Can Improved Stakeholder Representation Prevent Human-caused Mangrove Loss in the Mesoamerican Reef Ecoregion?

Grant Connette, Smithsonian Institution

LCLUC Science Team Meeting
April 2, 2024

Smithsonian Institution

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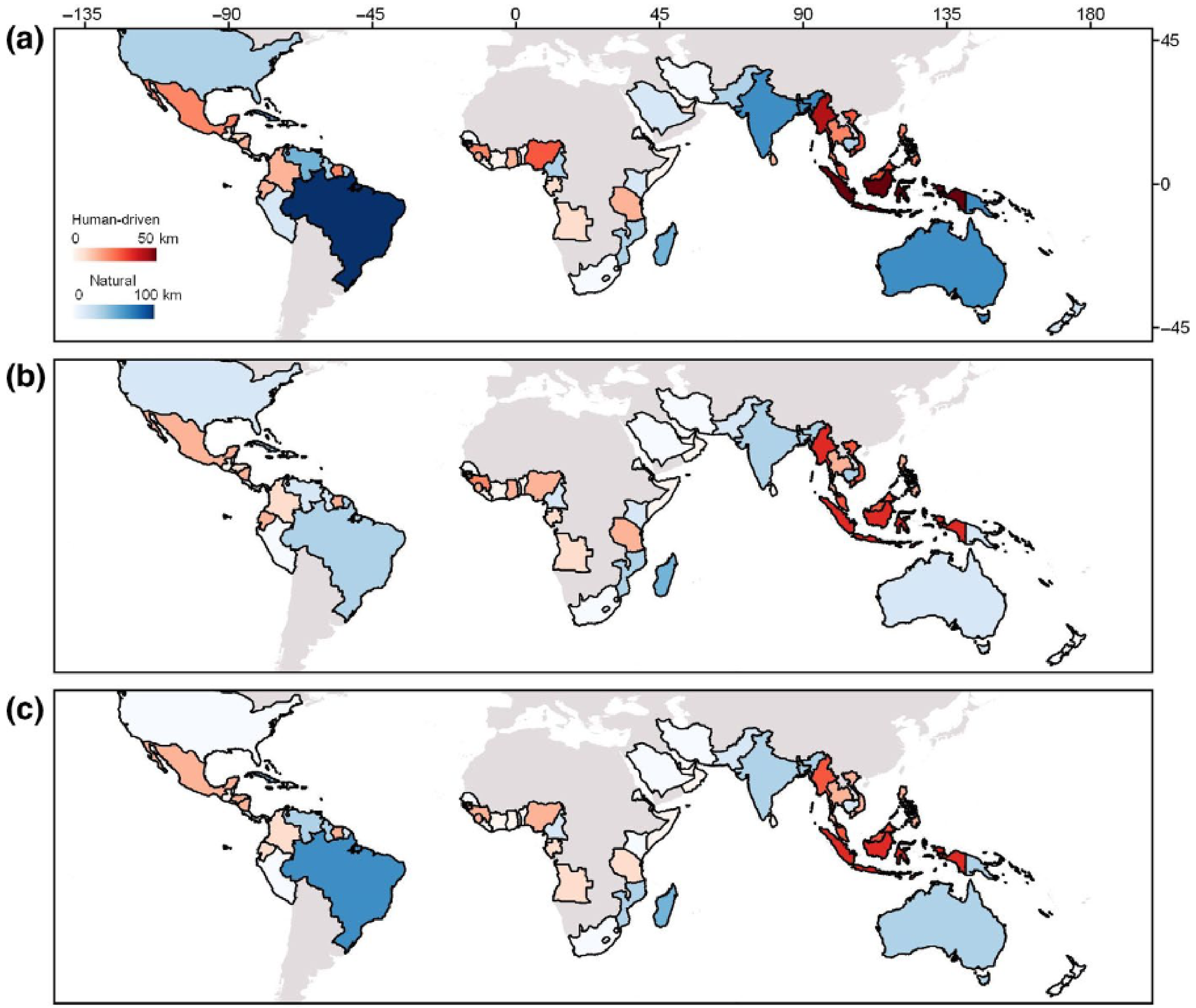
Photo credit: Hannah Morrissette

Understanding Mangrove Loss

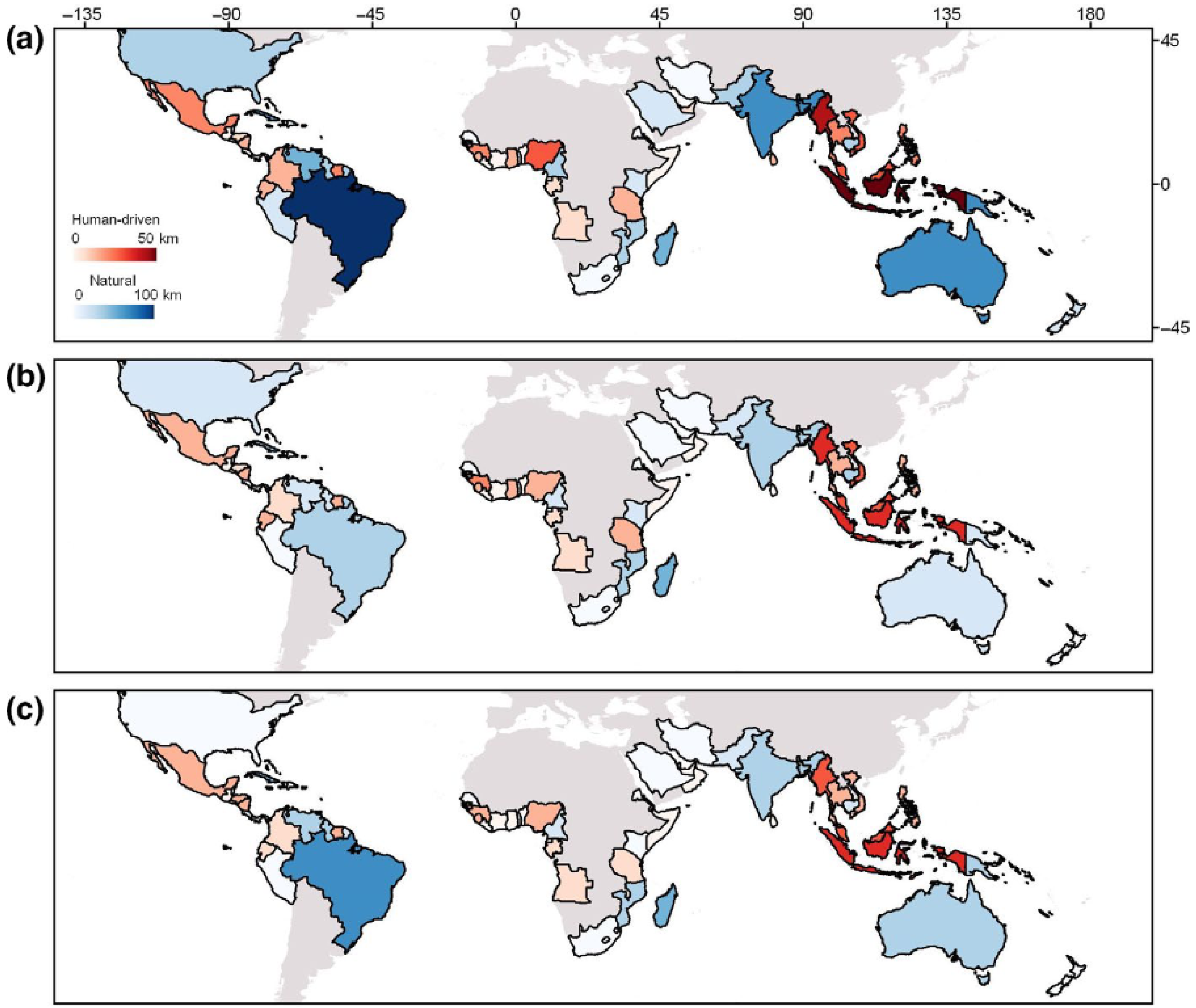
- Globally, rates of mangrove loss are slowing



Goldberg et al. 2020. Glob Change Biol. 26:5844–5855

Understanding Mangrove Loss

- Globally, rates of mangrove loss are slowing
- Rates of loss and primary drivers vary widely by country



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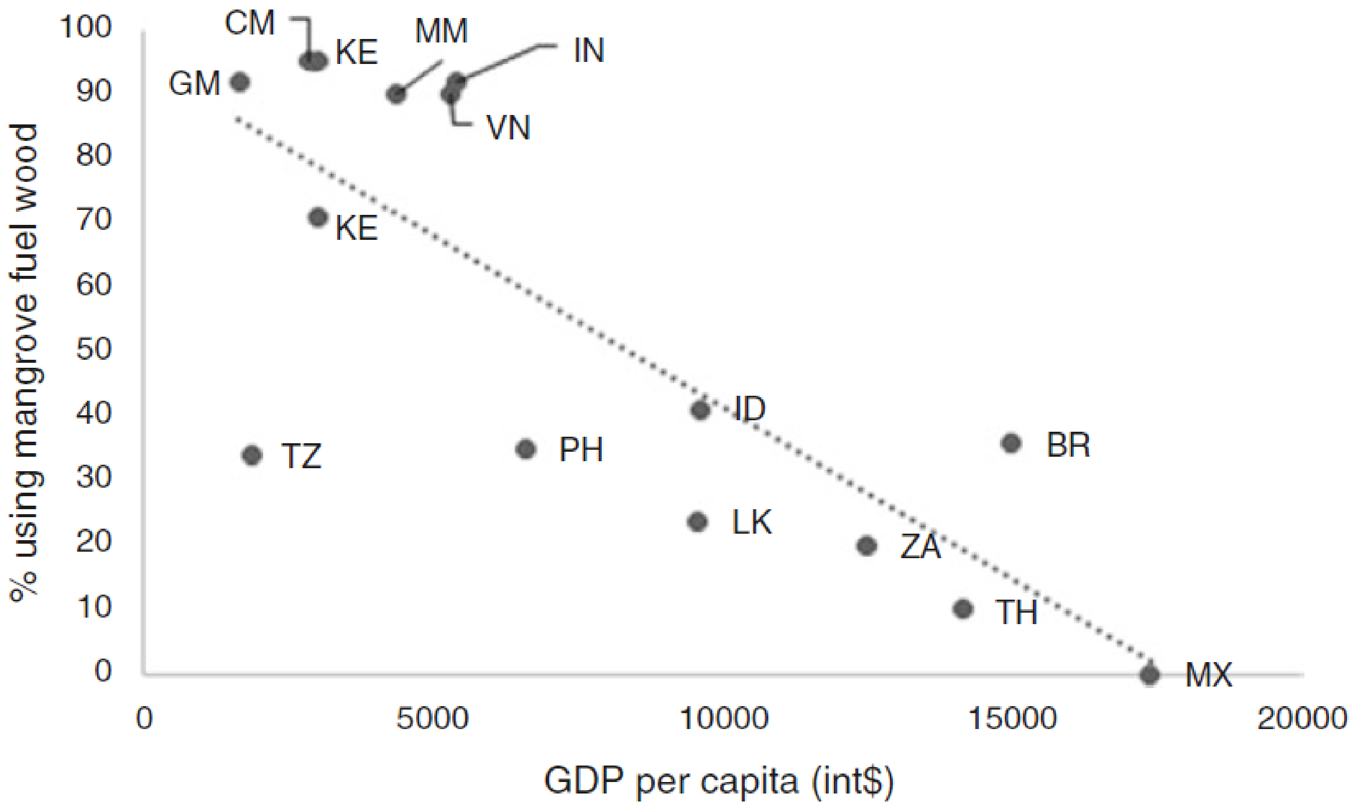
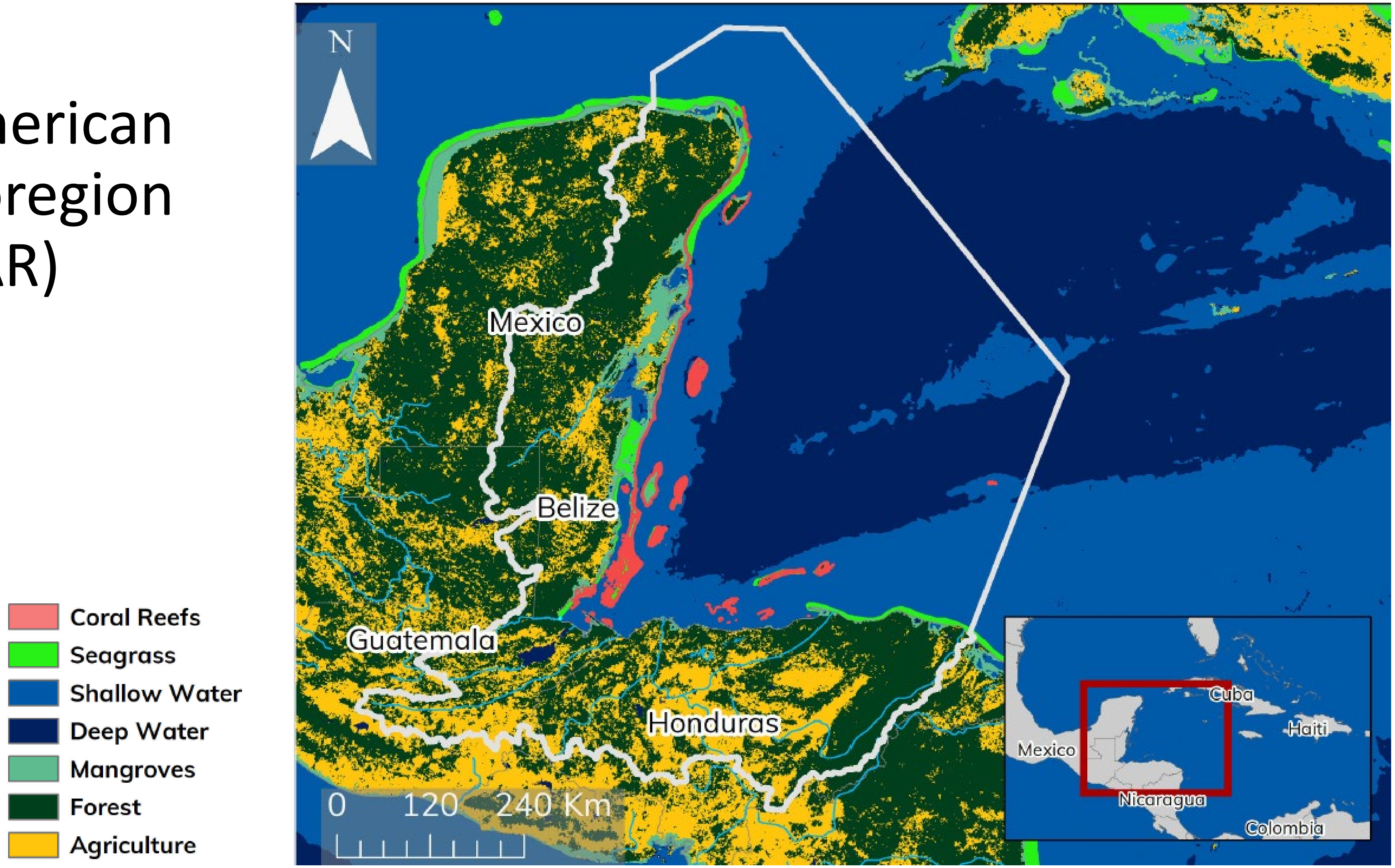
Understanding Mangrove Loss

- Globally, rates of mangrove loss are slowing
- Rates of loss and primary drivers vary widely by country
- Conversion pressure on mangroves depend on socioeconomic context



Huxham et al. 2017. *In*: Rivera-Monroy, V., Lee, S., Kristensen, E., Twilley, R. (eds) Mangrove Ecosystems: A Global Biogeographic Perspective.

Mesoamerican Reef Ecoregion (MAR)



Height:

- Dwarf : < 2 m
- Medium : 2 to 5 m
- Tall : > 5 m

Composition:

- *Rhizophora mangle* (red)
- *Avicennia germinans* (black)
- *Laguncularia racemose* (white)
- *Conocarpus erectus* (+ associated sps.)
- *Seagrasses*

Canopies:

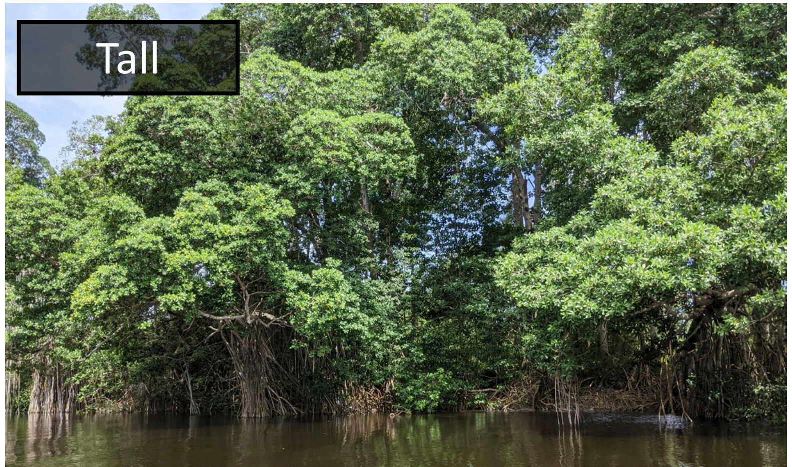
Dense to sparse

Monospecies or mixed canopies

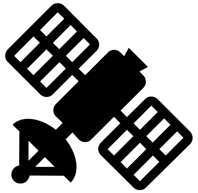
Understory:

Generally absent in mono-species stands

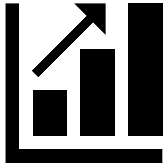
Can be present in mixtures



Research Questions



1. *What is the current extent of mangrove cover and where are hotspots of anthropogenic mangrove loss?*

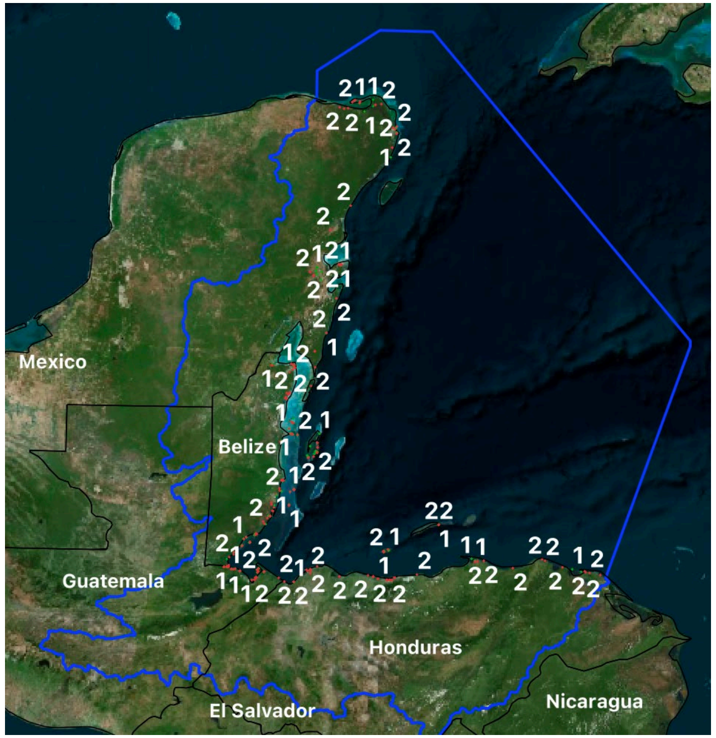


2. *How do socioeconomic conditions affect variation in rates of mangrove loss inside and outside of protected areas?*

3. *Do greater awareness of mangrove-derived benefits (i.e., ecosystem services) and more collaborative management by coastal communities result in reduced rates of mangrove loss?*

Training Dataset Generation

- 2020-2024 mangrove plot data from our team + collaborators
- 2004-2006 mangroves confirmed with Google Earth/Bing
- 70% of points for calibration and 30% for validation (per class)



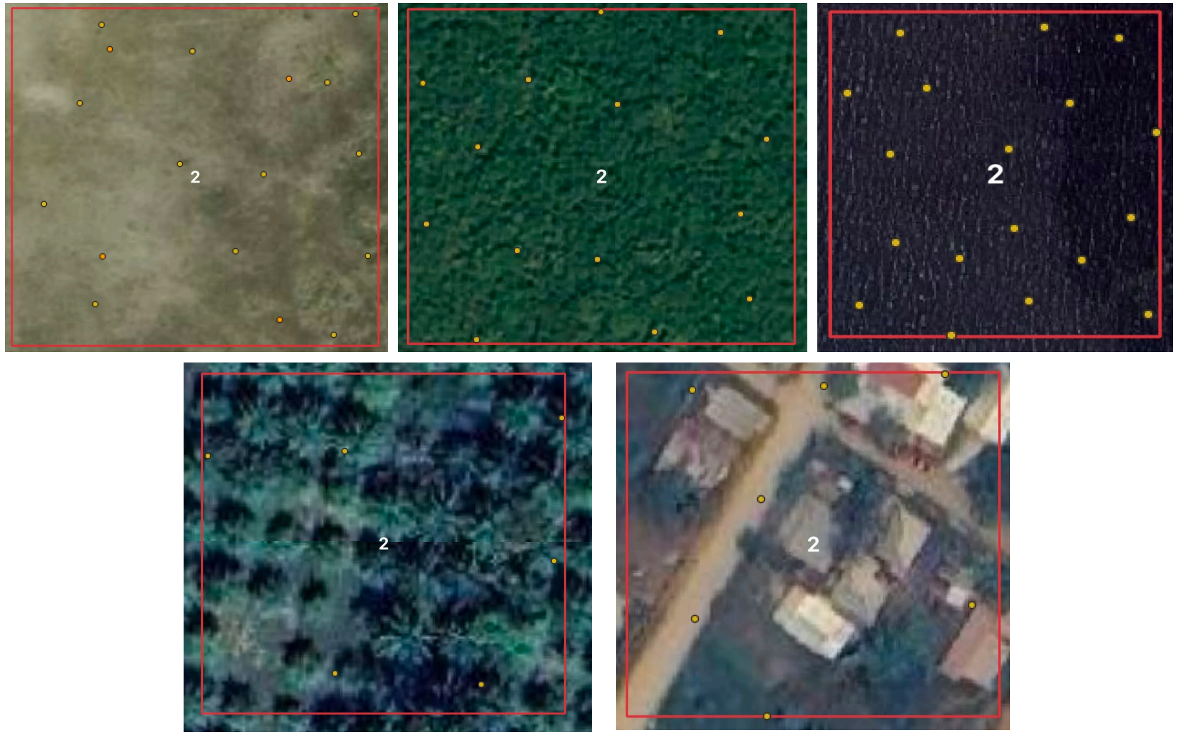
Class	Mangrove (2020~2024)	Non-mangrove (2020~2024)	Mangrove (2004~2006)	Non-mangrove (2004~2006)
Calibration Plots	122	145	118	141
Calibration Points	2267	2739	893	1068
Validation Plots	31	36	30	35
Validation Points	973	1173	375	476
Min. distance. Between points	20	20	40	40

Training Dataset Generation

- 2020-2024 mangrove field data from all four MAR countries
- Good representation of structural/species diversity
- Google Earth/Bing Maps used for historical mangroves and all non-mangroves

Mangrove

Non-mangrove



Random Forest Classification

Earth Observation Data:

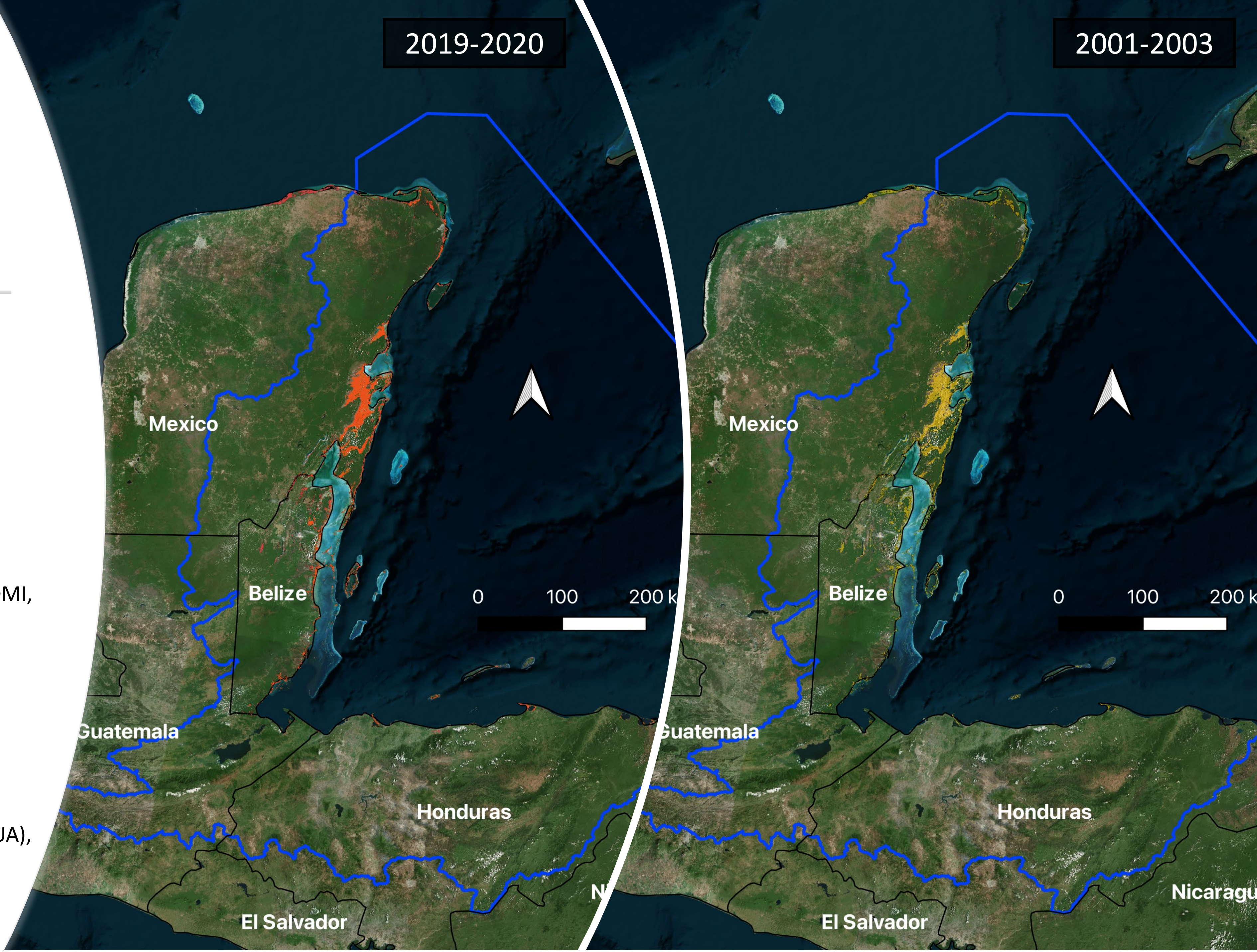
- 2019-2020: Sentinel-2 SR (10 m)
  Months: January to June
- 2001-2003: Landsat-5/7 SR (30 m)
  Months: January to June

Input Variables:

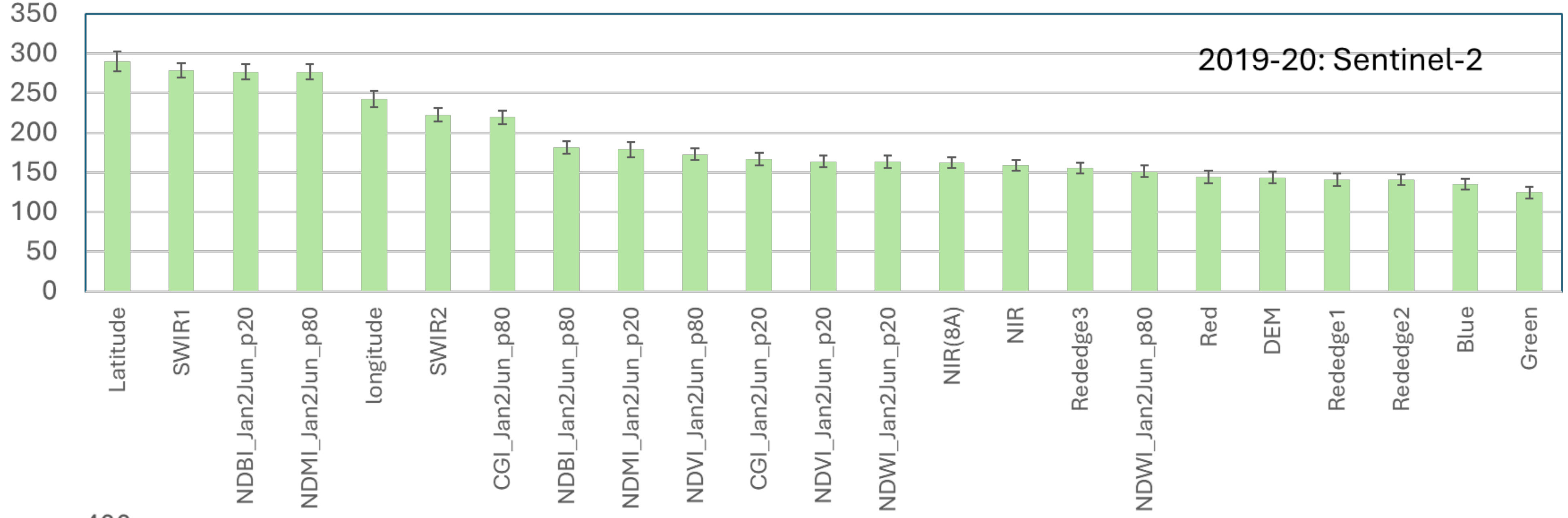
- Individual bands
- Spectral indices: 20th and 80th percentile composites for NDVI, NDMI, NDWI, NDBI, CGI (only for S2)
- Elevation (NASA SRTM, 30 m)
- Latitude and Longitude

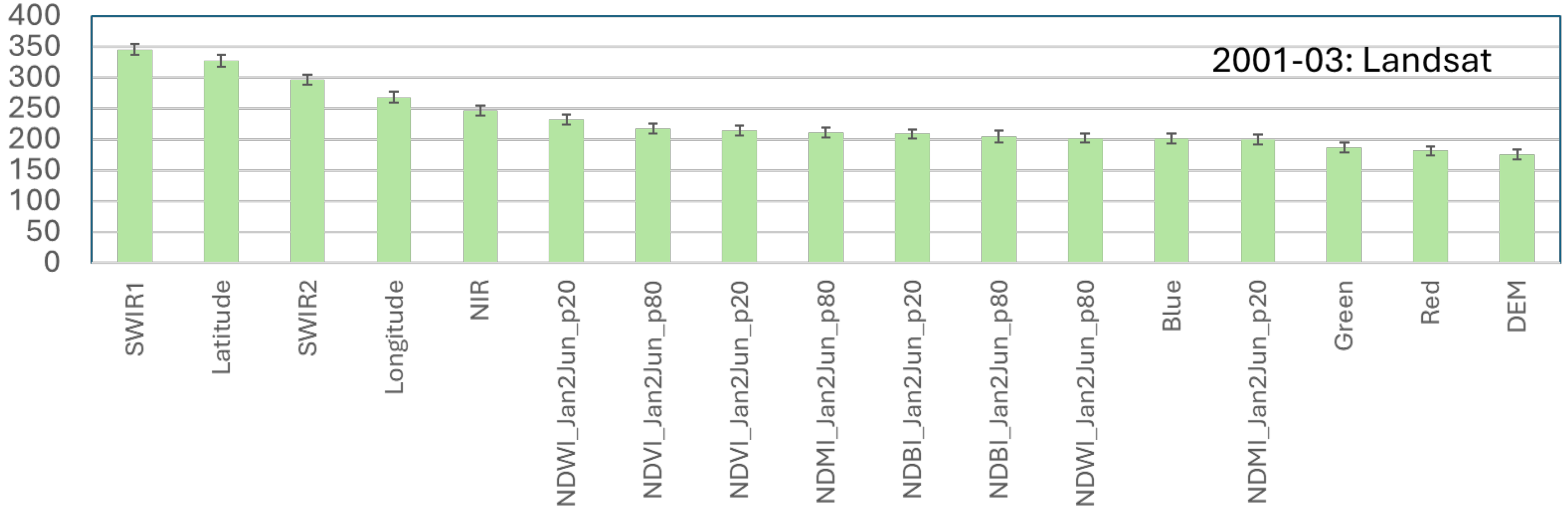
Model Performance:

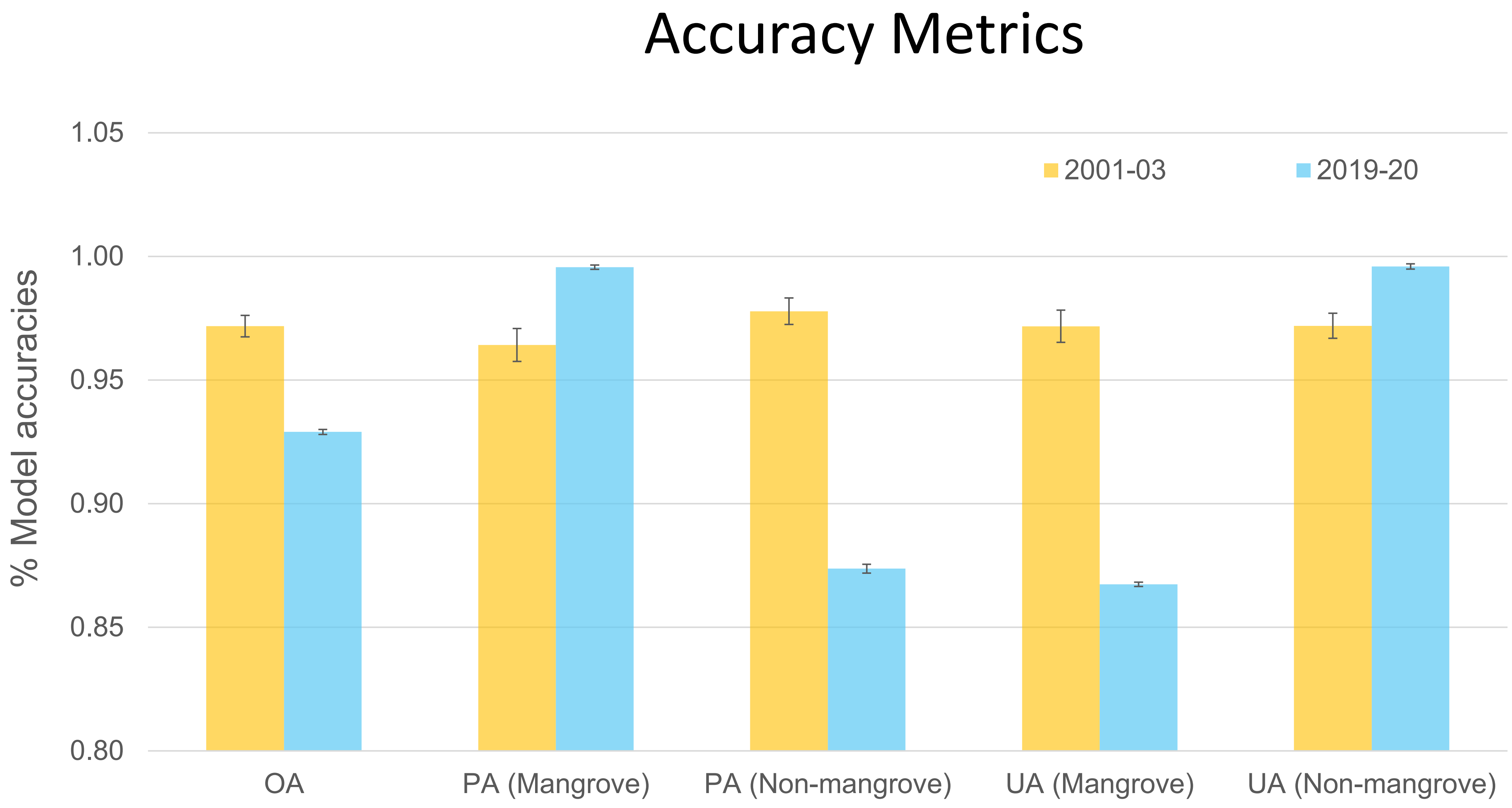
- Leave-one-out strategy for model validation and feature importance
- Overall accuracy, User's Accuracy (UA), Producer's Accuracy (PA)



Random Forest – Variable Importance







Accuracy Metrics
2001-03
2019-20
% Model accuracies
1.05
1.00
0.95
0.90
0.85
0.80
OA
PA (Mangrove)
PA (Non-mangrove)
UA (Mangrove)
UA (Non-mangrove)

Future Direction for Time Series Mapping

- ~25 years of mangrove extent maps

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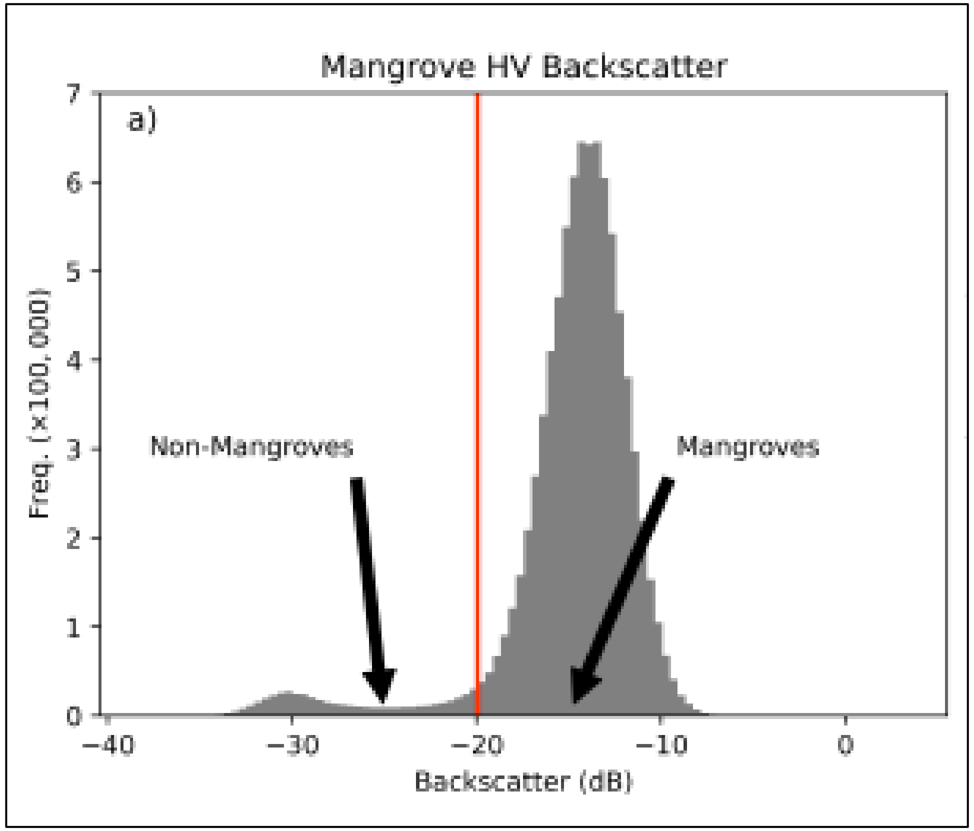
- Collaboration with Pete Bunting/Global Mangrove Watch
  - Regional implementation of global methods from GMW
    - LANDSAT vs. ALOS PALSAR
    - Regionally optimized thresholds
  - Use of old baseline (2001-03 map) to calibrate change
  - Evaluating change-detection methods: BFAST, CCDC



Bunting et al. 2022. *Remote Sens. 14*(15), 3657

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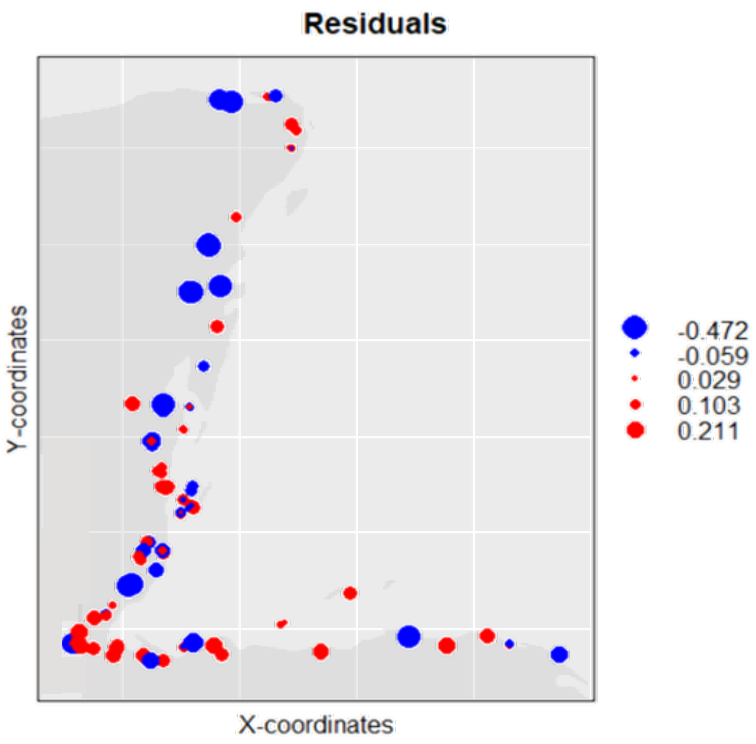
- Geographically-weighted classification



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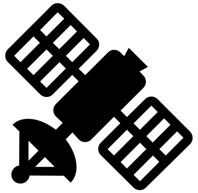

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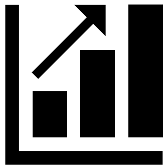
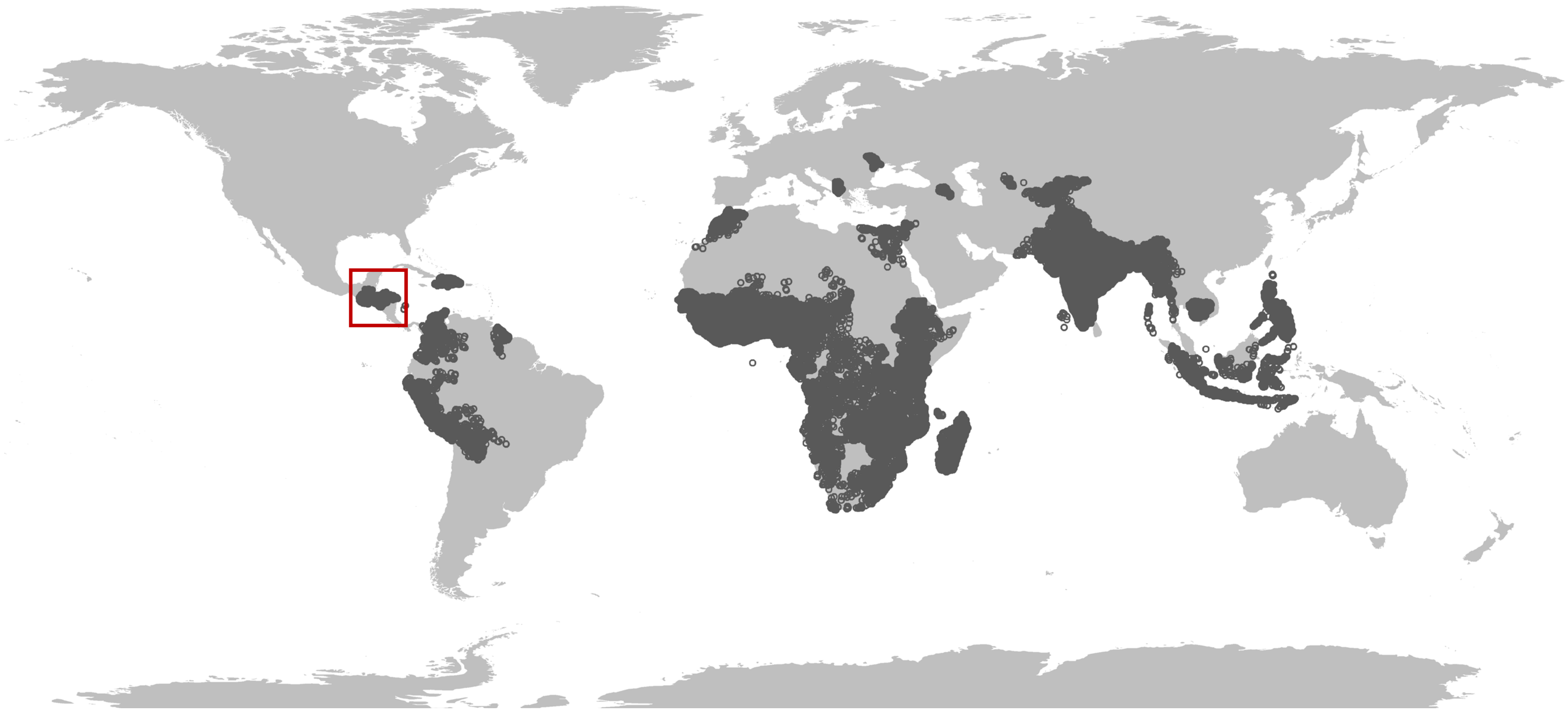


2. *How do socioeconomic conditions affect variation in rates of mangrove loss inside and outside of protected areas?*
   A) How does impact of area-based interventions vary as a function of socioeconomic context?
   B) Are there spillover effects of protected areas and how do these effects vary as a function of socioeconomic drivers?

3. *Do greater awareness of mangrove-derived benefits (i.e., ecosystem services) and more collaborative management by coastal communities result in reduced rates of mangrove loss?*

USAID Demographic and Health Surveys (DHS) data

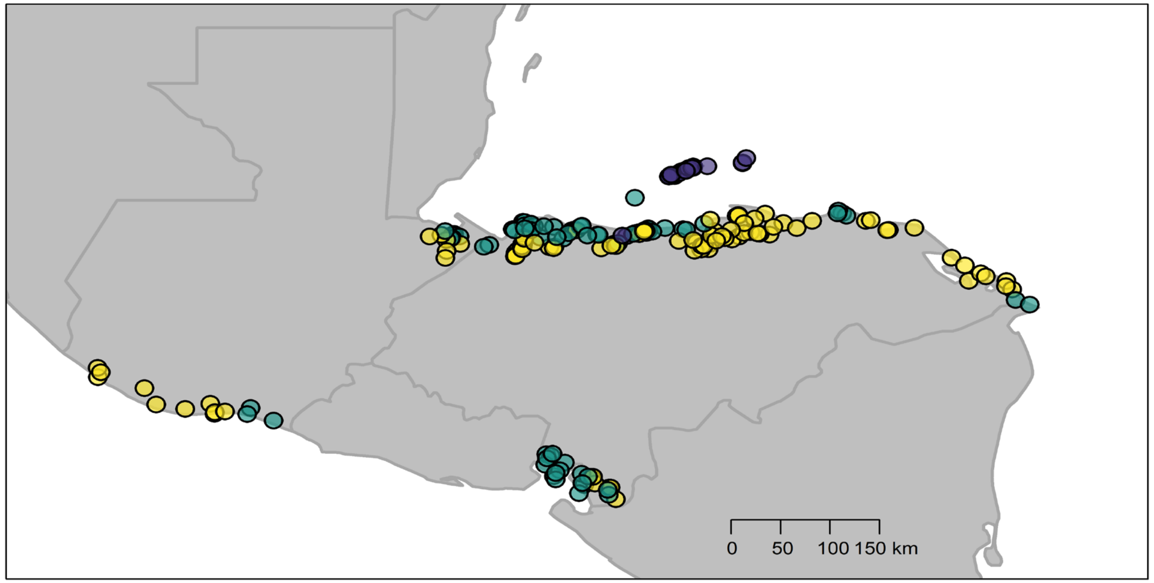


Quasi-experimental Approach to Evaluating PA Impacts

1) Extract USAID Demographic and Health Surveys (DHS) data:
   - Household wealth, food security (stunting and anemia), ownership of agricultural land, ownership of livestock, education level, occupation, type of cooking fuel used

2) Matched clusters near and far from MPAs based on potentially confounding geographic variables (e.g., population density, cyclone density, sea level rise, sea surface temperature)

3) Bayesian multilevel models to estimate overall effects of PAs on mangrove loss, including additive and interactive effects of DHS indicators



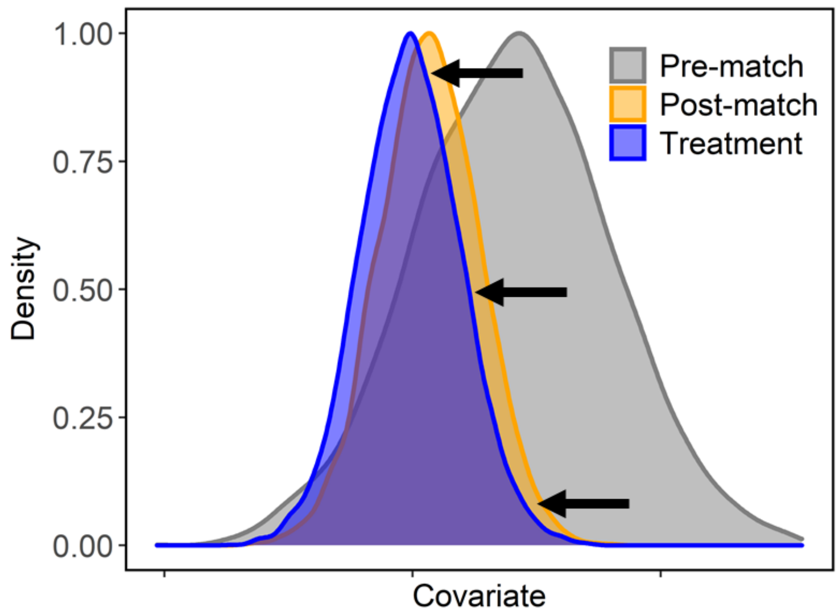
SCIENCE ADVANCES | RESEARCH ARTICLE

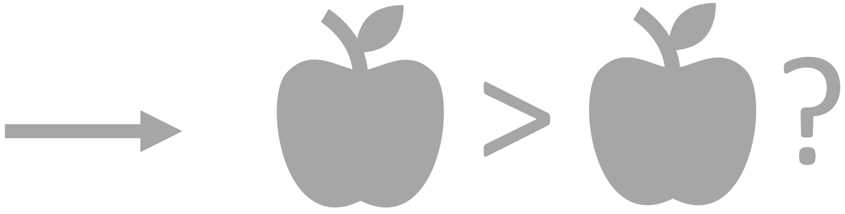
ECONOMICS

Evaluating the impacts of protected areas on human well-being across the developing world

R. Naidoo[1,2]*, D. Gerkey[3], D. Hole[4], A. Pfaff[5], A. M. Ellis[6], C. D. Golden[7], D. Herrera[8], K. Johnson[9†], M. Mulligan[10], T. H. Ricketts[11], B. Fisher[11]

Goal of matching: enable stronger causal inferences by improving balance in the *distributions* of potentially confounding variables between samples





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High and Far: Biases in the Location of Protected Areas

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1 Nicholas School of the Environment and Earth Sciences, Duke University, Durham, North Carolina, United States of America, **2** Public Policy, Economics, and Environment, Duke University, Durham, North Carolina, United States of America

A global-level assessment of the effectiveness of protected areas at resisting anthropogenic pressures

Jonas Geldmann[a,1], Andrea Manica[b], Neil D. Burgess[a,c,d], Lauren Coad[c,e], and Andrew Balmford[a]

[a]Conservation Science Group, Department of Zoology, University of Cambridge, CB2 3EJ Cambridge, United Kingdom; [b]Evolutionary Ecology Group, Department of Zoology, University of Cambridge, CB2 3EJ Cambridge, United Kingdom; [c]UN Environment Programme World Conservation Monitoring Centre (UNEP-WCMC), CB3 0DL Cambridge, United Kingdom; [d]Center for Macroecology, Evolution and Climate, Natural History Museum of Denmark, University of Copenhagen, 2100 Copenhagen E, Denmark; and [e]Centre for International Forestry Research, Bogor (Barat), 16115, Indonesia

Edited by Anthony J. Bebbington, Clark University, Worcester, MA, and approved September 30, 2019 (received for review May 13, 2019)

ARTICLES
https://doi.org/10.1038/s41559-021-01389-0
nature ecology & evolution
Check for updates

A forest loss report card for the world's protected areas

Christopher Wolf[1], Taal Levi[2], William J. Ripple[3], Diego A. Zárrate-Charry[4,5] and Matthew G. Betts[1,4]

nature communications

Article https://doi.org/10.1038/s41467-023-38073-9

The effectiveness of global protected areas for climate change mitigation

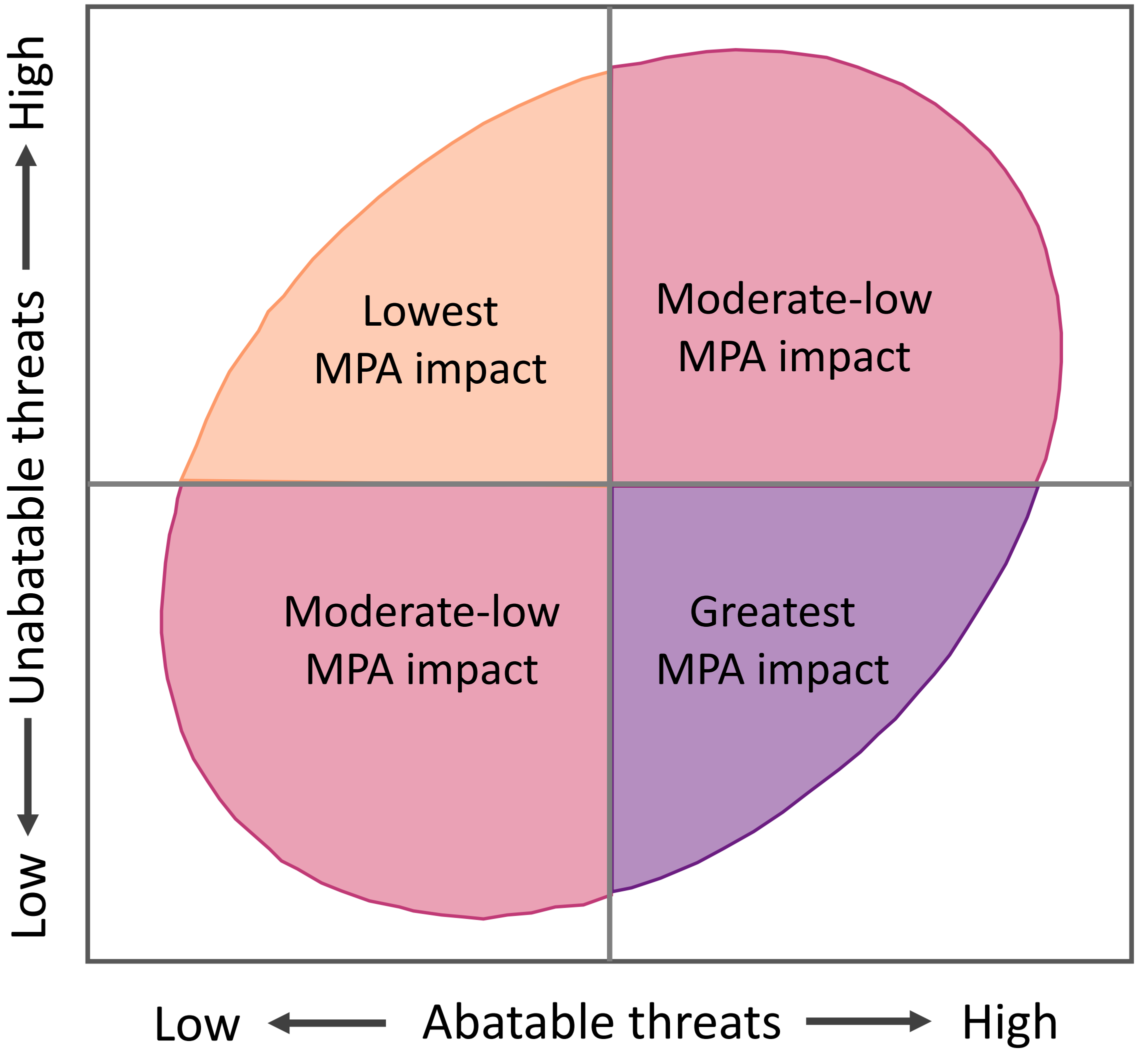
Received: 6 December 2022

Accepted: 14 April 2023

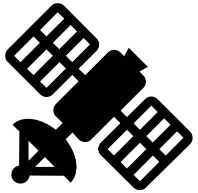
Published online: 01 June 2023

Check for updates

L. Duncanson[1], M. Liang[1], V. Leitold[1], J. Armston[1], S. M. Krishna Moorthy[1], R. Dubayah[1], S. Costedoat[2], B. J. Enquist[3,4], L. Fatoyinbo[5], S. J. Goetz[6], M. Gonzalez-Roglich[7], C. Merow[8], P. R. Roehrdanz[2], K. Tabor[5,9] & A. Zvoleff[2]


High
Unabatable threats
Low
Lowest
MPA impact
Moderate-low
MPA impact
Moderate-low
MPA impact
Greatest
MPA impact
Low
Abatable threats
High

Research Questions



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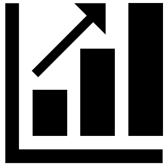

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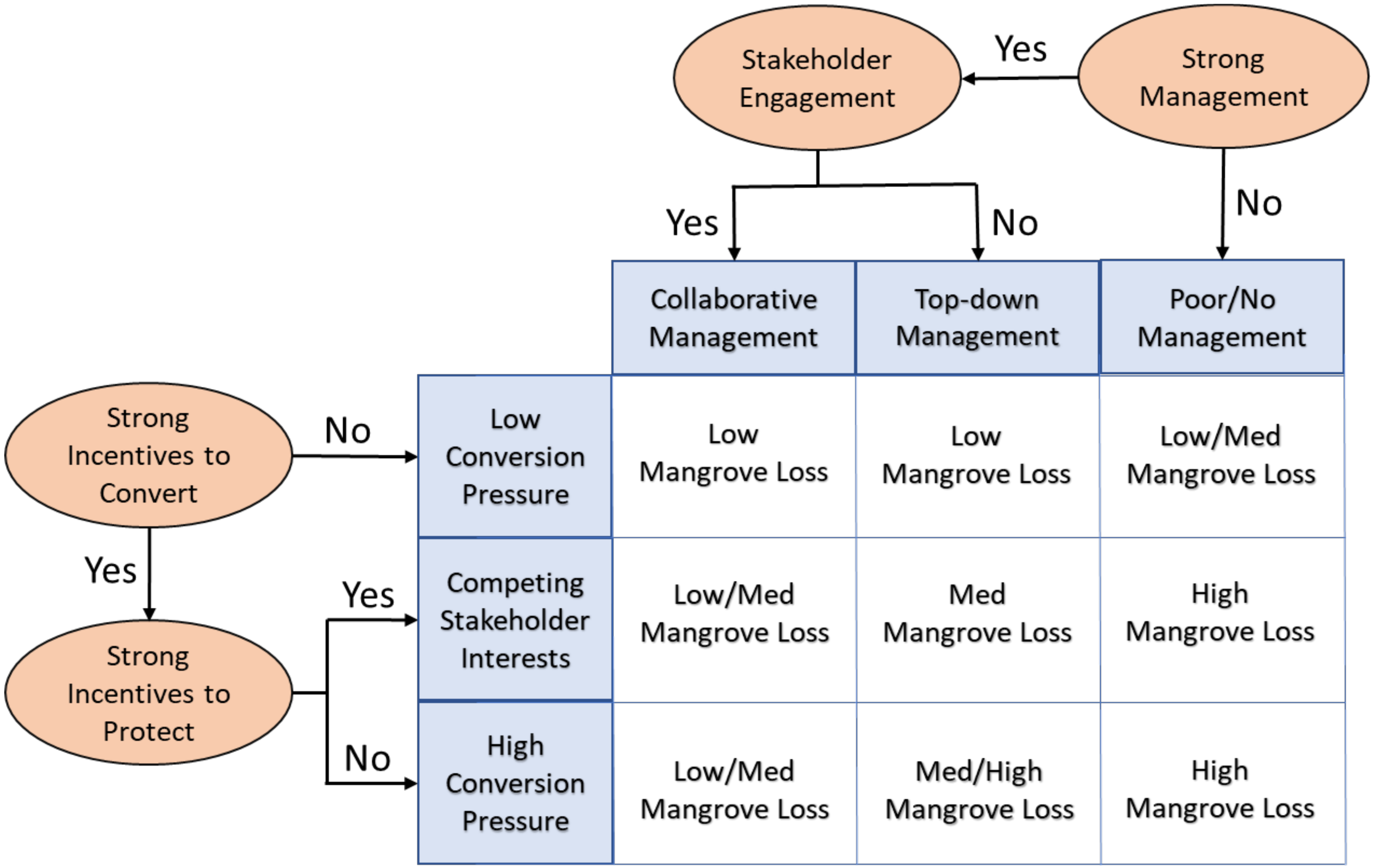
Stakeholder Engagement
Yes
Strong Management
Yes
No
No
Collaborative Management
Top-down Management
Poor/No Management
Strong Incentives to Convert
No
Low Conversion Pressure
Low Mangrove Loss
Low Mangrove Loss
Low/Med Mangrove Loss
Yes
Yes
Competing Stakeholder Interests
Low/Med Mangrove Loss
Med Mangrove Loss
High Mangrove Loss
Strong Incentives to Protect
No
High Conversion Pressure
Low/Med Mangrove Loss
Med/High Mangrove Loss
High Mangrove Loss

Key Informant Interviews

- **Interview Surveys:**
  - 16 case study communities (4/country)
  - 15-20 interviewees per community
  - Targeting governance-related actors, mangrove users, environmental experts

- **Focus Group Discussions:**
  - Follow-up with subset of interviewees
  - Interactive to generate collective insights and potential solutions

- **Key Themes:**
  - Current status and threats to mangroves
  - Ecosystem services provided
  - Community participation in management
  - Gender inclusivity

Overall Goals:

- Improved delineation and understanding of loss hotspots
- Improved understanding of protected area effectiveness and the spatial/socioeconomic contexts in which they're most successful
- Identification of best management practices with respect to community outreach and engagement
- Reduce rates of mangrove loss throughout the MAR through collaboration and information sharing with our resource management partners in the region

Thank You!