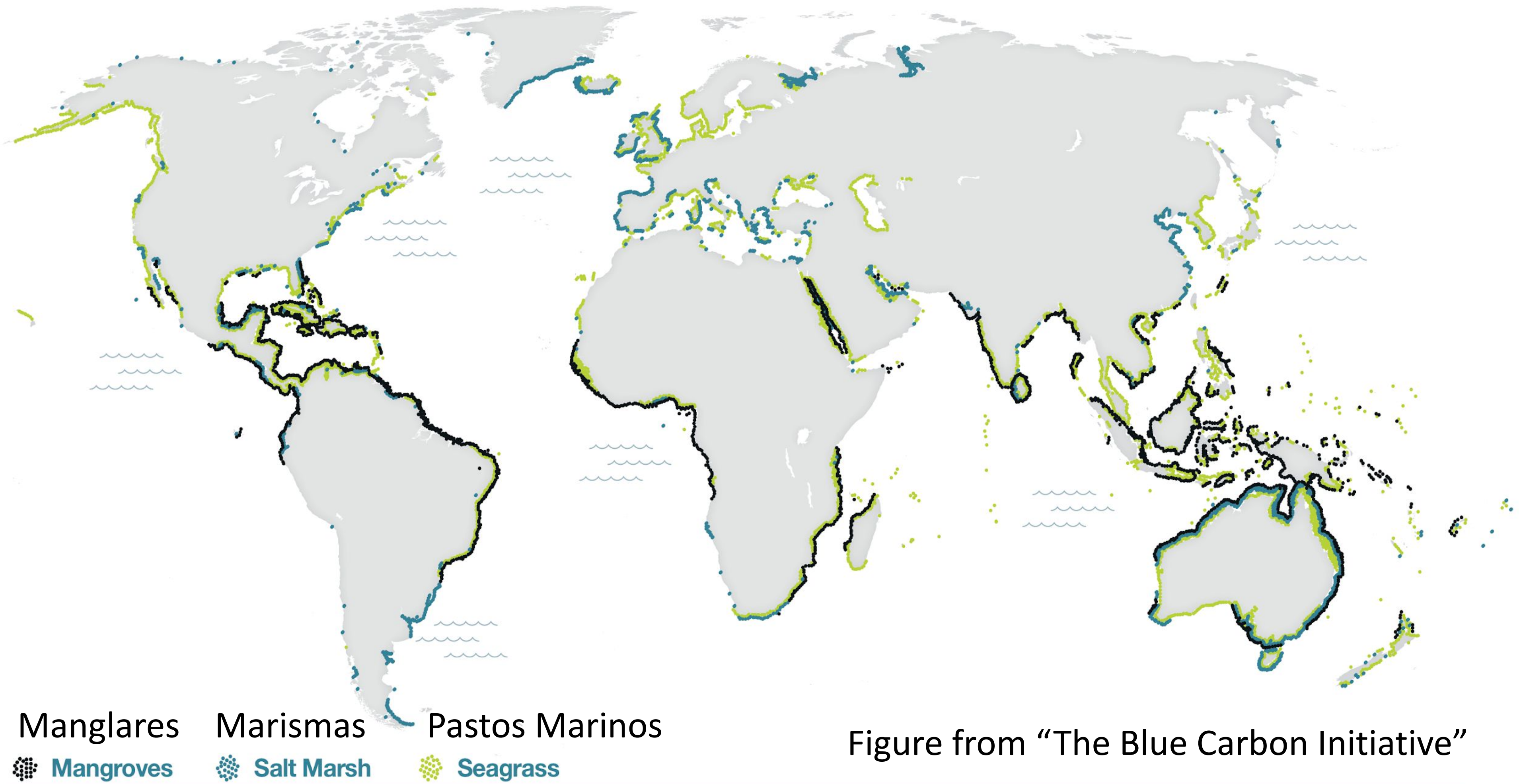
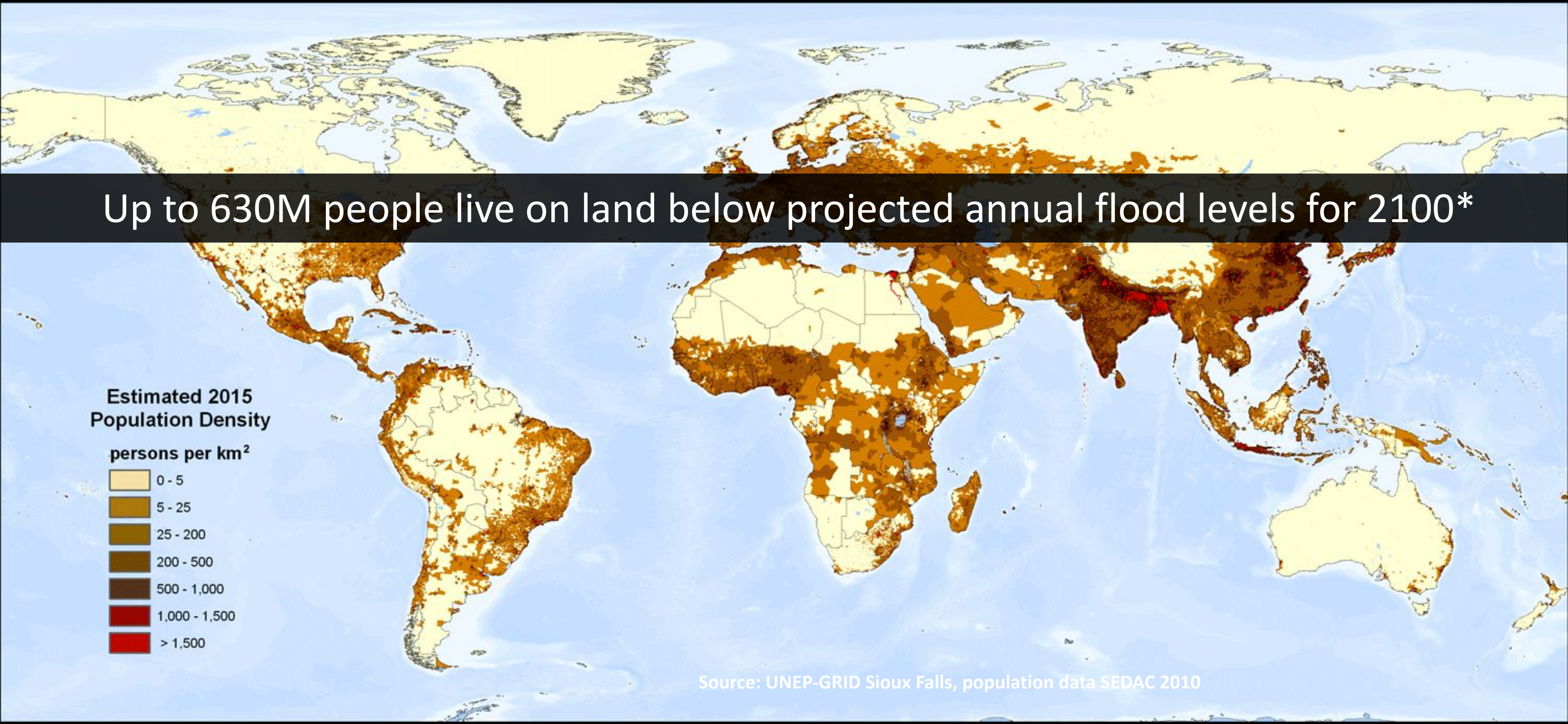


Figure from "The Blue Carbon Initiative"

~40% of World's Population (2.4B) Live Within 100km of the Coast



Up to 630M people live on land below projected annual flood levels for 2100*

*Kulp, S. A., & Strauss, B. H. (2019). "New elevation data triple estimates of global vulnerability to sea-level rise and coastal flooding." *Nature communications*, *10*(1), 1-12

Mangrove/marsh continuum

Marshes-Mangroves

Coastal Ocean

Mangrove/marsh continuum

Threatened by Sea Level Rise

(Amenazados por el incremento del nivel de mar)

Marshes-Mangroves

Coastal Ocean

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Mangrove/marsh continuum

Threatened by Sea Level Rise

(Amenazados por el incremento del nivel de mar)

Anthropogenic   Marshes-Mangroves   Coastal Ocean

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Lots of carbon in soils

- ~1000 t C/ha
- 49-98% C within soil, only AGB observed from remote sensing

Mangrove Ecosystem Services

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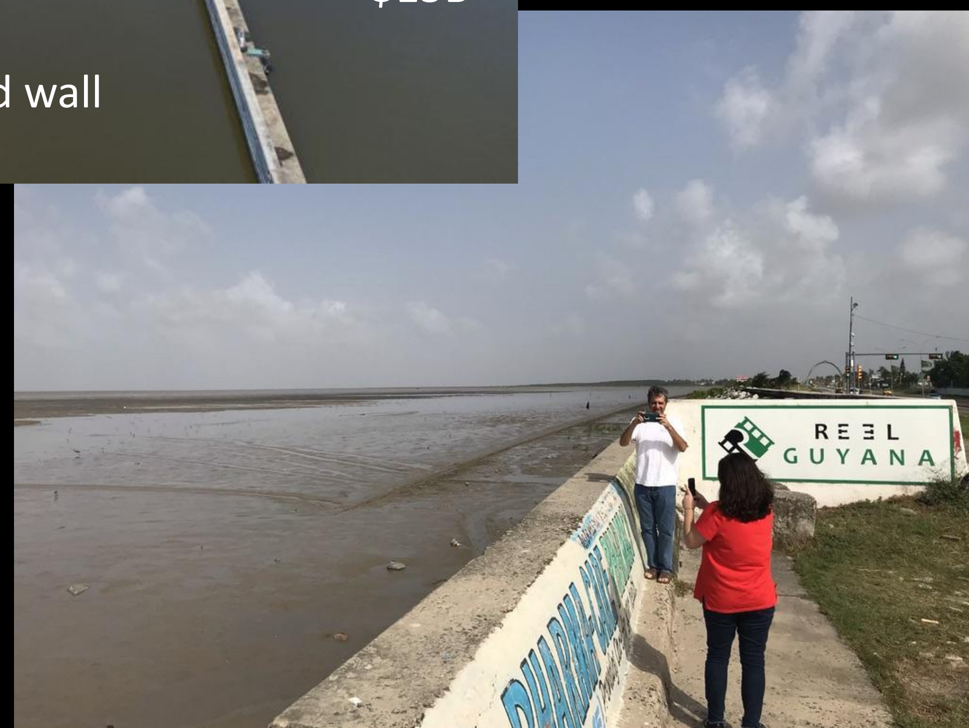
Loosing Coastal Ecosystems such as Mangroves and Saltmarshes Means Loosing All Its Services

Adaptation #1-Building Walls

~$15B

New Orleans flood wall



Adaptation #2

Managed retreat

Purposeful, coordinated movement of people and buildings away from risks.

Managed realignment

To improve coastal stability, essentially replacing artificial 'hard' coastal defence with natural 'soft' coastal landform.

*Still need to retreat.

NATIONAL ACADEMIES *Sciences Engineering Medicine*

Board on Environmental Change and Society

CALL FOR PERSPECTIVES

Managed Retreat in the U.S. Gulf Coast Region

The National Academies of Sciences, Engineering, and Medicine's Committee on Managed Retreat in the U.S. Gulf Coast Region is inviting the public to share their experiences, thoughts, and ideas about the movement and relocation of people, infrastructure, and communities away from particularly environmentally high-risk areas in the Gulf Coast region of the United States. We value all submissions and greatly appreciate the time taken to complete the Managed Retreat in the U.S. Gulf Coast Region Call for Perspectives.

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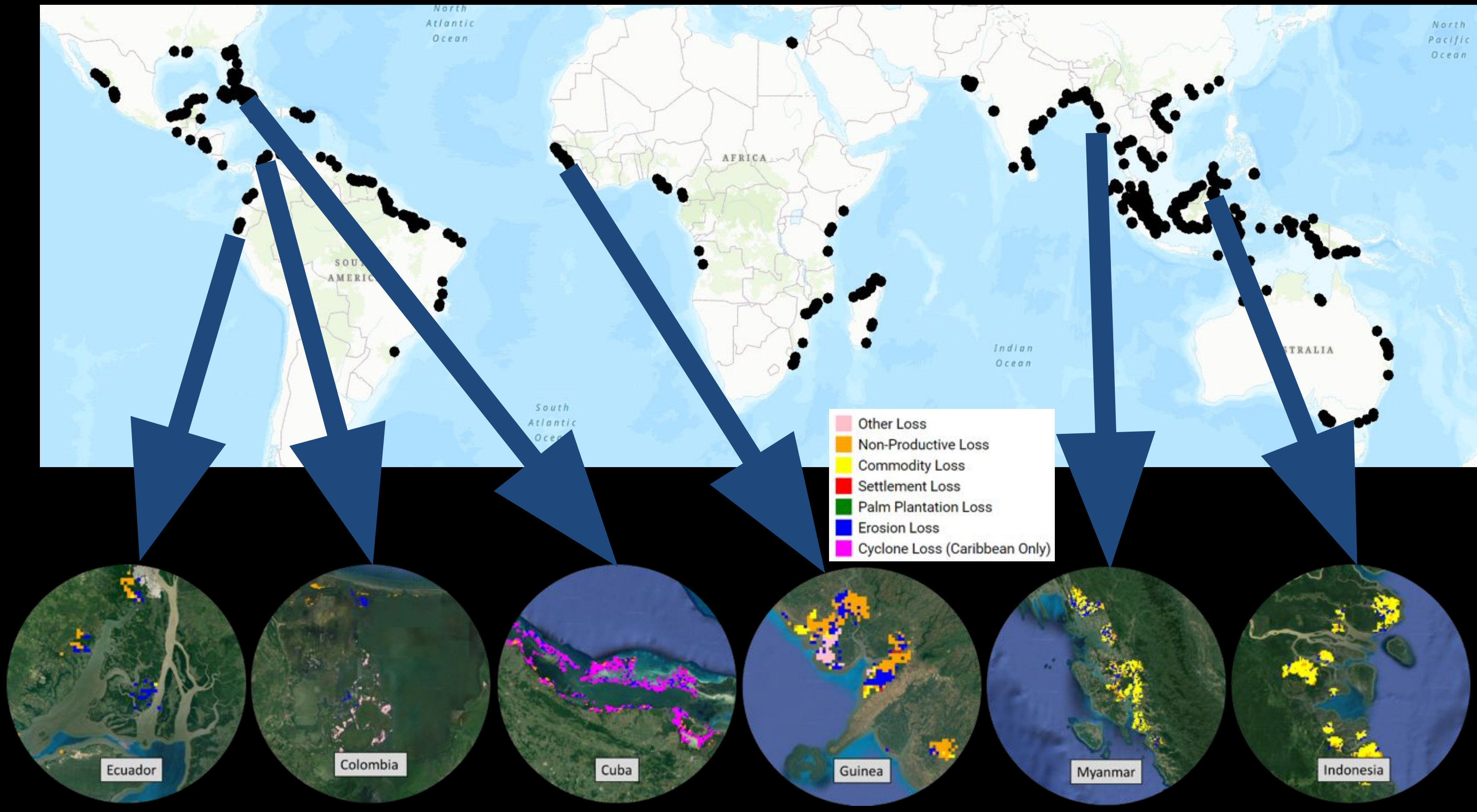
Goal: generate a globally consistent assessment of historical changes in mangrove forest extent and develop relationships between the proximate drivers of change and a priori characteristics of forest structure and environmental setting.



Advancing Global Perspective through regional and local Analysis

ARTICLES
https://doi.org/10.1038/s41561-018-0279-1
nature geoscience

Mangrove canopy height globally related to precipitation, temperature and cyclone frequency

Marc Simard[1*], Lola Fatoyinbo[2*], Charlotte Smetanka[1,3], Victor H. Rivera-Monroy[4], Edward Castañeda-Moya[4,5], Nathan Thomas[2,6] and Tom Van der Stocken[1]

Mangrove wetlands are among the most productive and carbon-dense ecosystems in the world. Their structural attributes vary considerably across spatial scales, yielding large uncertainties in regional and global estimates of carbon stocks. Here, we present a global analysis of mangrove canopy height gradients and aboveground carbon stocks based on remotely sensed measurements and field data. Our study highlights that precipitation, temperature and cyclone frequency explain 74% of the global trends in maximum canopy height, with other geophysical factors influencing the observed variability at local and regional scales. We find the tallest mangrove forests in Gabon, equatorial Africa, where stands attain 62.8 m. The total global mangrove carbon stock (above- and belowground biomass, and soil) is estimated at 5.03 Pg, with a quarter of this value stored in Indonesia. Our analysis implies sensitivity of mangrove structure to climate change, and offers a baseline to monitor national and regional trends in mangrove carbon stocks.

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The Global Mangrove Canopy Height and Above Ground Biomass Map Using SRTM (A Baseline map for year 2000)

Source: Simard, M., Fatoyinbo, L., Smetanka, C. *et al.* Mangrove canopy height globally related to precipitation, temperature and cyclone frequency. *Nature Geosci* **12,** 40–45 (2019). https://doi.org/10.1038/s41561-018-0279-1

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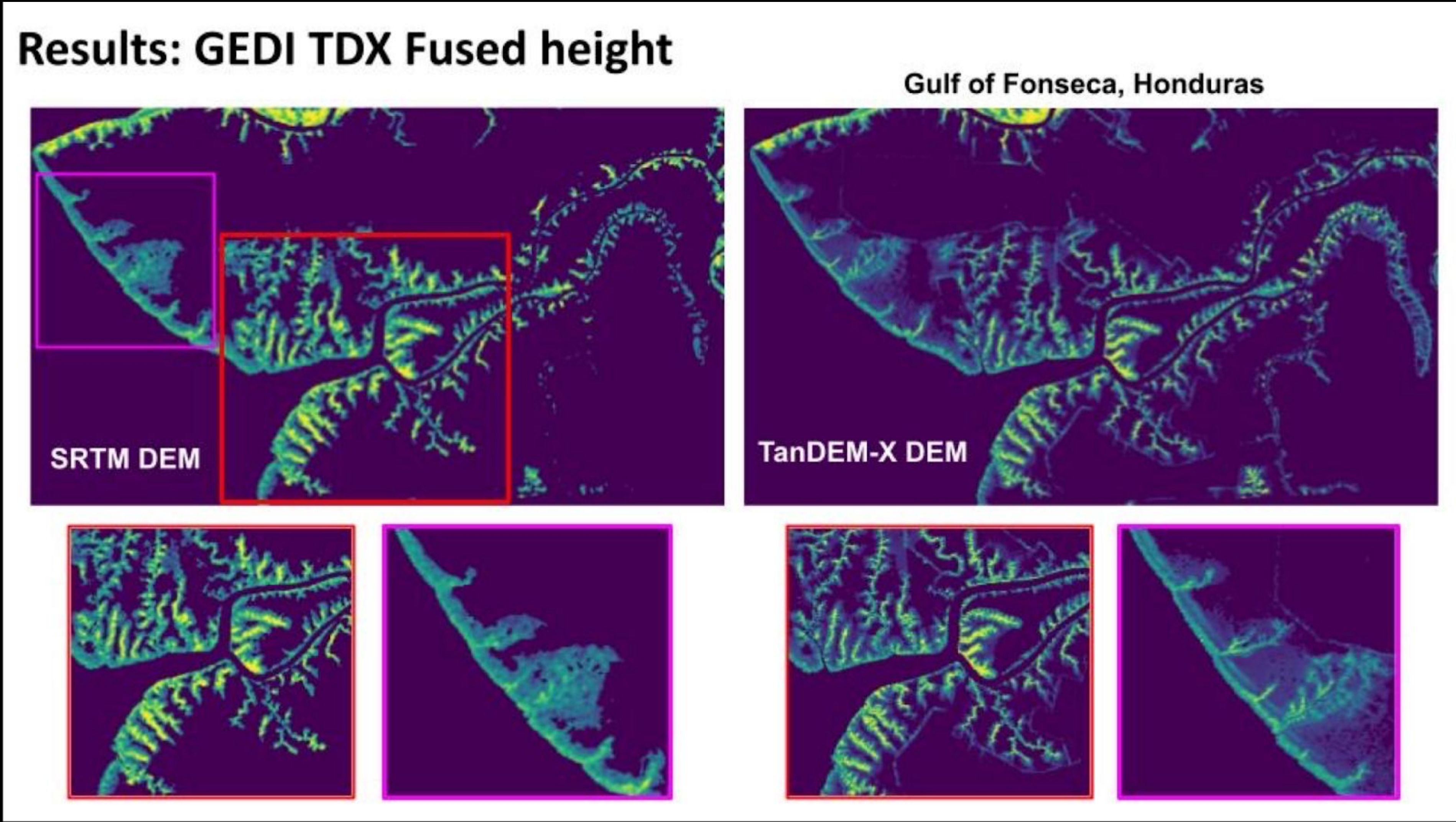
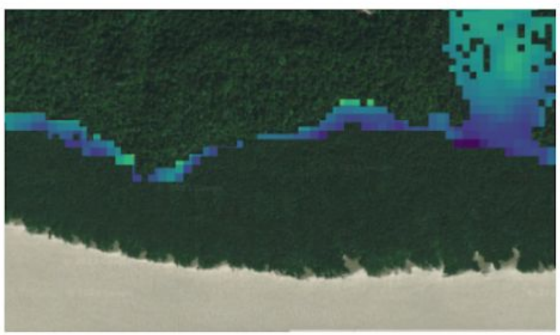
A new global map of mangrove canopy height with 12-meters resolution

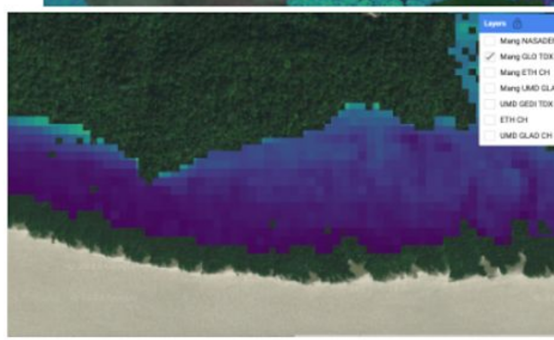


Comparing Canopy Height Products in Mangroves

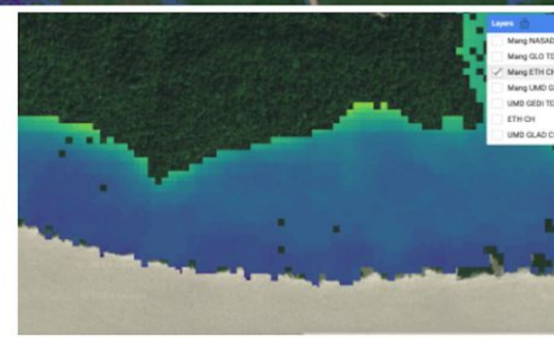
Growth example West Papua



SRTM

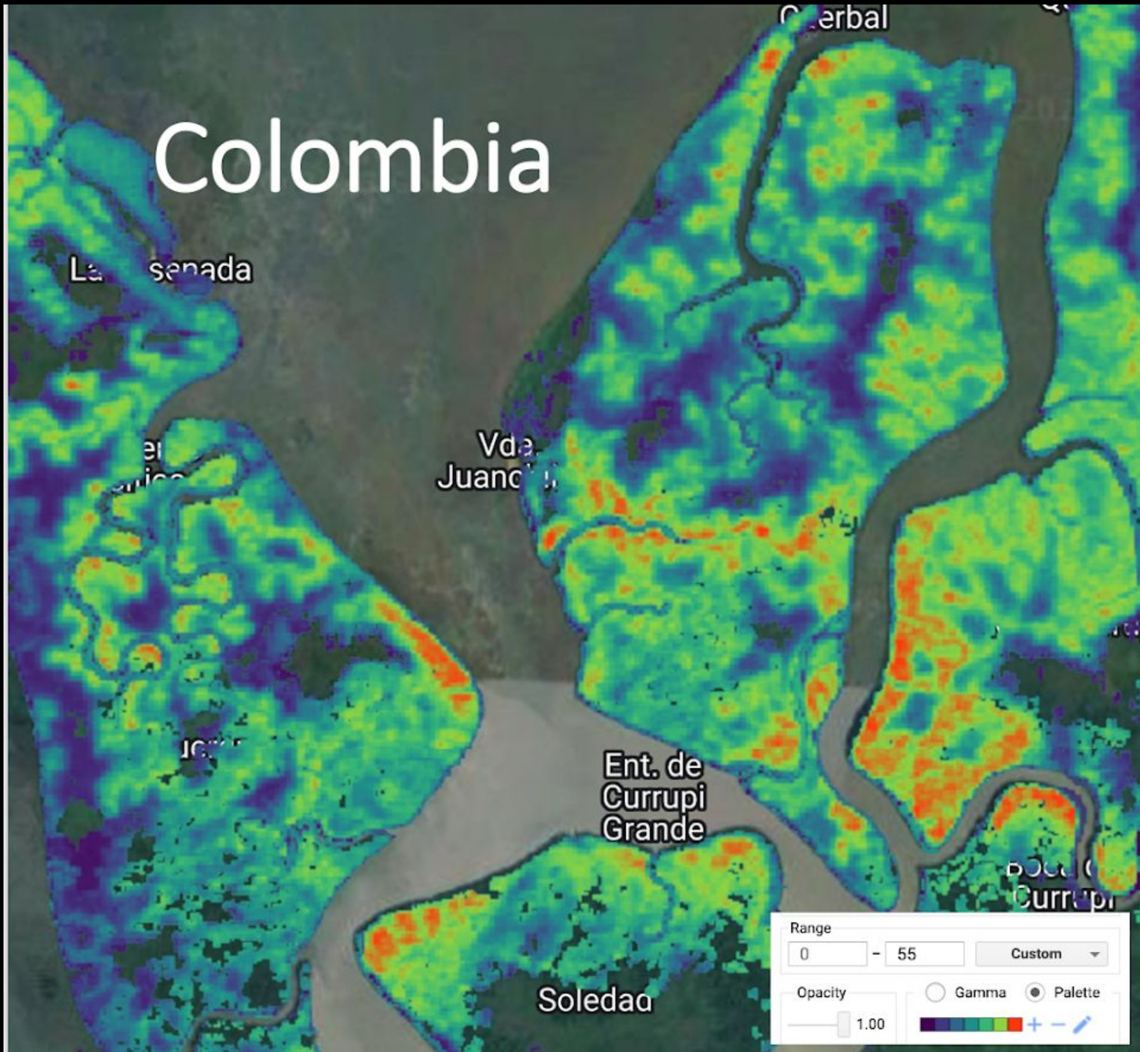


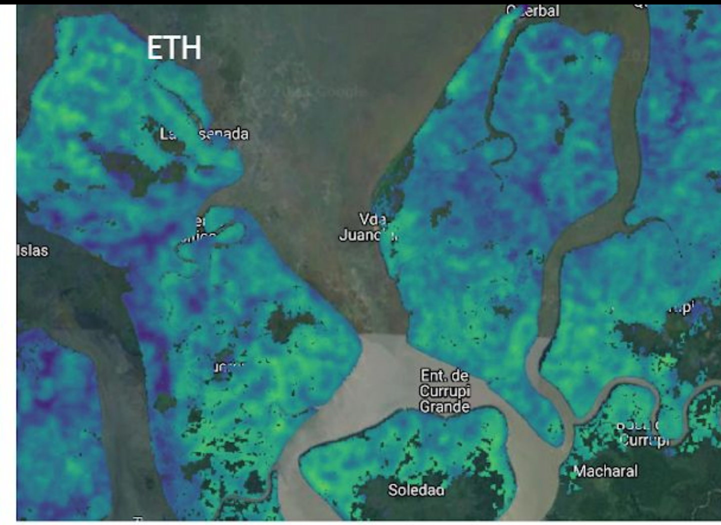
TDX

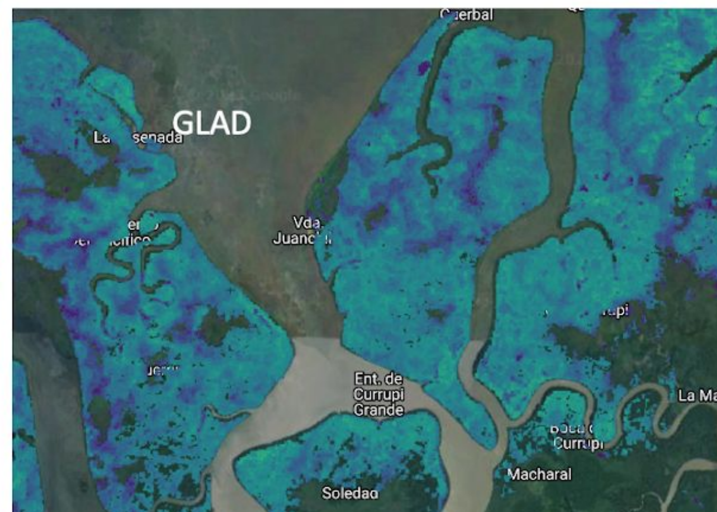


ETH

Comparing Canopy Height Products in Mangroves







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DEM limitations

- These DEMs can inform (no more) on mangrove extent change.
- SRTM (2000) and TanDEM-X (~2015) DEM do not provide accurate date of gain/loss.
- Need to know what happens to mangrove extent in between and during other times.

Generating globally consistent assessment of historical changes in mangrove forest extent

- Google Earth Engine (GEE) to map global LCLUC in mangrove forests currently between ~1990 to 2020, globally.

1. The algorithm uses a Landsat NDVI time series.
2. Identified "mangrove change hotspots" within various level of administrative boundaries and region sizes. Both mangrove loss and gain regions were identified.
   - We analyzed 4 different neighborhood distance models and here, provide a visualization of the
   - cumulative sum of the model outputs. Here, we estimate the number of hotspot grid cells within
   - Used the Marine Ecosystems of the World (MEOW - TNC), and their respective provinces.
3. We highlight the the top 10 ecoregions, the top 5 provinces, and the top 20 largest hotspot patches, regardless of ecoregion

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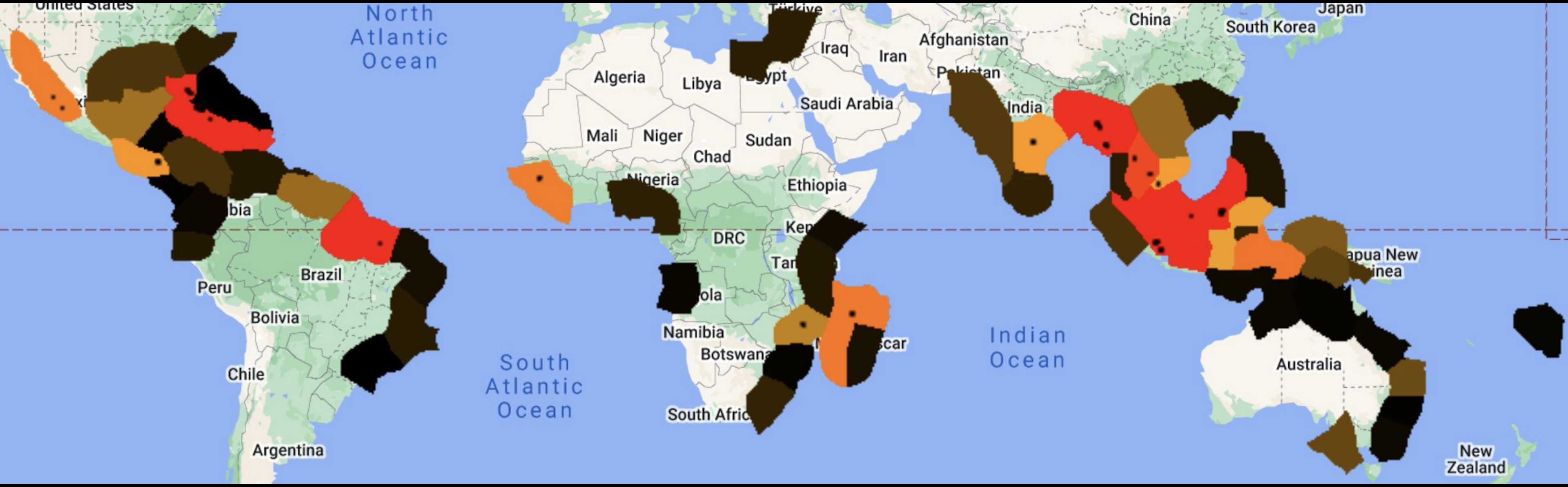
Total Hotspots by Marine Ecoregion*



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*MEOW database, Nature Conservancy

Top 5 Hotspot Provinces

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Top 10 Hotspot Ecoregions

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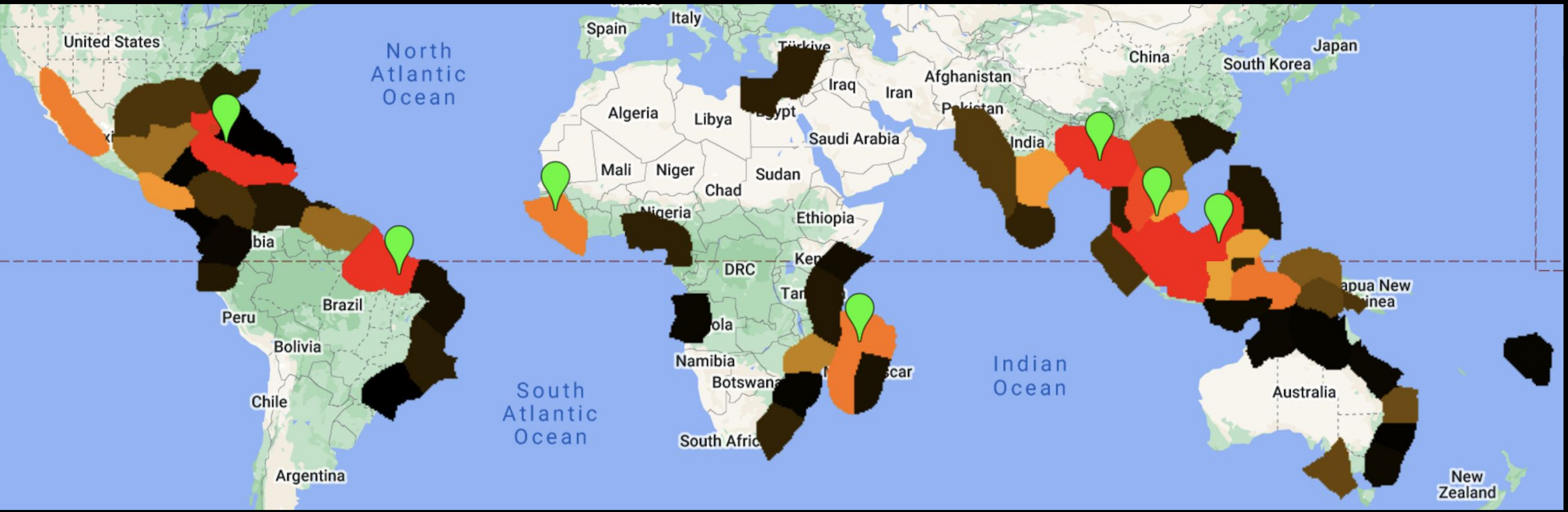
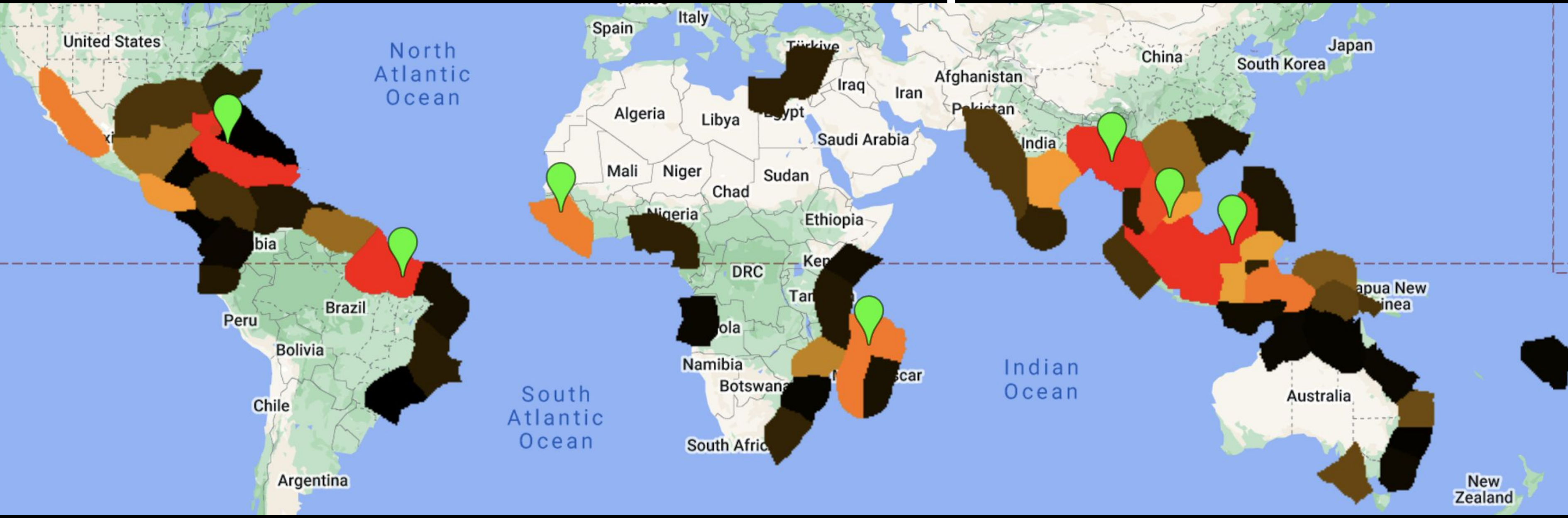


United States
North Atlantic Ocean
Spain
Italy
Türkiye
Iraq
Iran
Afghanistan
China
South Korea
Japan
Algeria
Libya
Saudi Arabia
India
Mali
Niger
Chad
Sudan
Ethiopia
DRC
Brazil
Peru
Bolivia
Chile
Argentina
South Atlantic Ocean
Namibia
Botswana
Indian Ocean
Australia
New Zealand

Global Hotspots



1. Rakhine, Myanmar (coal production)
2. Sulawesi, Indonesia (Forontalo National park and aquaculture);
3. Bangkok, Thailand (Urbanization);
4. Boeny, Madagascar (River Delta);
5. Conacri/Kindia, Guinea (Urbanization and lumber);
6. Saõ Luis/Belem, Brazil(Erosion/TBD);
7. Florida, USA (Cyclones);
8. Cuba (Cyclones, droughts);
9. Niger Delta, Nigeria (oil infrastructure and spills);
10. Cienega Grande de Santa Marta, Colombia (water diversion);
11. Guayas, Ecuador (Shrimp farming);
12. Kalimantan, Timur; Yucatan, Mexico

White: automatic

Green: add diversity of drivers

Hotspots…since when?

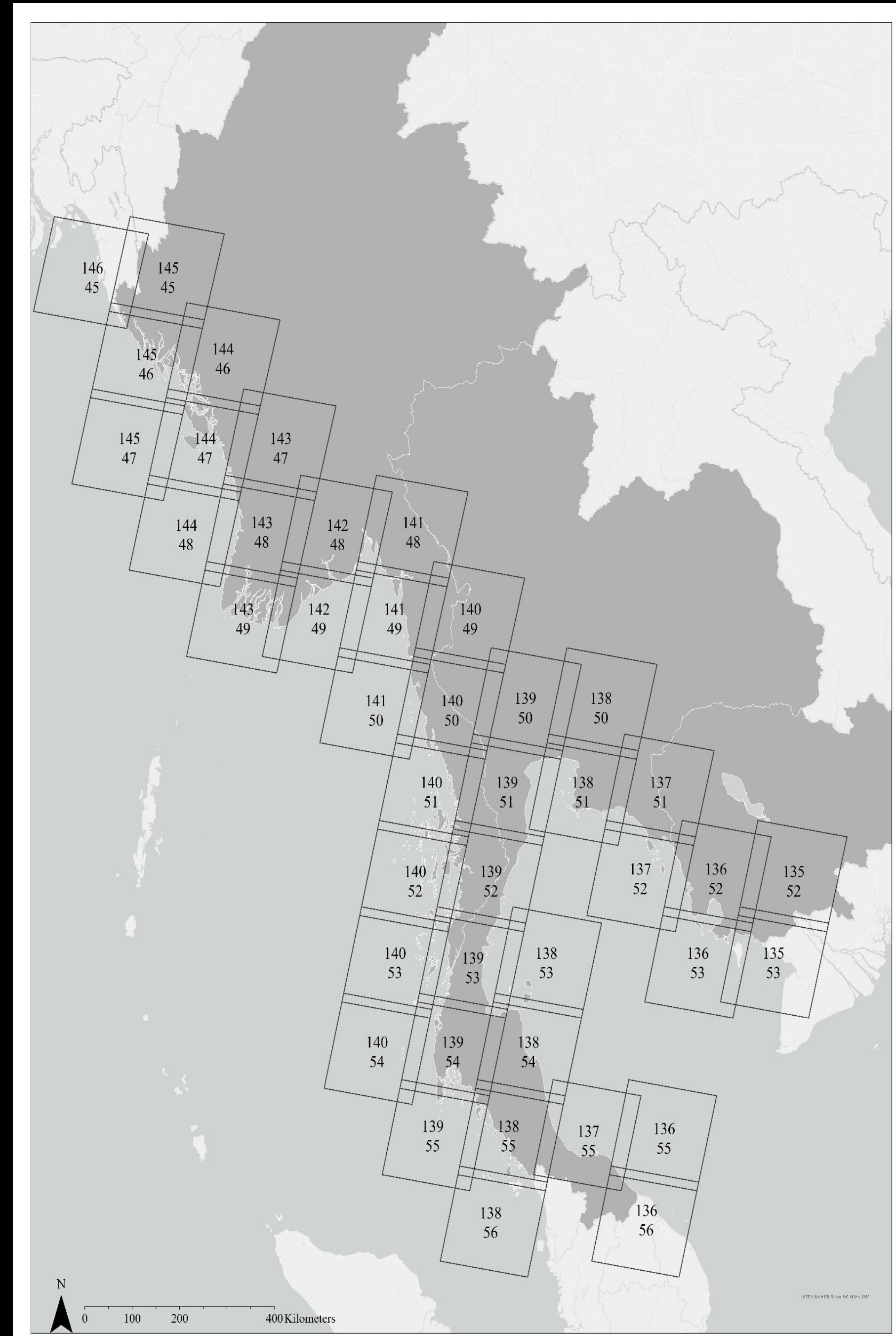
Case Study: Southeast Asia

Total mangrove area 3,264.12 km² in 2016*

Mangrove loss of 596.8 km² 1996-2016*.

Main drivers of change are salt production, coal extraction, aquaculture, and urbanization.

*JAXA's GMW Global mangrove Watch Program



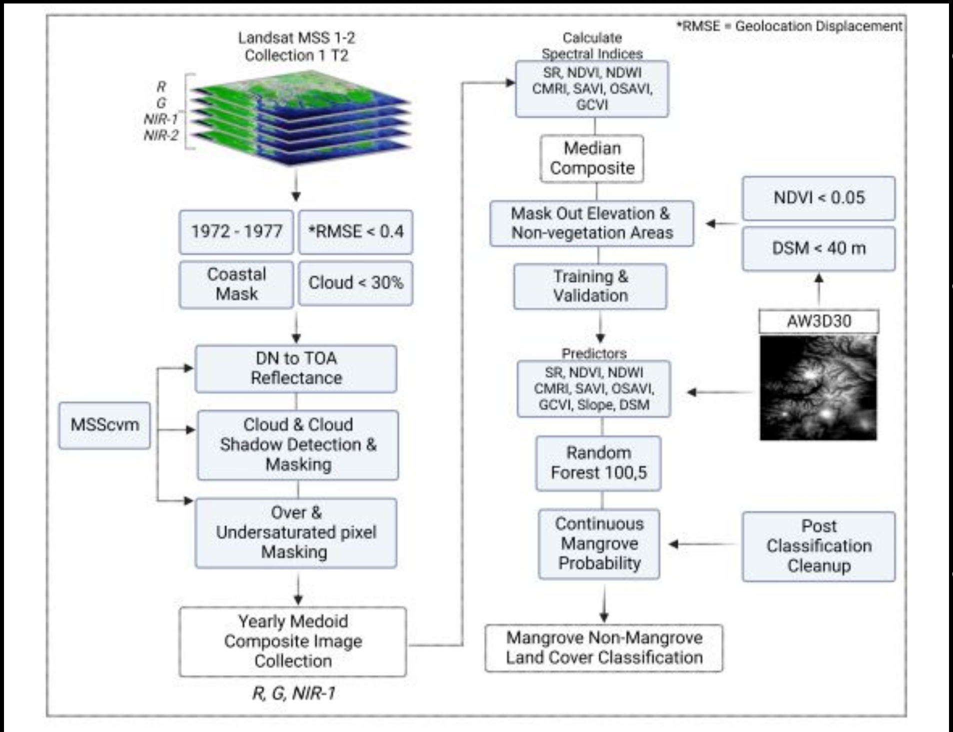
A Regional Map of Mangrove Extent for Myanmar, Thailand, and Cambodia Shows Losses of 44% by 1996

Priscilla Baltezar, Paulo Murillo-Sandoval, Kyle Cavanaugh, Cheryl Doughty,
David Lagomasino, Thida Tieng, Marc Simard, and Temilola Fatoyinbo.

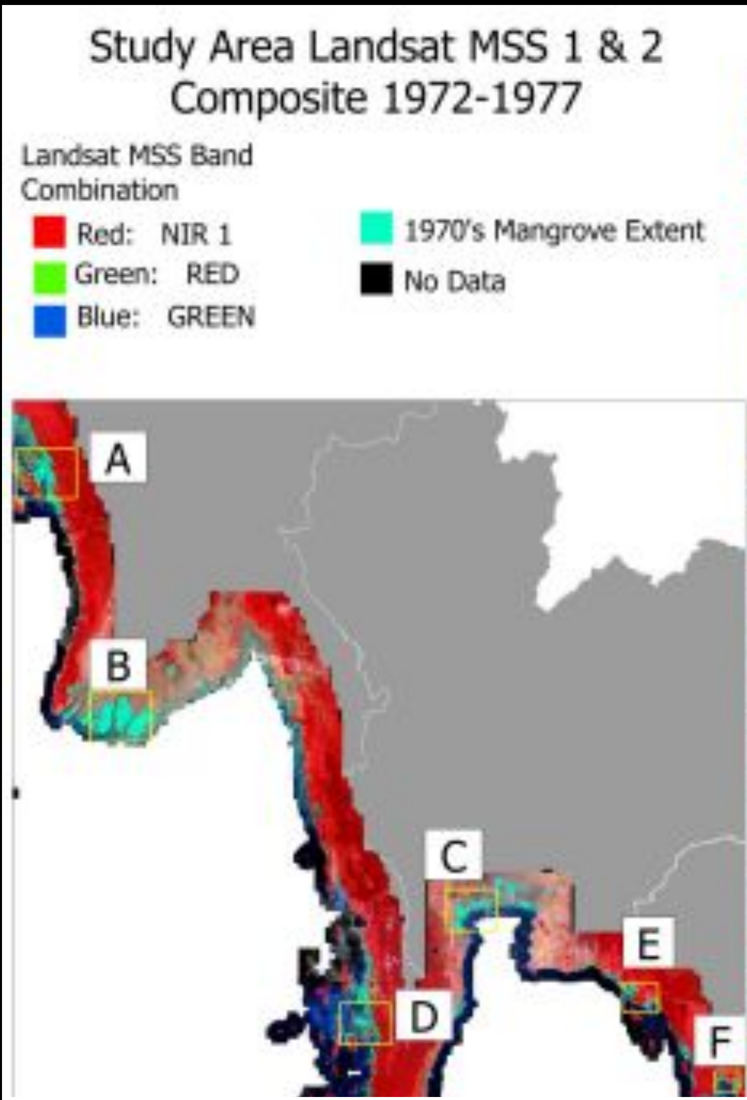
Accepted for publication in Frontiers in Marine Science April 2023.

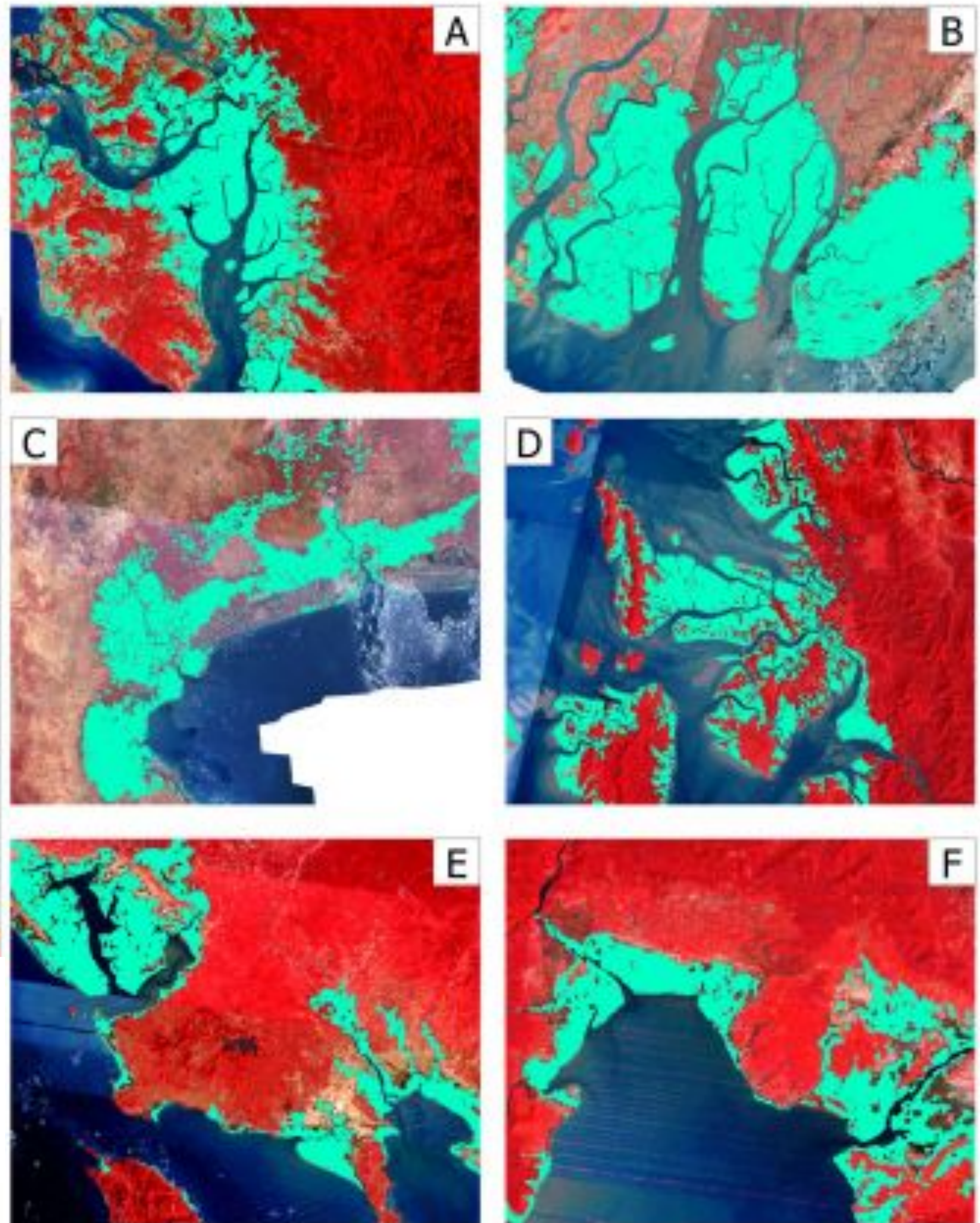
- Southeast Asia is home to some of the planet's most carbon-dense, biodiverse, and threatened mangrove ecosystems.
- There is still much uncertainty on the timing and magnitude of changes in mangrove cover over the past 50 years in this region, as data prior to the mid-1990s is limited due to the scarcity of Earth Observation data of sufficient quality and the historical limitations to publicly available EO.
- We capitalize on the growing availability of EO data and algorithms to extend mapping of mangrove baselines into the 1970s.

MSS 1-2 Time-series processing 1972-77



- Processed Landsat MSS 1-2 using MSScvm algorithms (Braaten et al. 2015) to remove cloudy pixels from images
- Regional composites were impacted by image availability and quality, with only 12% of images being usable in our study area from 1972-77
- Our Random Forest classifiers predicted mangrove with 95.3% overall accuracy



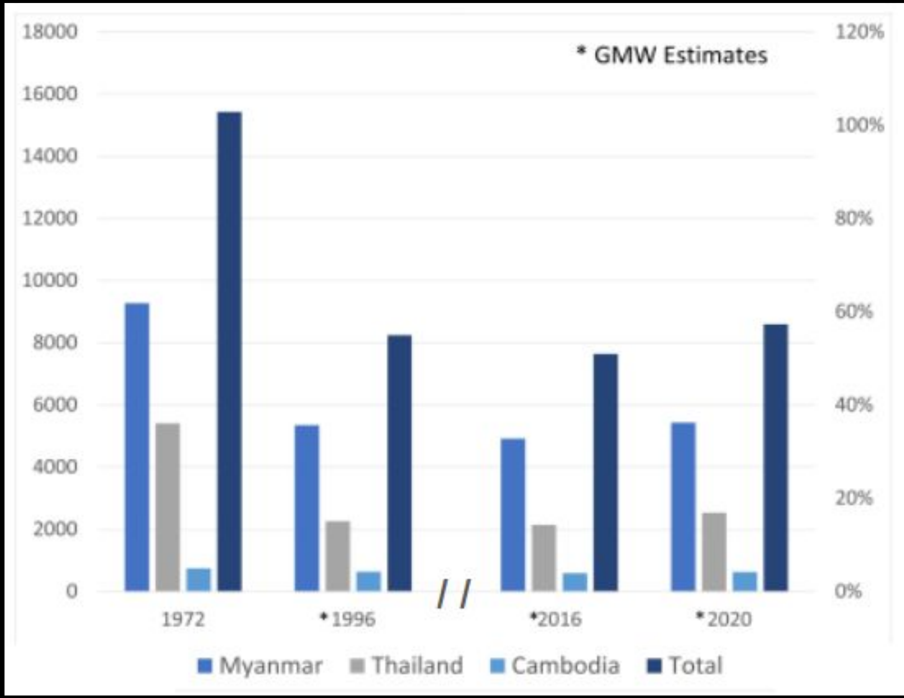


We mapped a total extent of 15,420 km^2 of mangroves in the region for the 1970s:

- 9,272 km^2 in Myanmar
- 5,407 km^2 in Thailand
- 742 km^2 in Cambodia

0 75 150 300Kilometers

Mangrove extent change



6,830 km^2 of total mangrove area has been lost in the past 48 years compared to the Global Mangrove Watch (GMW).

- Over 14,000 km^2 were lost between 1972 and 1996:
- Myanmar and Thailand exhibited sharp declines in mangrove extent between 1970s and 1996 due to complex political, social, and economic drivers; after which GMW detects declining deforestation rates
- Shifting baselines of mangrove extent have implications for mangrove management & restoration .

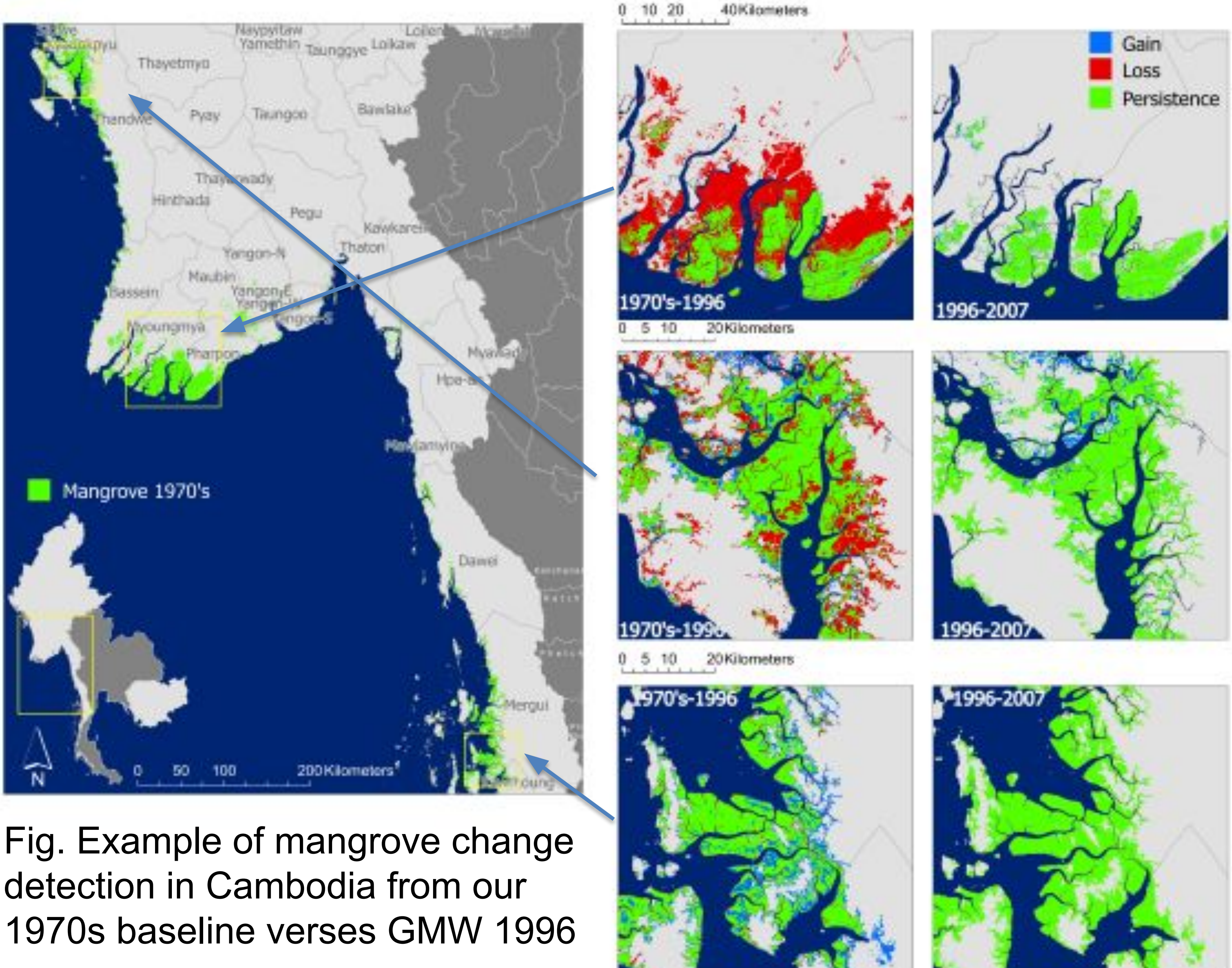


Fig. Example of mangrove change detection in Cambodia from our 1970s baseline verses GMW 1996

Conclusion

- We identified hotspots regions of mangrove change globally
- Mapped mangrove change globally since ~1990
- Mapped mangrove change in Southeast Asia since ~1975.
- Developed a new 12m global mangrove canopy height map.

On-going tasks

- Analyze high-resolution optical and radar data to detect disturbances based on existence of hotspots (alert system)
- Identify proximate drivers of change in the hotspots regions
- Develop driver relationships with environmental setting and structure
- Publish related papers