



Part 1: Intro to SDG 6.6 and Remote Sensing Techniques for Mangroves

Abigail Barenblitt & Temilola Fatoyinbo

Nov 5th, 2020



Course Structure and Materials

- Three, 1.5-hour sessions on November 5, 12, and 19
- The same content will be presented at two different times each day:
 - Session A: 10:00-11:30 EST (UTC-5)
 - Session B: 15:00-16:30 EST (UTC-5)



Course Structure and Materials

- Webinar recordings, PowerPoint presentations, and the homework assignment can be found after each session at:
 - <https://appliedsciences.nasa.gov/join-mission/training/english/remote-sensing-mangroves-support-un-sustainable-development-goals>
 - Q&A following each lecture and/or by email at:
 - lola.fatoyinbo@nasa.gov or
 - abigail.barenblitt@nasa.gov



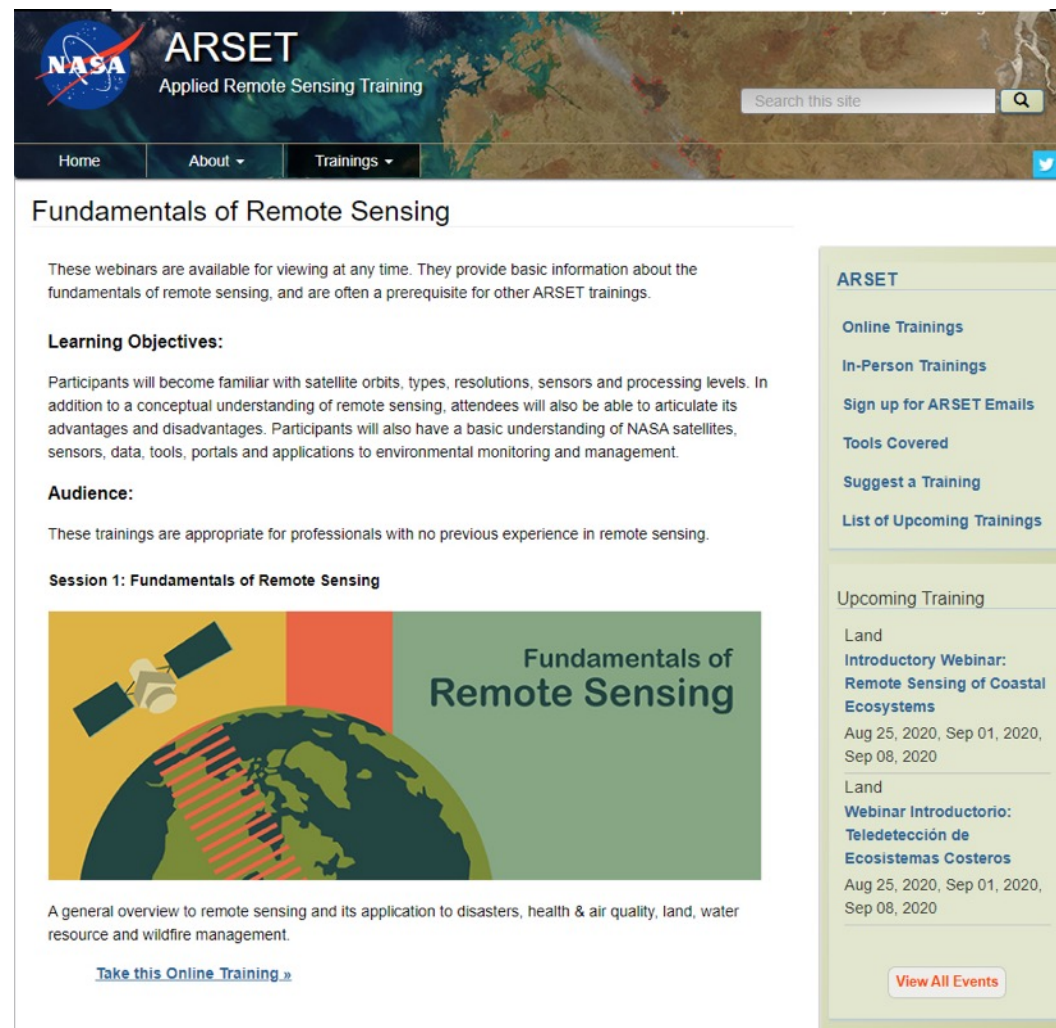
Homework and Certificates

- **Homework:**
 - Three homework assignments, assigned after each weekly Part
 - Answers must be submitted via Google Forms
- **Certificate of Completion:**
 - Attend all three live webinars
 - Complete the homework assignments by the deadline (access from ARSET website)
 - You will receive certificates approximately two months after the completion of the course from: marines.martins@ssaihq.com



Prerequisites

- Required Version of QGIS: 3.10 <https://www.qgis.org/en/site/forusers/download.html>
 - Download and Install Class Accuracy Plug-in for QGIS: <https://github.com/remotesensinginfo/classaccuracy>
 - For instructions for installation refer to this video: <https://www.youtube.com/watch?v=NJRdKpmujRo>
 - [Fundamentals of Remote Sensing](#)
 - [Intro to JavaScript for GEE](#)
 - Create a Google Earth Engine Account
- Optional:
- [GEE Beginner's Cookbook](#)
 - [GEE Managing Assets](#)
 - [Introduction to Google Earth Engine Tutorial](#)



ARSET
Applied Remote Sensing Training

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Home About Trainings

Fundamentals of Remote Sensing

These webinars are available for viewing at any time. They provide basic information about the fundamentals of remote sensing, and are often a prerequisite for other ARSET trainings.


Learning Objectives:

Participants will become familiar with satellite orbits, types, resolutions, sensors and processing levels. In addition to a conceptual understanding of remote sensing, attendees will also be able to articulate its advantages and disadvantages. Participants will also have a basic understanding of NASA satellites, sensors, data, tools, portals and applications to environmental monitoring and management.

Audience:

These trainings are appropriate for professionals with no previous experience in remote sensing.

Session 1: Fundamentals of Remote Sensing



Fundamentals of Remote Sensing

A general overview to remote sensing and its application to disasters, health & air quality, land, water resource and wildfire management.

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- Tools Covered
- Suggest a Training
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Upcoming Training

Land

Introductory Webinar: Remote Sensing of Coastal Ecosystems

Aug 25, 2020, Sep 01, 2020, Sep 08, 2020

Land

Webinar Introductorio: Teledetección de Ecosistemas Costeros

Aug 25, 2020, Sep 01, 2020, Sep 08, 2020

[View All Events](#)



Learning Objectives

By the end of this presentation, you will:

- Become familiar with the UN Sustainable Development Goals
- Understand SDG 6.6 and how mangroves serve as an indicator
- Learn how remote sensing can be used to study mangroves





Lola Fatoyinbo



Abigail Barenblitt



Nathan Thomas



Liza Goldberg



Celio Souza



Atticus Stovall



David Lagomasino



Marc Simard



Carl Trettin



Seung-Kuk Lee



The Mangroves



Outline

- 1) Mangroves and Clean Water
- 2) Overview of SDG 6
- 3) Remote Sensing of Mangroves
- 4) Research Examples
- 5) Google Earth Engine Apps for Communication



Why Mangroves?

- Numerous Ecosystem Services
 - Nutrient Cycling
 - Fishery Support
 - Flood Control
 - Water Quality
 - Coastline Stabilization
 - Carbon Sequestration



Image Credit: NASA



What do we learn from studying mangroves?

- Biomass and Carbon Stocks
- Ecosystem Condition (Intact vs. Degraded)
- Environmental Drivers
- Management and Restoration



Image Credit: Mangrove Science Lab



Mangroves and Clean Water

- Complex root system filters nitrates, phosphates, heavy metals
- Trap sediments flowing downstream
- Stabilization of coastlines reduces damage from hurricanes



Image Credit: NASA



Risks to Mangroves

- Land-Use Change
- Sea Level Rise
- Degradation and Conversion
- Invasive Encroachment
- Oil Exploration



UN Sustainable Development Goals (SDGs)

- 2030 Agenda for Sustainable Development
- 17 SDG's and 169 targets aiming to end poverty, protect the planet, and improve the lives of everyone
- All UN member countries



Image Credit: United Nations



In this webinar series, we will focus on Goal 6.

6 CLEAN WATER AND SANITATION



Image Credit: United Nations



SDG 6: Clean Water and Sanitation

- UN SDG 6 seeks to “Ensure availability and sustainable management of water and sanitation for all.”
- From 2000 – 2017, the proportion of the population with access to safe drinking water increased from 61% to 71%.
- Climate change is expected to decrease the extent of freshwater bodies.

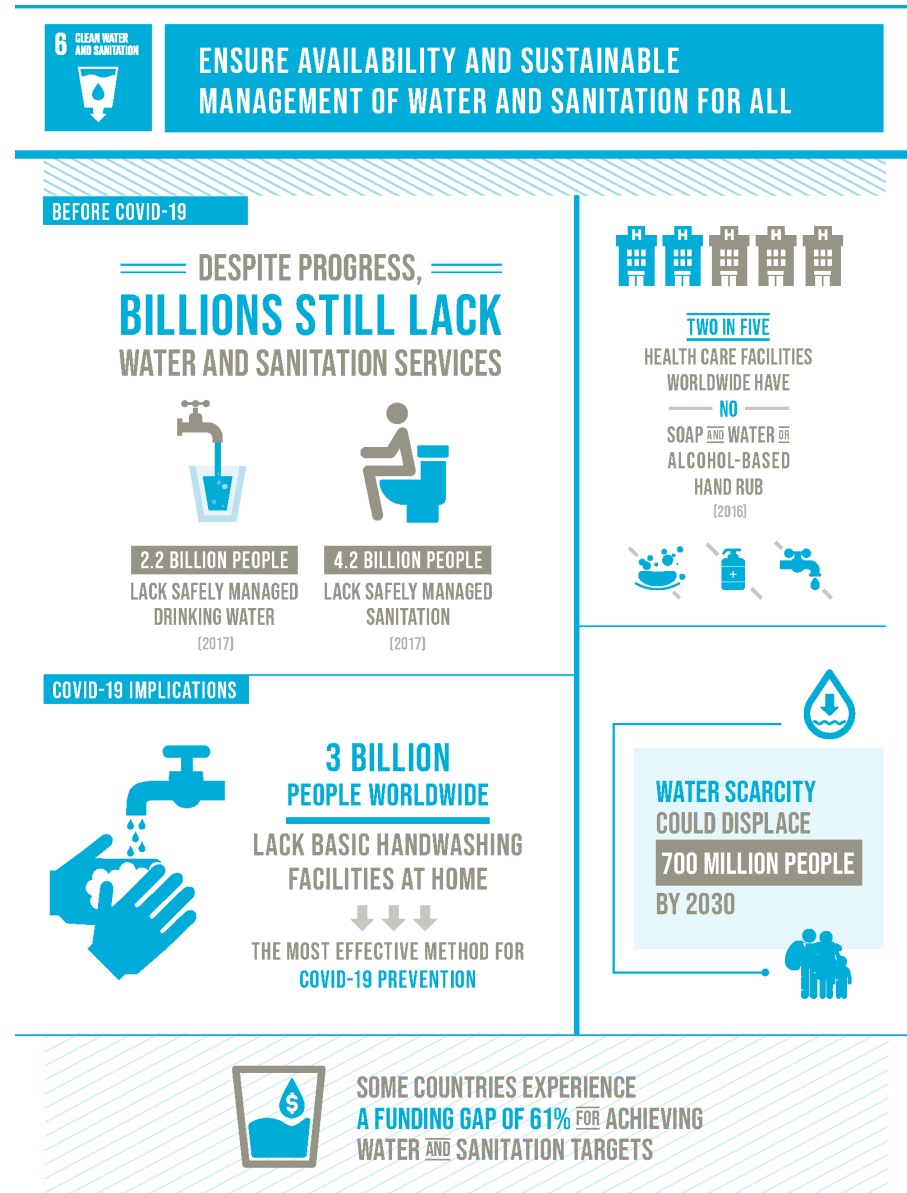


Image Credit: United Nations



Indicator 6.6.1: Change in extent of water-related ecosystems over time

- "By 2020, protect and restore water-related ecosystems, including mountains, forests, wetlands, rivers, aquifers and lakes"
- Halt the degradation of water-related ecosystems and assist in recovery
- Improve knowledge of water-related ecosystems to drive action towards protection and recovery
- Example Indicators:
 - Salt Marshes
 - Wetlands
 - Mangroves



Partnering Organizations

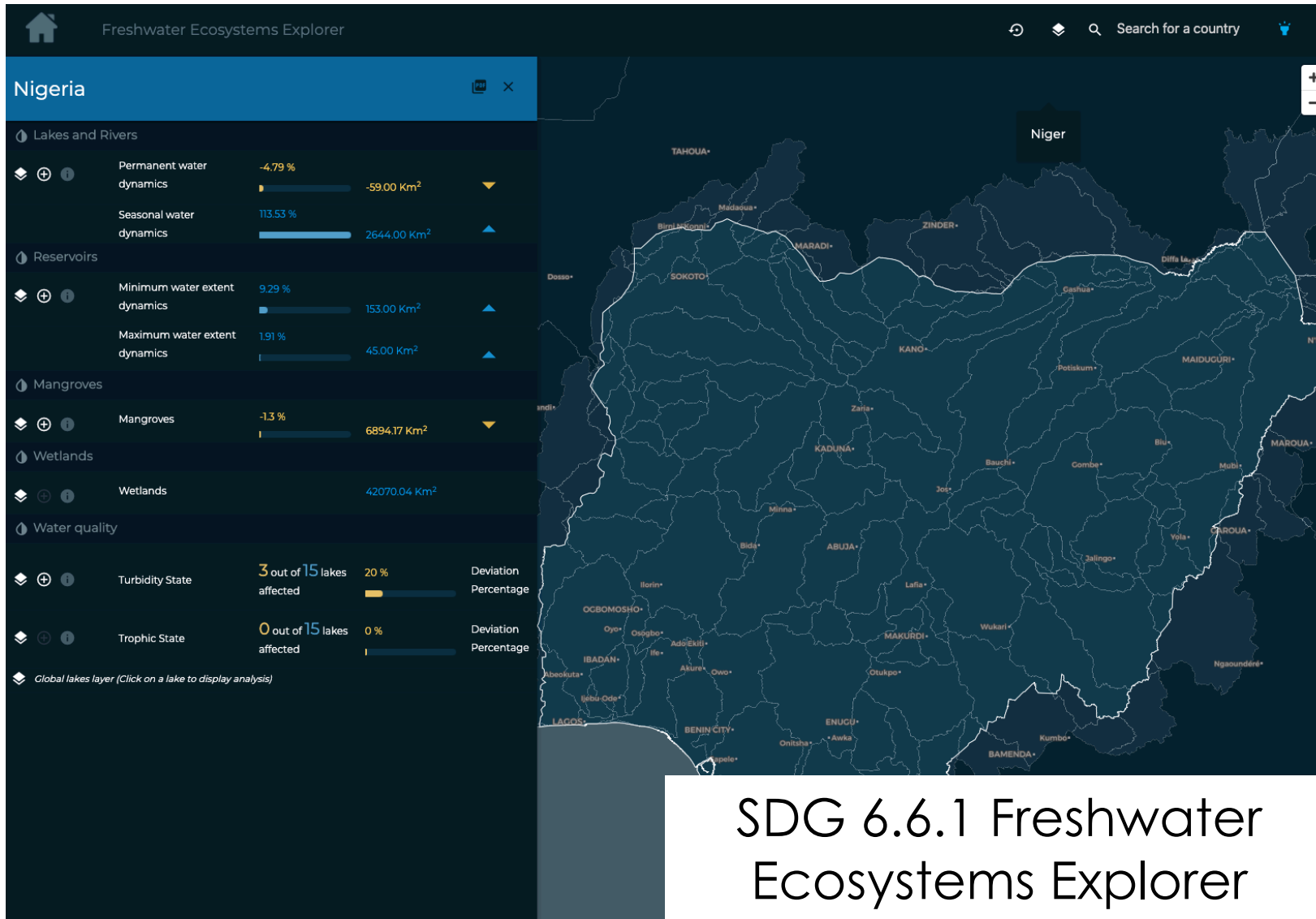


Food and Agriculture
Organization of the
United Nations



With support from:





SDG 6.6.1 Freshwater Ecosystems Explorer
<https://www.sdg661.app/>





The Freshwater Ecosystems Explorer is a free and easy to use data platform. It provides accurate, up-to-date, high-resolution geospatial data depicting the extent freshwater ecosystems change over time.

Measuring changes in mangrove area

Why measure mangroves?

Mangrove swamps are forested intertidal ecosystems that are distributed globally between approximately N32° (Bermuda) to S39° (Victoria, Australia). Mangroves perform critical landscape-level functions related to the regulation of freshwater, nutrients and sediment inputs into marine areas. They also help to control the quality of marine coastal waters and are of critical importance as breeding and nursery sites for birds, fish, and crustaceans. It has been estimated that nearly two thirds of all fish harvested globally in the marine environment ultimately depend on the health of tropical coastal ecosystems. Mangroves furthermore receive large inputs of matter and energy from both land and sea and constitute important pools for carbon storage (Lucas et al., 2014).

Once abundant along the world's tropical and subtropical coastlines, mangroves are in decline at a rate similar to that of terrestrial (natural) forest, with about four to five percent of the global coverage lost during the past two decades (Ramsar Convention, 2018; FAO, 2015). Significant drivers of change include removal for aquaculture, agriculture, energy exploitation and other industrial development, with an unknown proportion of the remaining mangroves fragmented and degraded (Thomas et al., 2017). Mangroves are also sensitive to climate change effects such as sea level rise, temperature extremes and geographic range, and changes in hydrology.

Information on the state and change trends of mangroves at both national and global levels is limited. This is due in part because mangroves often fall between the national jurisdictions of wetlands and for forestry, and in part because of their often remote and inaccessible locations, which make periodic mapping and monitoring by conventional means costly and time consuming. Mangrove soils hold over 6 billion tons of carbon and can sequester up to 3-4 times more carbon than their terrestrial counterparts but are categorized as forests within the UN Framework Convention on Climate Change's REDD+ scheme¹ (IUCN, 2017), and should therefore be included in national emissions reports.

Description of the method used to measure mangrove area

Global mangrove area maps were derived in two phases, initially producing a global map showing mangrove extent (for 2010) and thereafter producing six additional annual data layers (for 1996, 2007, 2008, 2009, 2015 and 2016). The method uses a combination of radar (ALOS PALSAR) and optical (Landsat-5, -7) satellite data. Approximately 15,000 Landsat scenes and 1,500 ALOS PALSAR (1 x 1 degree) mosaic tiles were used to create optical and radar image composites covering the coastlines along the tropical and sub-tropical coastlines in the Americas, Africa, Asia and Oceania. The classification was confined using a mangrove habitat mask, which defined regions where mangrove ecosystems can be expected to exist. The mangrove habitat definition was generated based on geographical parameters such as latitude, elevation and distance from ocean water. Training for the habitat mask and classification of the 2010 mangrove mask was based on randomly sampling some 38 million points using historical mangrove maps for the year 2000 (Giri et al., 2010; Spalding et al., 2010), water occurrence maps (Pekel et al, 2017), and Digital Elevation Model data (SRTM-30).

The maps for the other six epochs were derived by detection and classification of mangrove losses (defined as a decrease in radar backscatter intensity) and mangrove gains (defined as a backscatter increase) between the 2010 ALOS PALSAR data on one hand, and JERS-1 SAR (1996), ALOS PALSAR (2007, 2008 & 2009) and ALOS-2 PALSAR-2 (2015 & 2016) data on the other. The change pixels for each annual dataset were then added or removed from the 2010 baseline raster mask (buffered to allow detection of mangrove gains also immediately outside of the mask) to produce the yearly extent maps.

Classification accuracy of the 2010 baseline dataset was assessed with approximately 53,800 randomly sampled points across 20 randomly selected regions. The overall accuracy was estimated to 95.25 %, while User's (commission error) and Producer's (omission error) accuracies for the mangrove class were estimated at 97.5% and 94.0%, respectively. Classification accuracies of the changes were assessed with over 45,000 points, with an overall accuracy of 75.0 %. The User's accuracies for the loss, gain and no-change classes respectively were estimated at 66.5%, 73.1% and 83.5%. The corresponding Producer's accuracies for the three classes were estimated as 87.5%, 73.0% and 69.0%, respectively.

¹ Reducing emissions from deforestation and forest degradation in developing countries, and the role of conservation, sustainable management of forests, and enhancement of forest carbon stocks in developing countries



Studying SDG's

- Indicators are the backbone of monitoring progress regionally and globally.
- SDG Indicators are used to make target management goals.
- There are 100 Global Monitoring Indicators.



Other SDG's Mangroves Support

- SDG 1: No Poverty
- SDG 2: Zero Hunger
- SDG 8: Decent Work and Economic Growth
- SDG 12: Responsible Consumption and Production
- SDG 13: Climate Action
- SDG 14 : Life Below Water
- SDG 15: Life on Land



Studying Mangroves

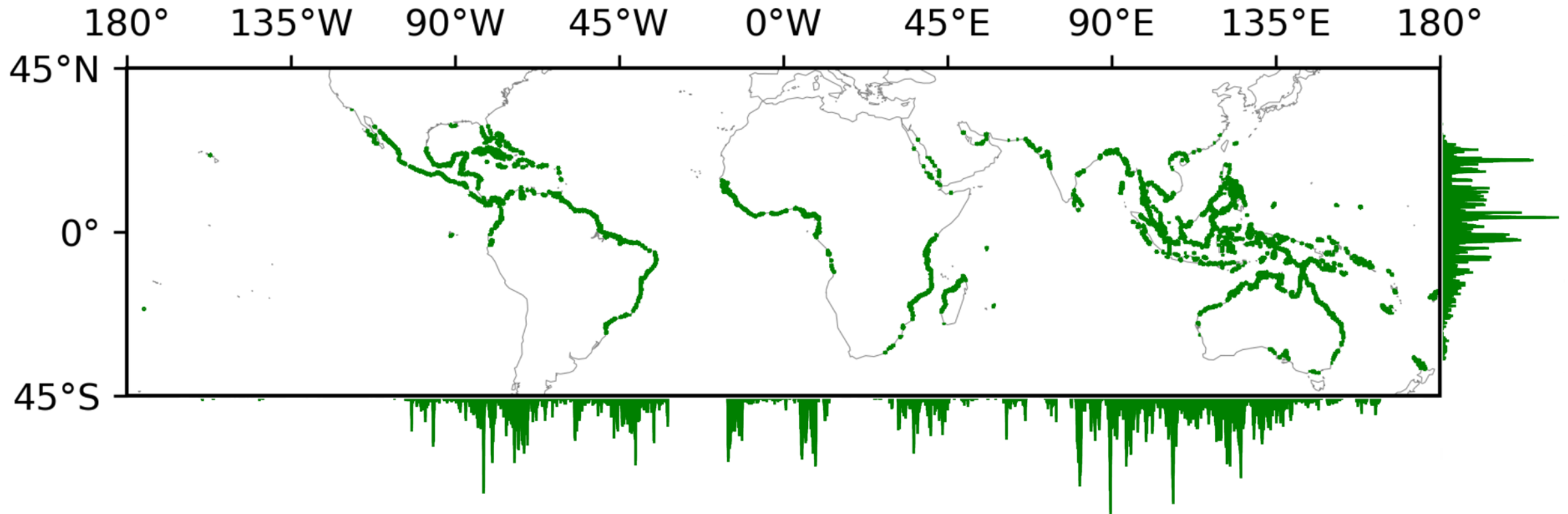
- Regional and Global Mangrove Monitoring and Vulnerability Modeling
- Wetland and forest extent, change, and carbon stock mapping
- Assisting National Forest Inventories
- Natural Capital Accounting
- 3-D mapping of Forest Structure from Lidar, Radar, and Stereo-Photogrammetry



Radar image of Mangroves in Brazil.
Image Credit:
NASA



Mangrove Distribution Globally



Outline of coastlines where mangroves are found globally. Image Credit: Global Mangrove Watch



Challenges of Mapping Mangroves

- On-the-ground surveys are costly and time-consuming.
- Rapid urbanization and human development leads to constant changes.
- Mangroves are often found in cloudy regions, resulting in obscured imagery.





Remote Sensing of Mangroves

Remotely Sensing Mangroves

- We can measure extent, change height, biomass, and carbon stock using:
 - Passive Optical
 - Synthetic Aperture Radar
 - LiDAR



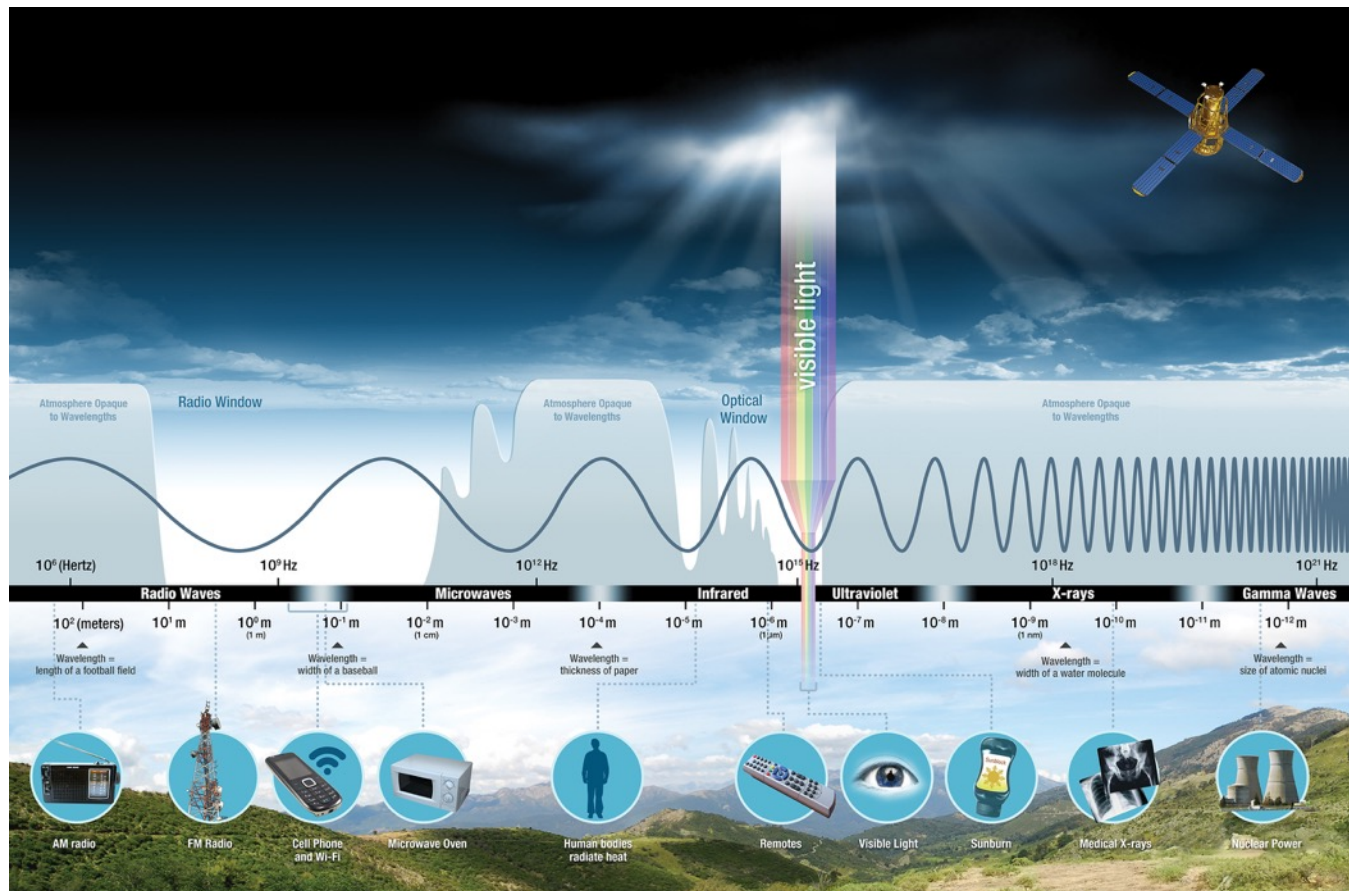
Imagery of the Sundarbans, Image Credit: Jesse Allen with the Earth Observatory



Passive Optical

- Uses waves from the electromagnetic spectrum
- Ex: Landsat 8 measures visible, near-infrared, and short-wave infrared (SWIR)
- Used to calculate indices like Normalized Difference Vegetation Index

$$\text{NDVI} = \frac{(\text{NIR} - \text{VIS})}{(\text{NIR} + \text{VIS})}$$

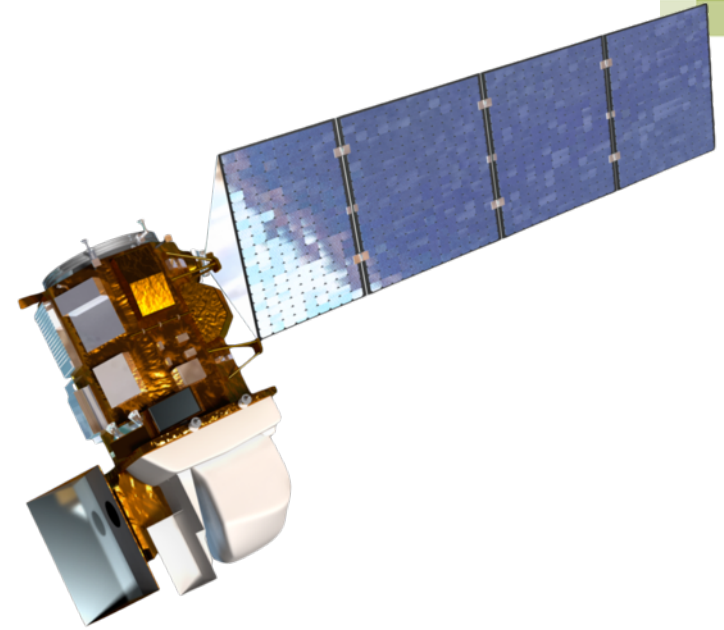


Visualization of Electromagnetic Spectrum, Image Credit: NASA



Landsat and Sentinel 2 Series

- Optical imagery at 25-30 m resolution
- Sentinel 1 SAR 10, 25, or 40 m resolution
- Used to measure extent
 - SAR used for structure
- Bands used as predictors in Machine Learning models



Commercial Very High Resolution

- Passive Optical, similar to Landsat and Sentinel 2
- Commercial data from companies like Digital Globe and Planet
- Optical and Stereophotogrammetric data
- 31 cm - 5 m resolution

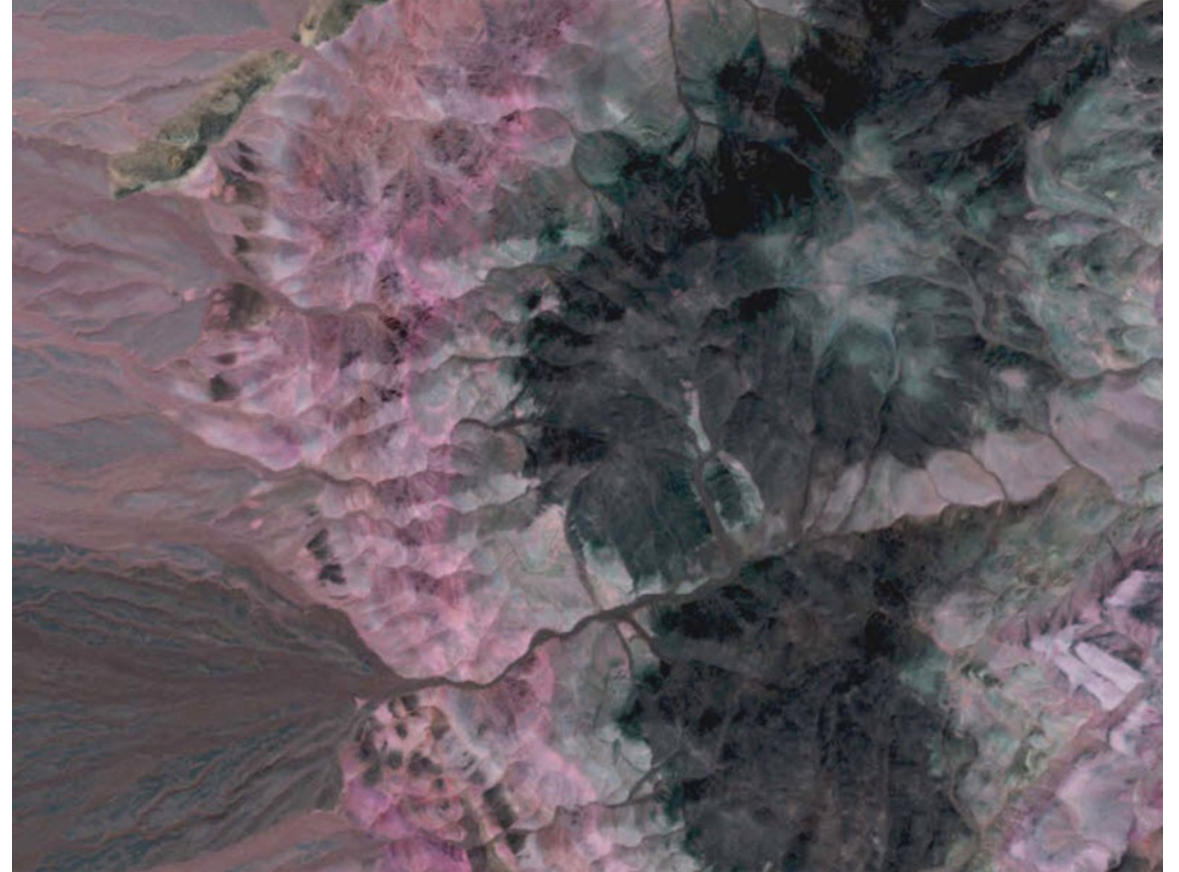


Image Credit: Digital Globe



Synthetic Aperture Radar

- Uses radio waves to determine range, angle, and velocity
- Used for meteorology, soil moisture, and land cover studies
- Backscatter distinguishes between simple and complex land cover

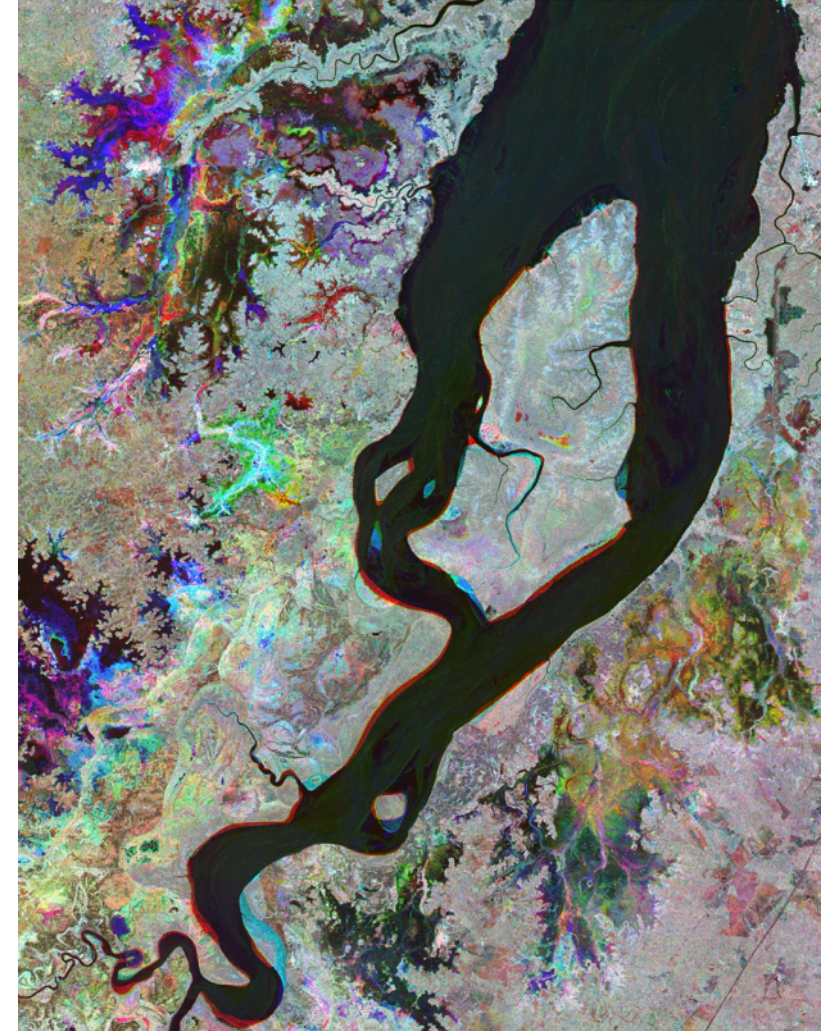


Image Credit: European Space Agency



SAR

- Senses water volume in vegetation
- Can be used to estimate forest biomass from backscatter
- Can be used to measure topography, changes in elevation and canopy height
- Can be used to improve Land cover extent maps, particularly water related ecosystems and flooded forests.

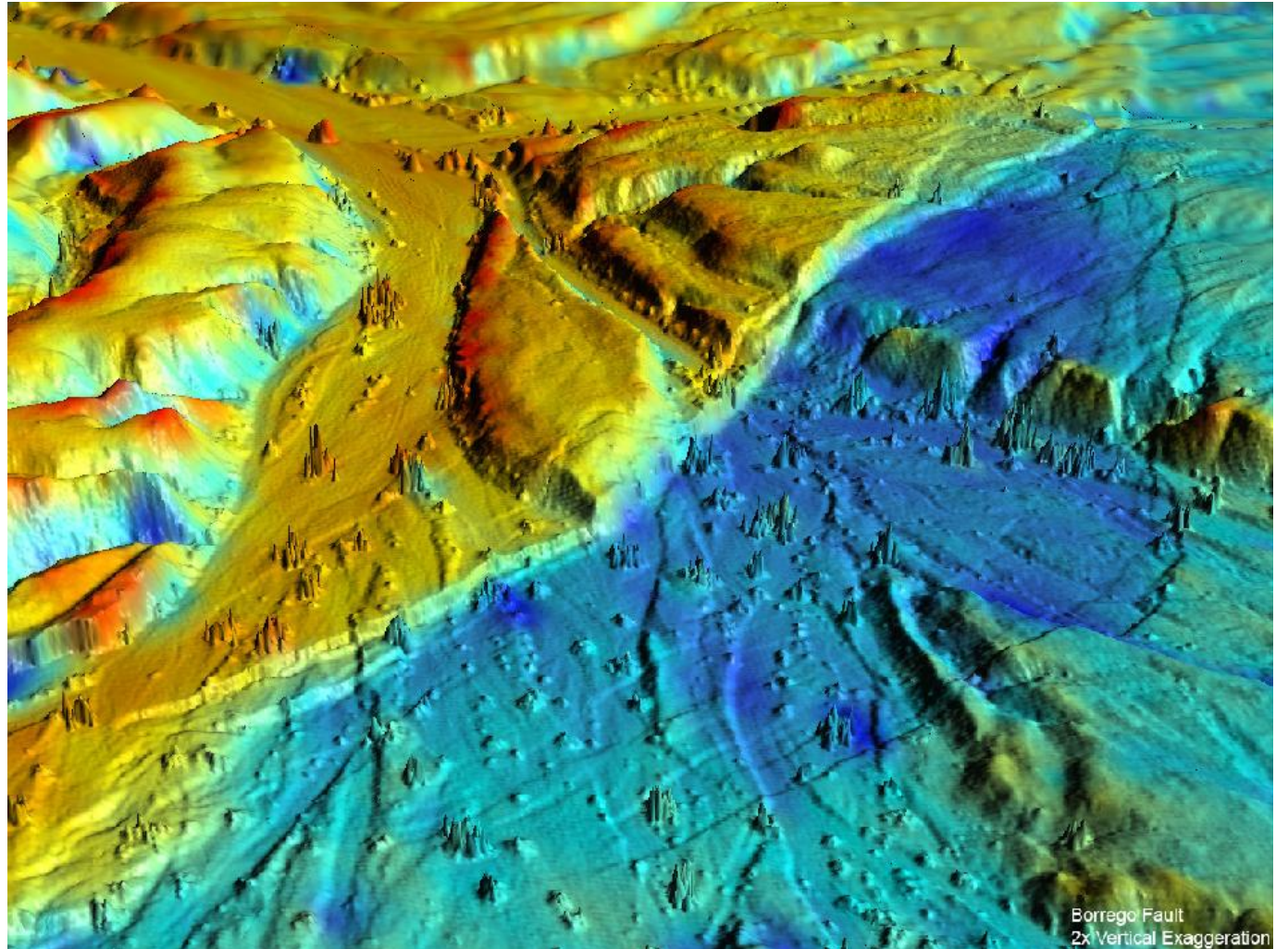


ALOS PALSAR Timeseries of northern Brazil
Image Credit: Nathan Thomas, ©JAXA



LiDAR (Light Detection and Ranging)

- Emits laser pulses
- Return time to sensor allows us to distinguish structural elements
- Airborne and Spaceborne sensors



3D visualization of Borrego Fault, Image Credit: NASA





Example Research

Radar/Lidar Fusion for Mangrove 3D Structure

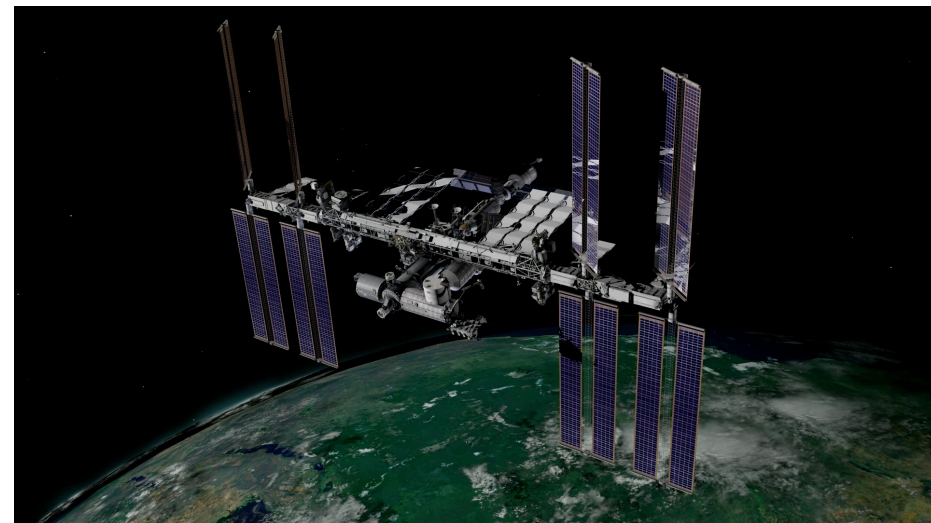
TanDEM-X Digital Elevation Model



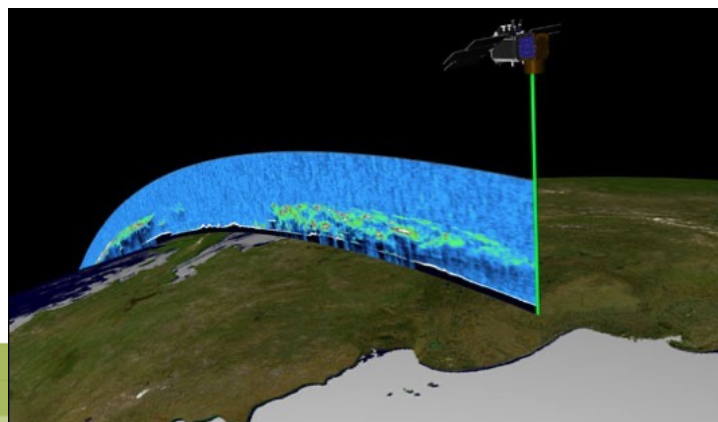
SRTM DEM



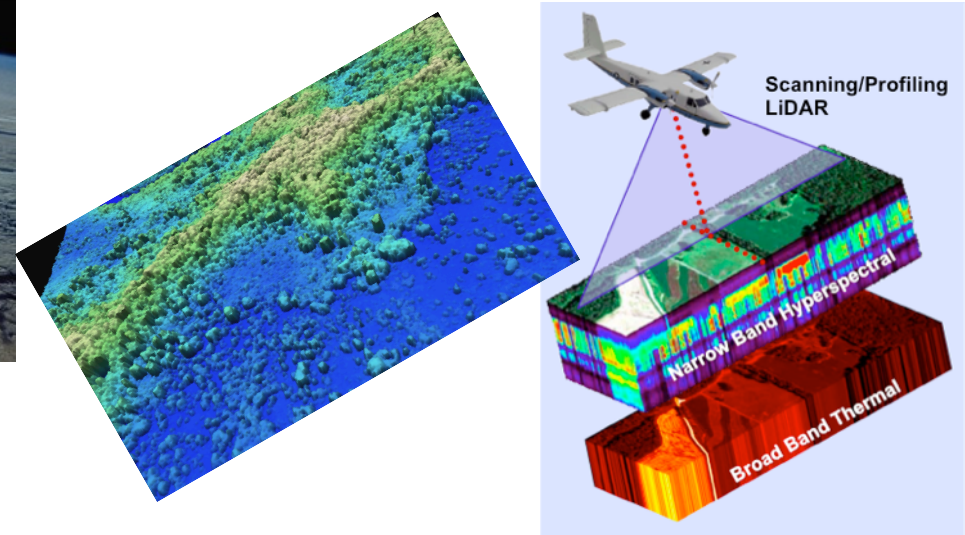
Global Ecosystem Dynamics Investigation (GEDI) Lidar



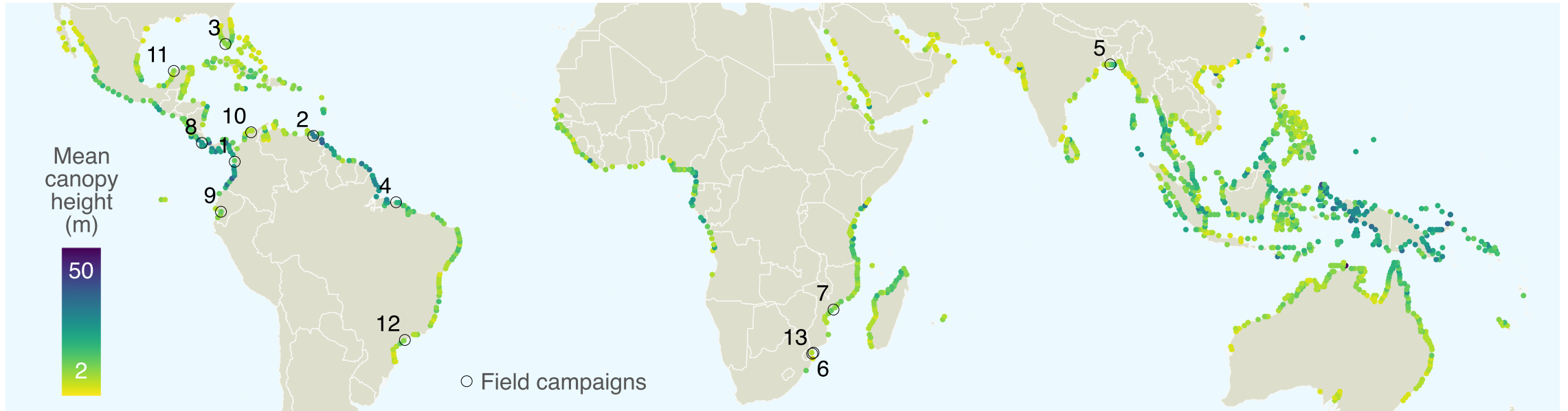
IceSat/GLAS



Airborne Lidar



Global Mangrove Height, AGB, and Carbon 2000



<https://mangrovescience.earthengine.app/view/mangroveheightandbiomass>

Earth Engine Apps **Experimental** Search places

Global Mangrove Height & Biomass Explorer

This tool maps global mangrove canopy height and biomass results from Simard et al. 2018. The data can be downloaded at https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1665

Select a map layer.
Canopy Height (Hmax) ▾

Select a metric to compute by country.
Total Carbon ▾

Country	Total_Carbon
Colombia	75,973,344
Costa Rica	13,998,836
Panama	58,979,743
..	

Clear results Display results as chart

Select a metric to compute by country.
Maximum Canopy Height ▾

Maximum Height Comparison

Country	Max_Height
Colombia	~54.5
Costa Rica	~46.5
Panama	~51.5

Clear results Display results as table

Map data ©2019 Google Imagery ©2019 TerraMetrics | 20 km Terms of Use

Here we can provide relevant results as table or bar chart



Mangrove Loss Drivers



Image Credit: NASA G-LiHT



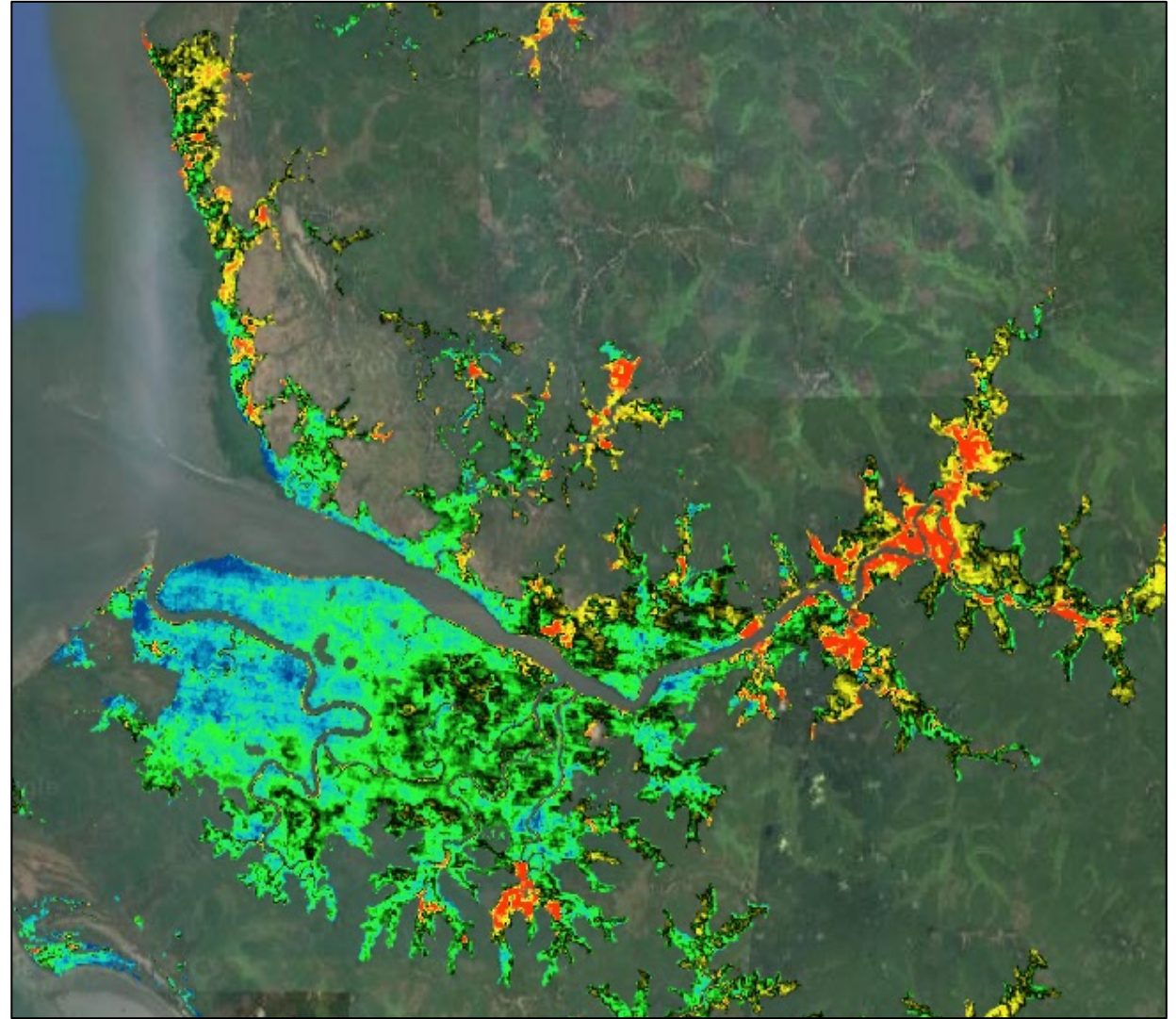
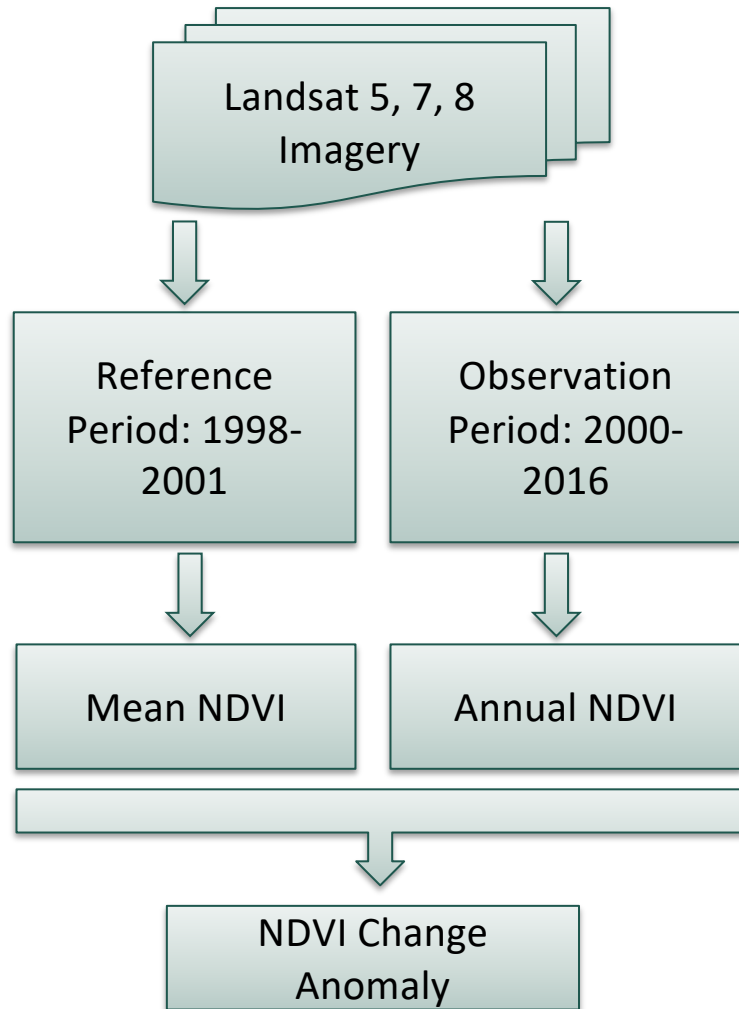
Gulf of Carpentaria, Australia



Image Credit: Liza Goldberg

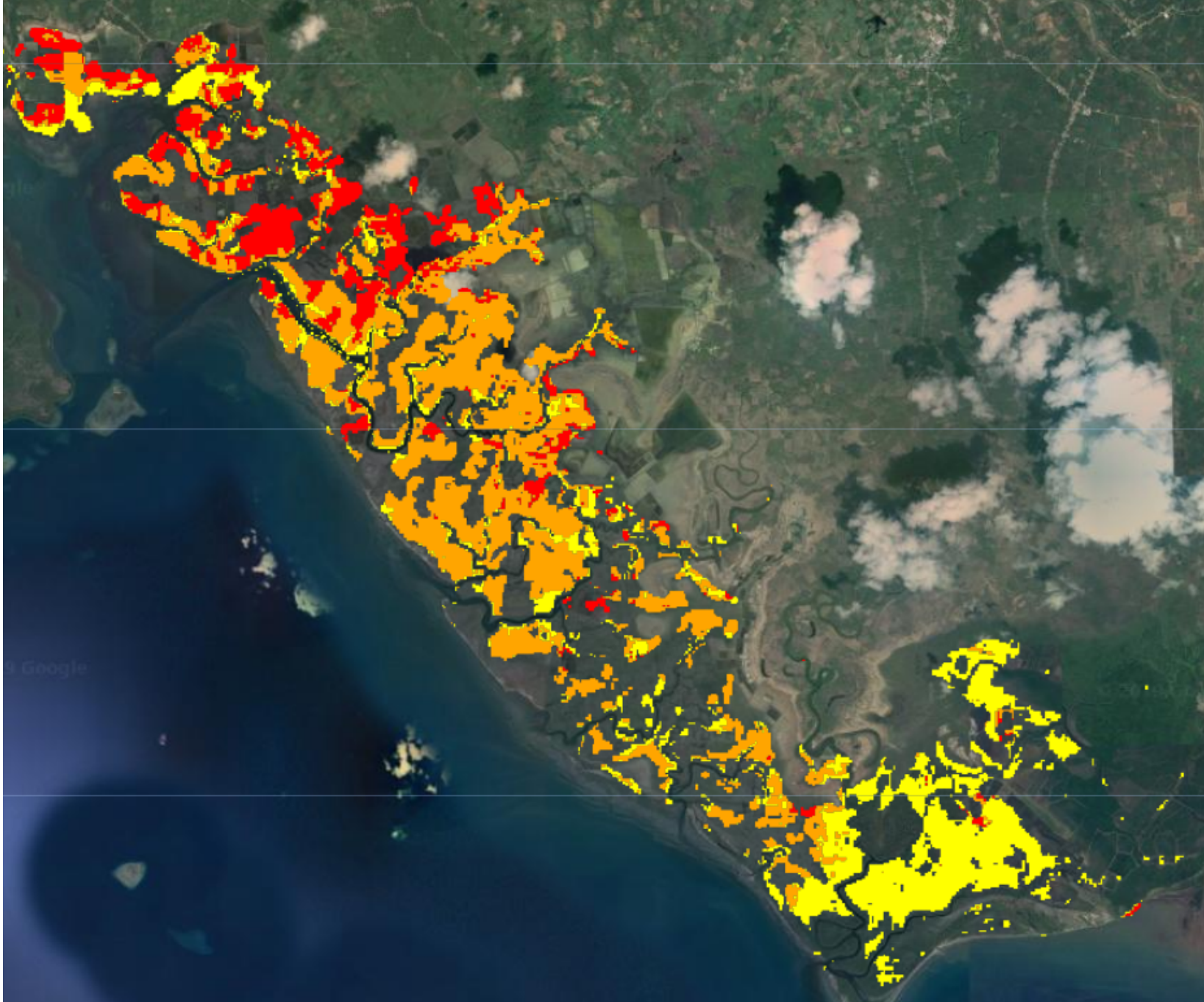


Loss Extent Mapping

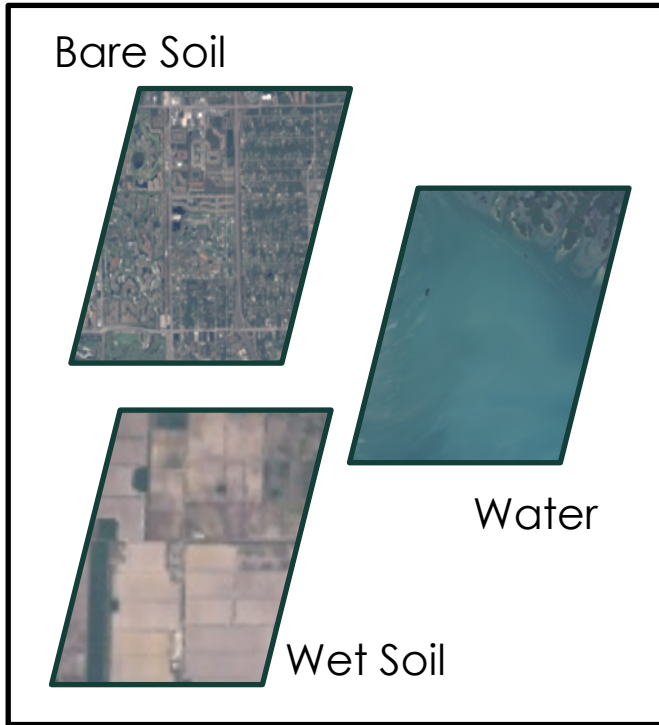


Yawri Bay, Sierra Leone, Image Credit: Dr. David Lagomasino

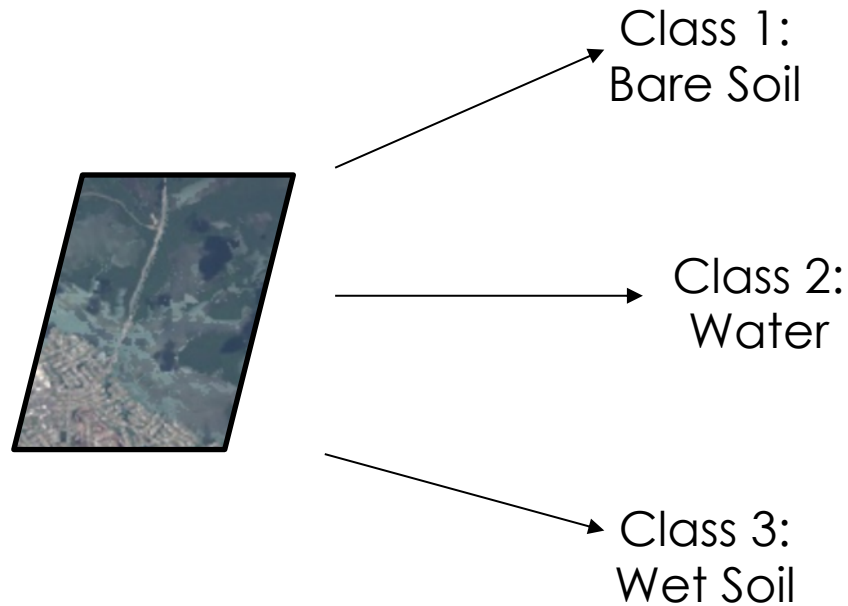




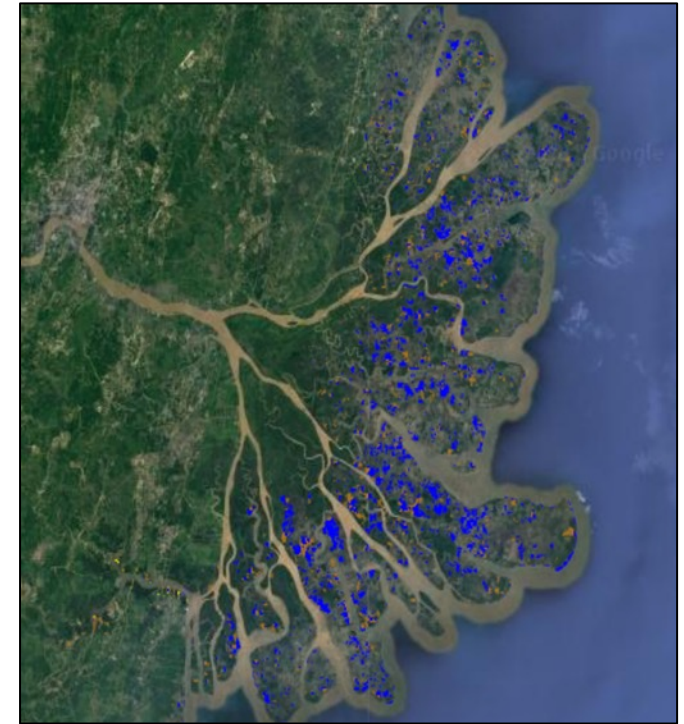
Random Forest Land Cover Change Classification



Training Data:
Landsat 7,8 imagery in
classified regions



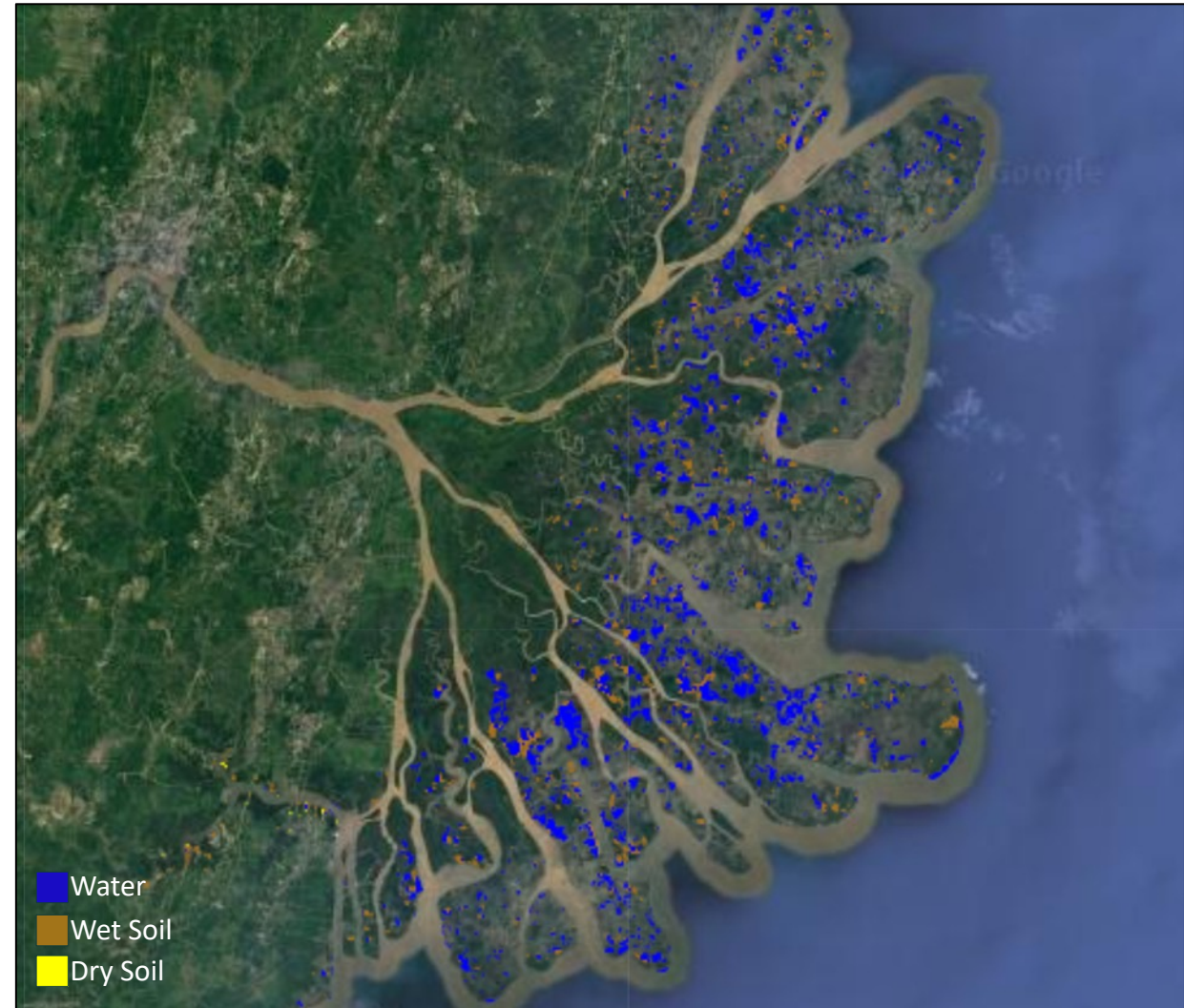
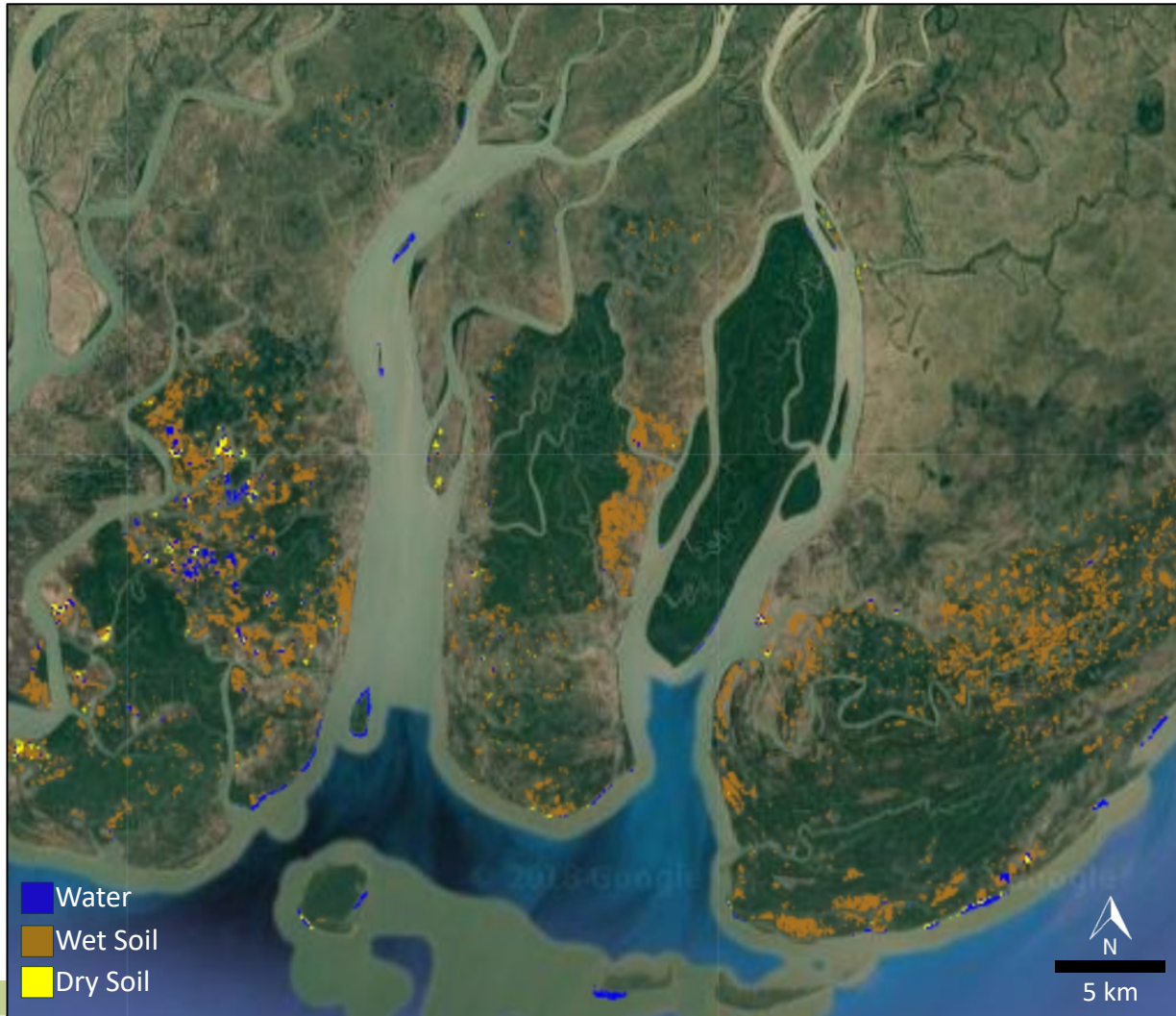
RF Classification:
Landsat 7,8 imagery in
all mangrove loss
regions



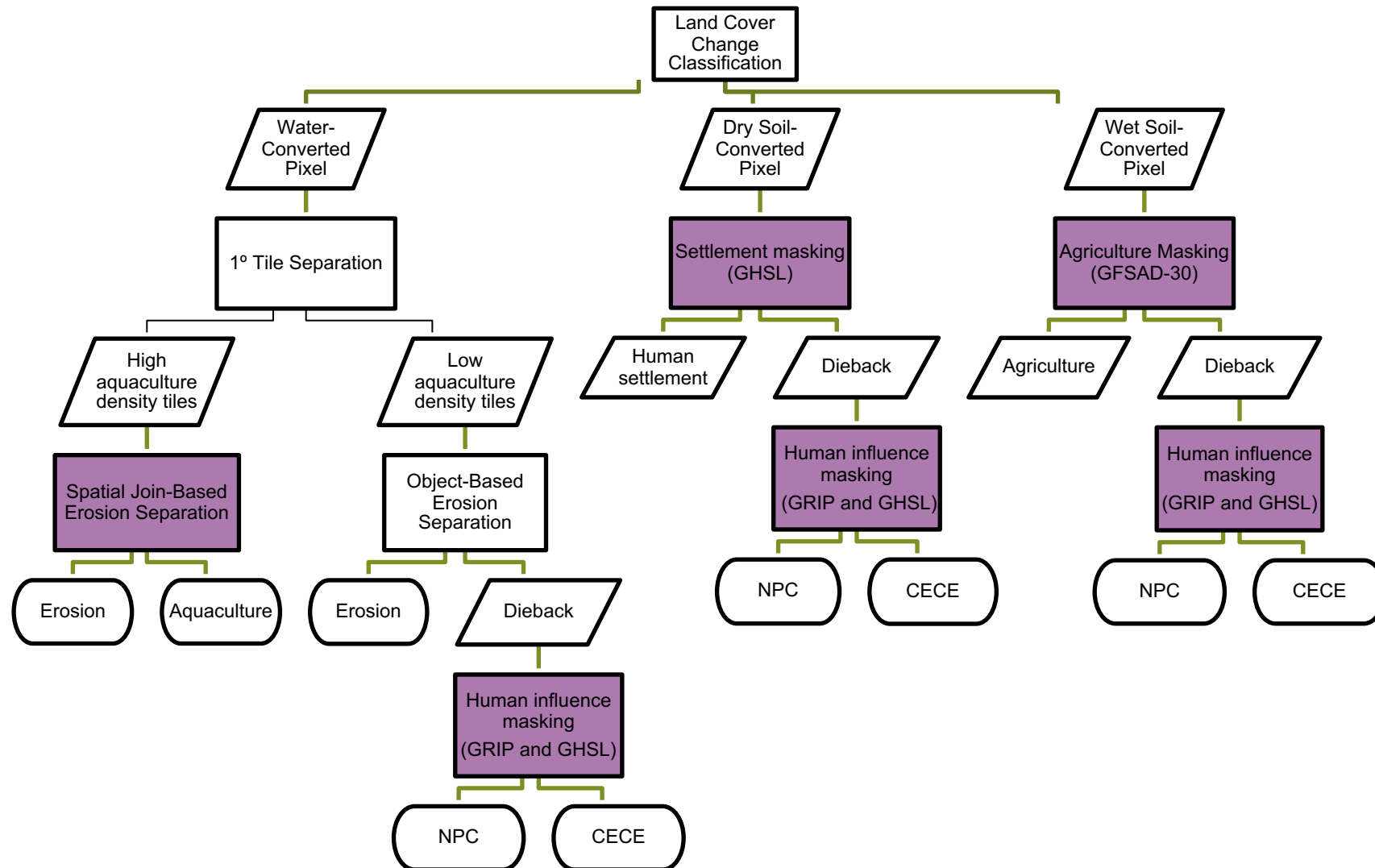
**Land Cover Change
Classification**



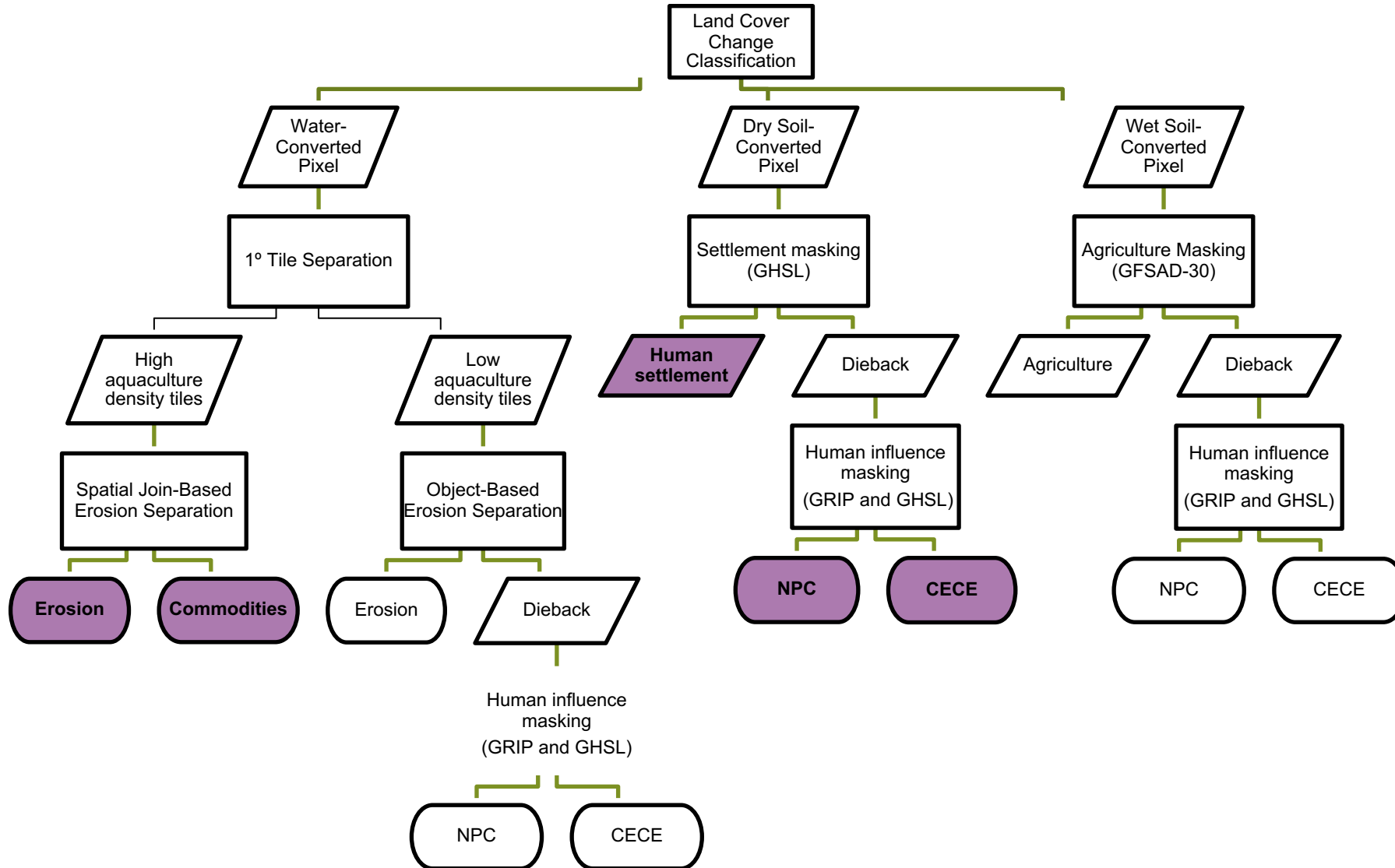
Random Forest Land Cover Change Classification



Land Uses Change Decision Trees

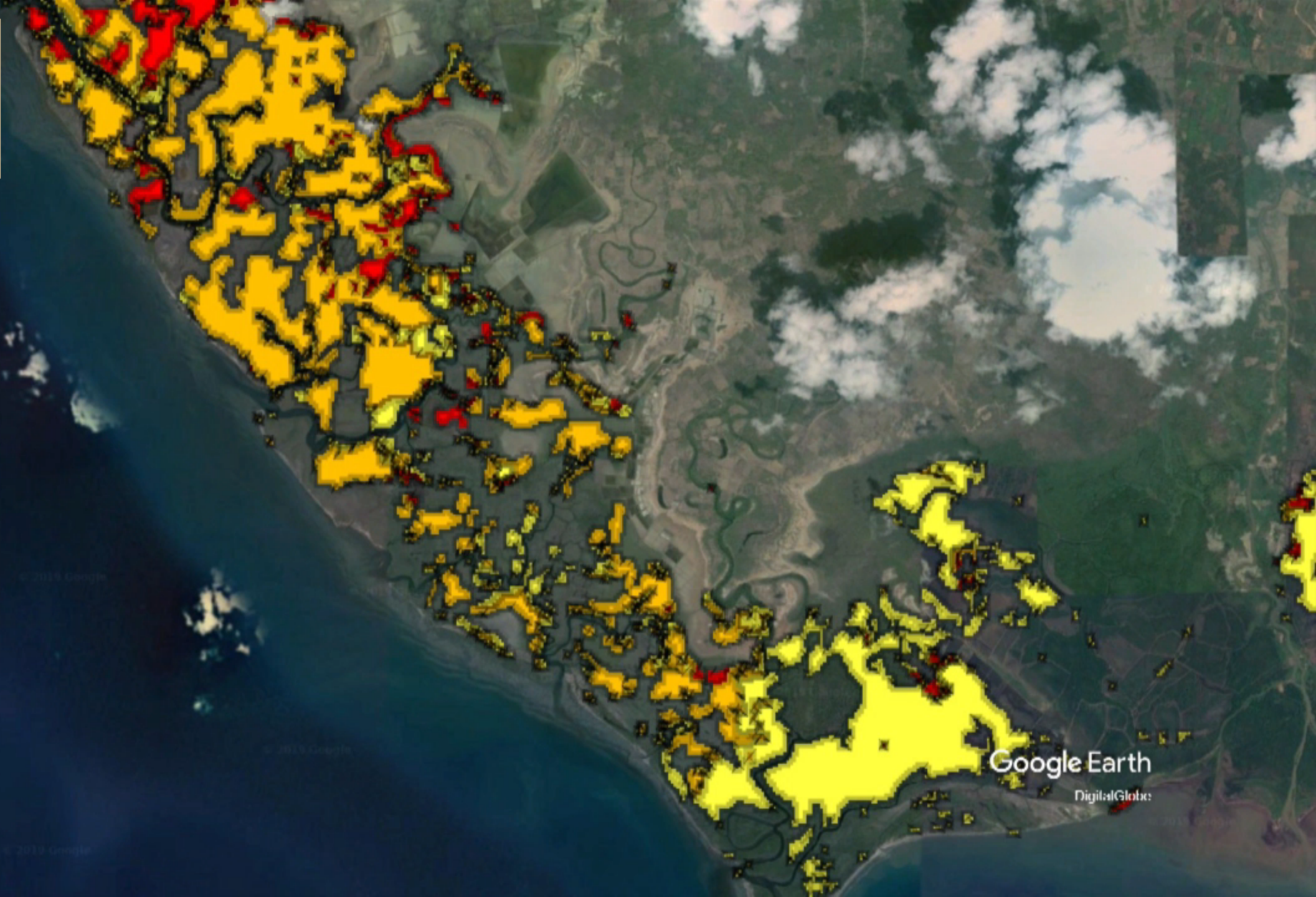


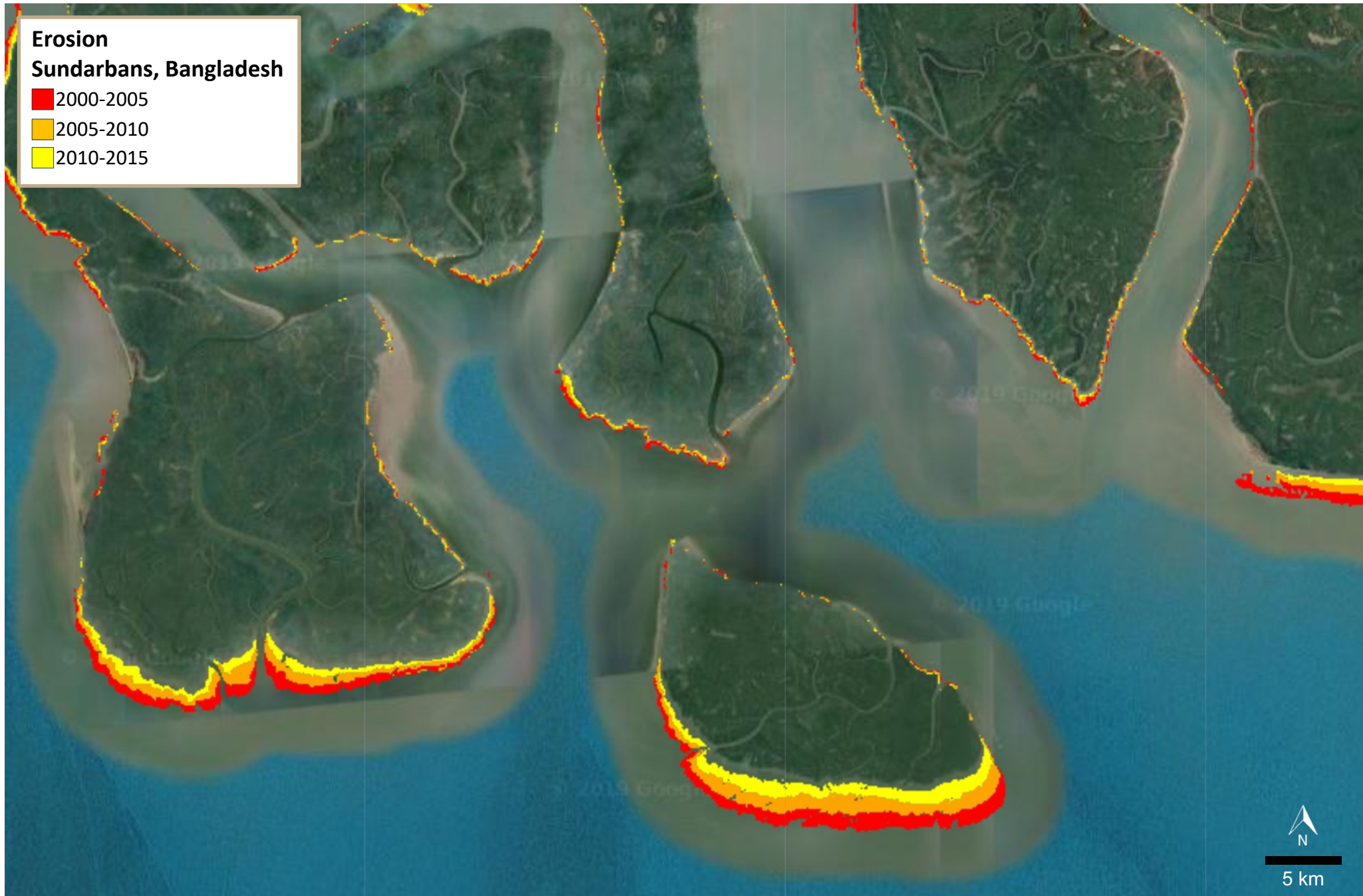
Land Uses Change Decision Trees



**Commodities, 27%
Sulawesi, Indonesia**

- 2000-2005
- 2005-2010
- 2010-2015





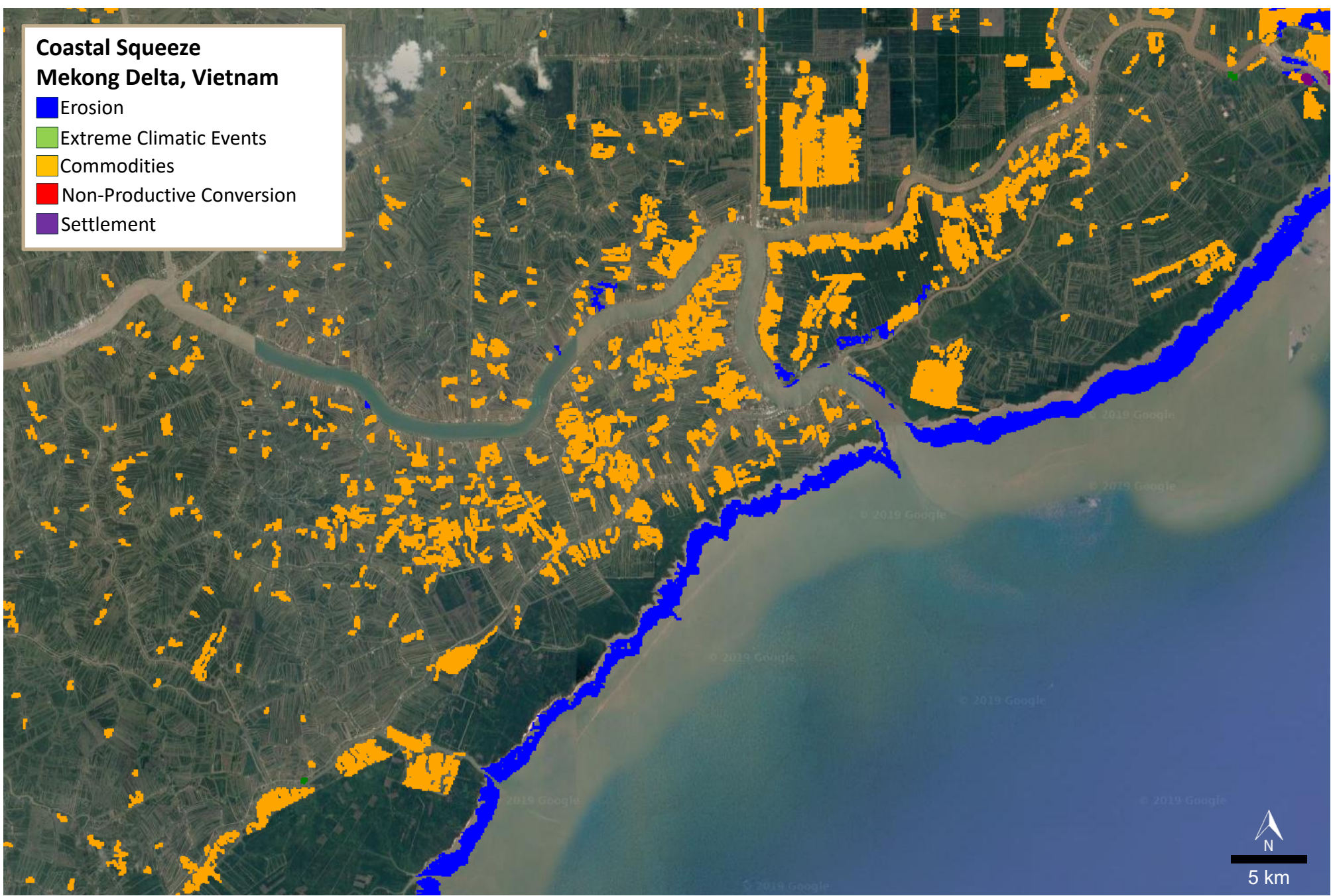
Erosion
Sundarbans, Bangladesh

- 2000-2005
- 2005-2010
- 2010-2015

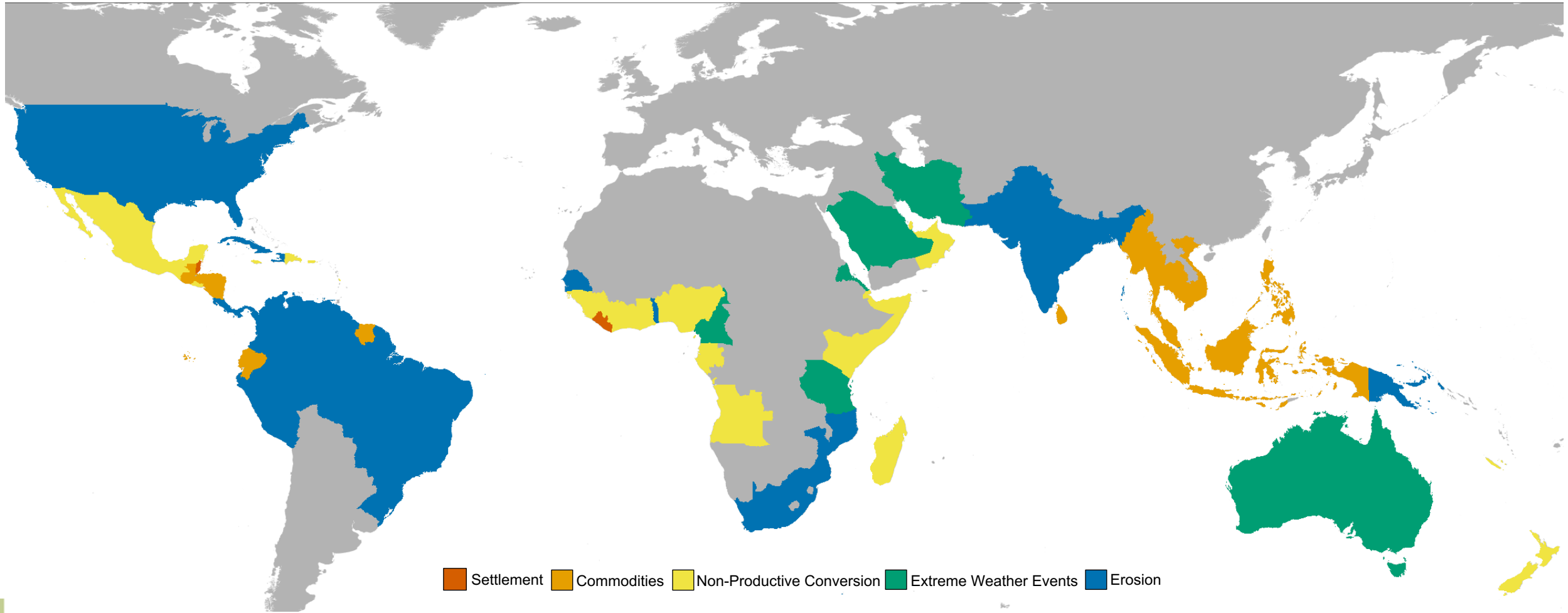


Coastal Squeeze Mekong Delta, Vietnam

- Erosion
- Extreme Climatic Events
- Commodities
- Non-Productive Conversion
- Settlement



National Loss Driver Trends – 2000-2016



■ Settlement ■ Commodities ■ Non-Productive Conversion ■ Extreme Weather Events ■ Erosion



National Loss Driver Trends – 2000-2016

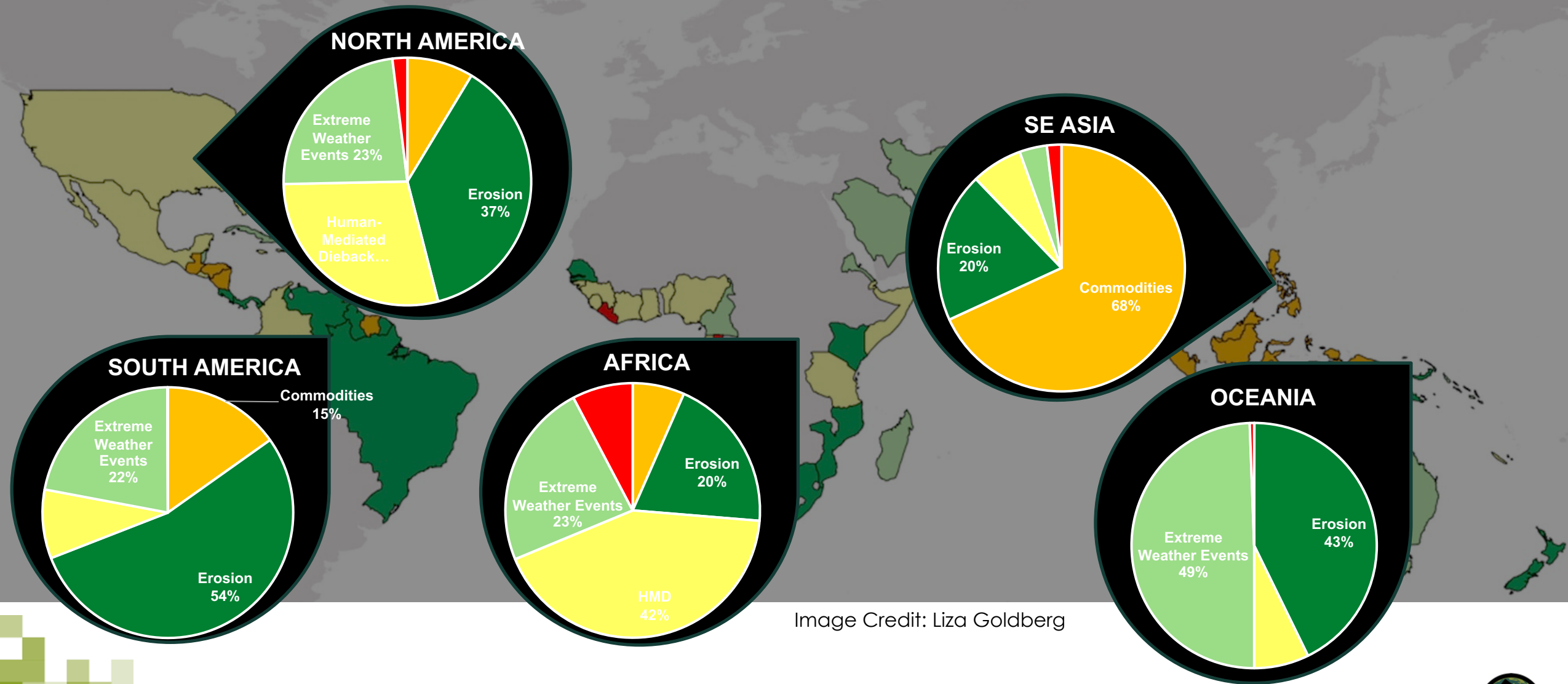


Image Credit: Liza Goldberg



National Loss Driver Trends – 2000-2016

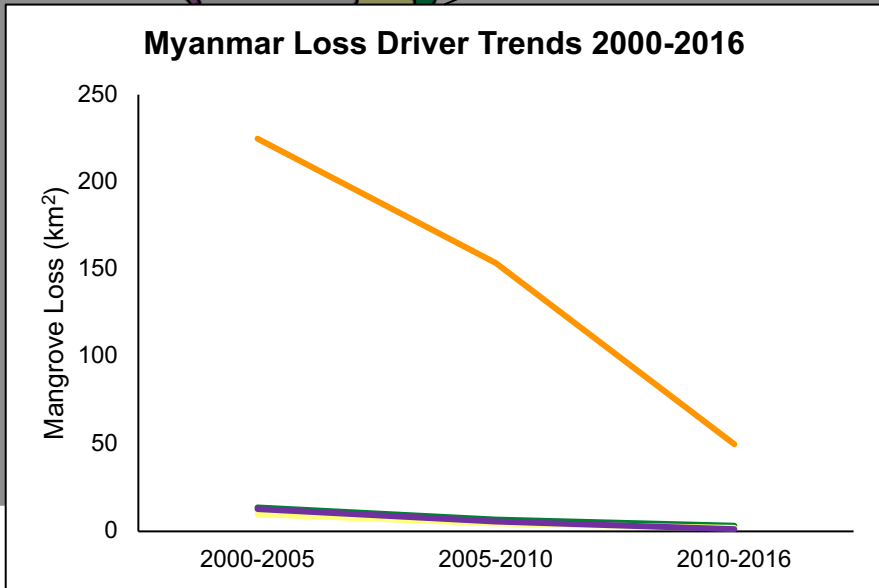
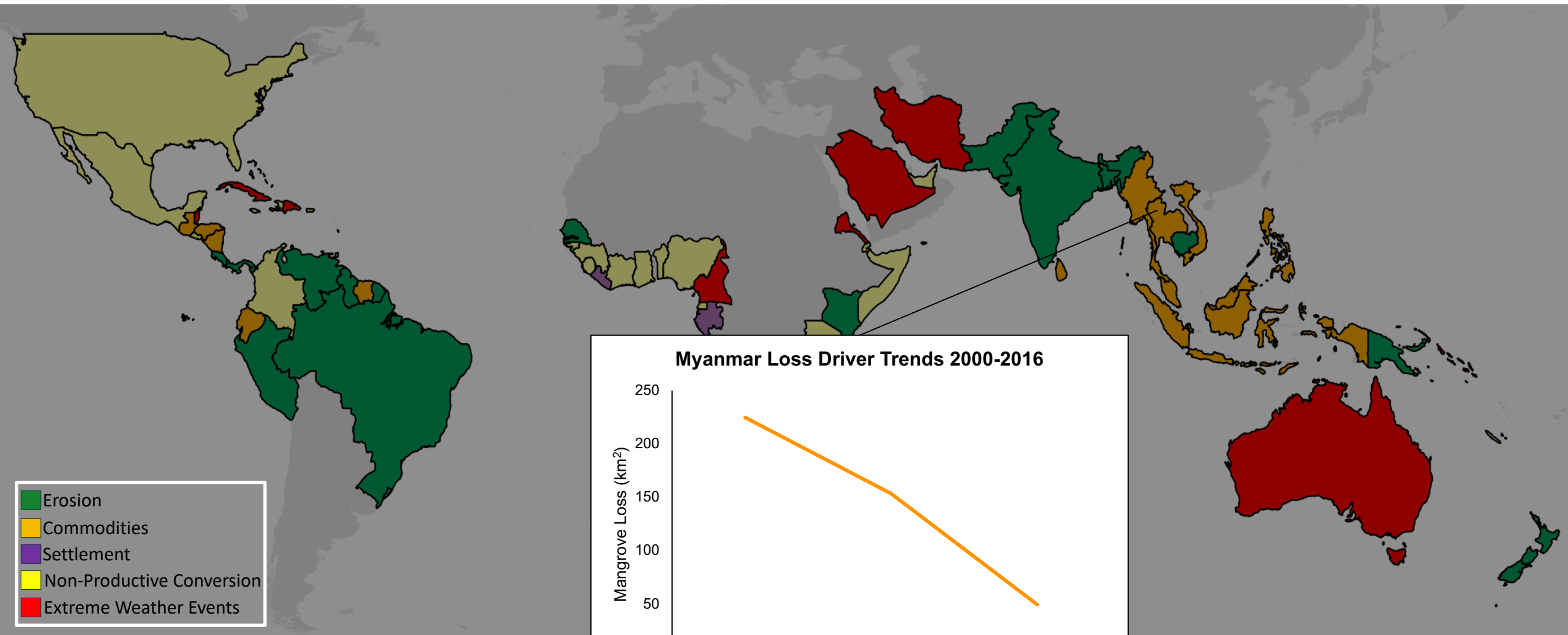


Image Credit: Liza Goldberg

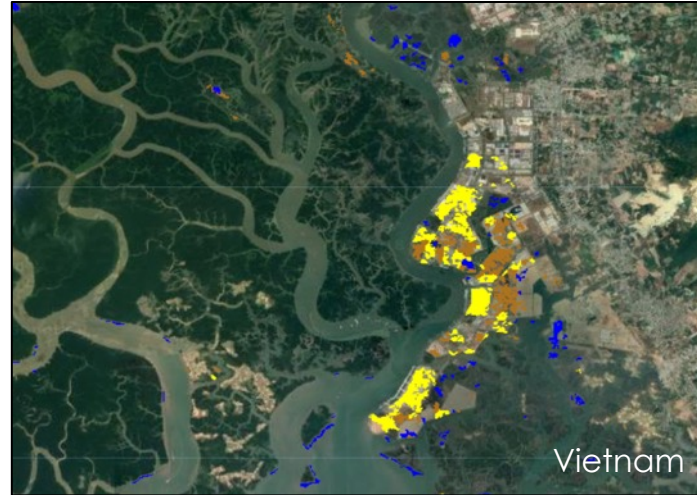


Towards Global Mangrove Vulnerability Assessment

Losses and Gains



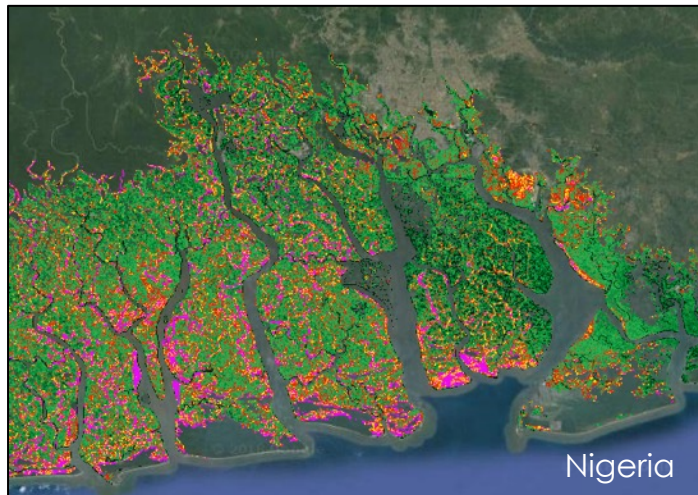
Land Cover Change



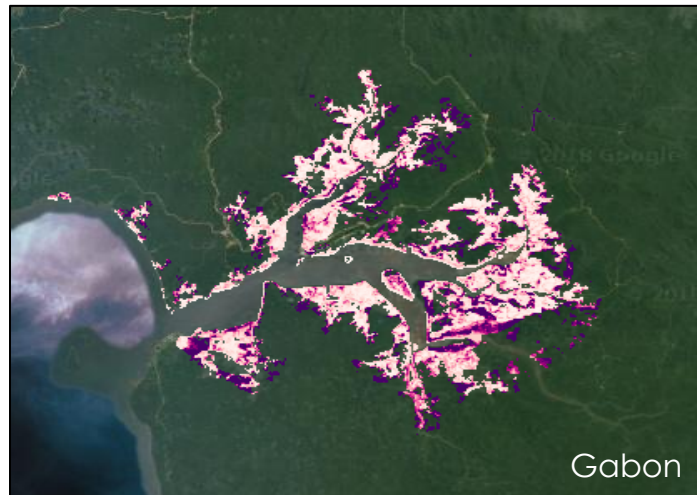
Loss Drivers



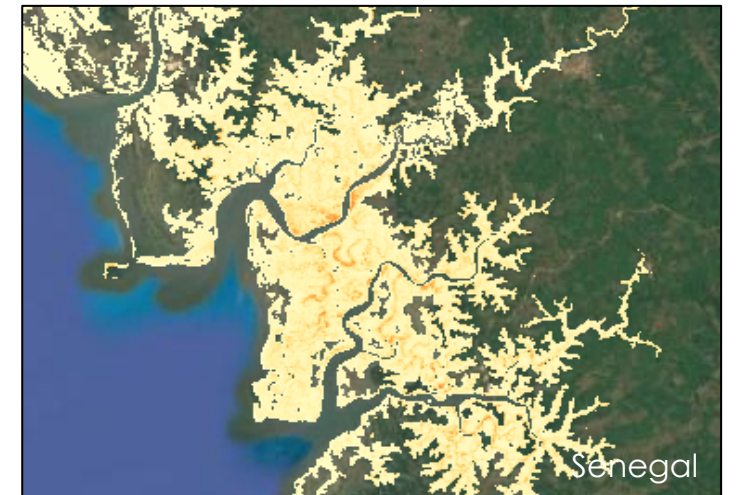
Canopy Height



Aboveground Biomass

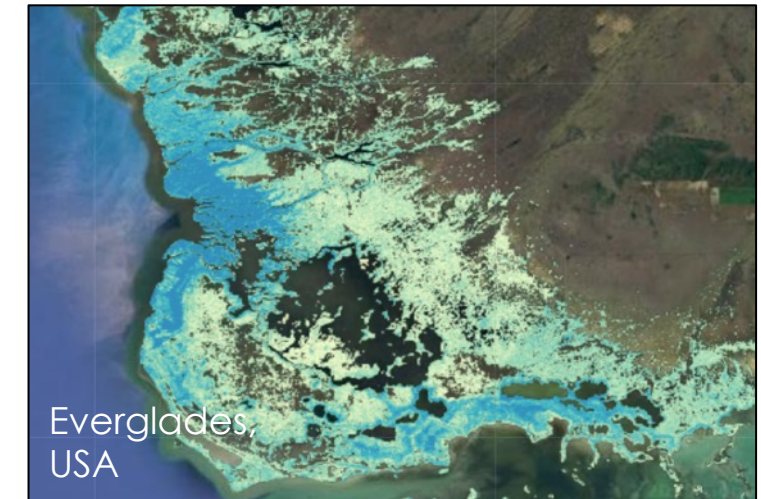
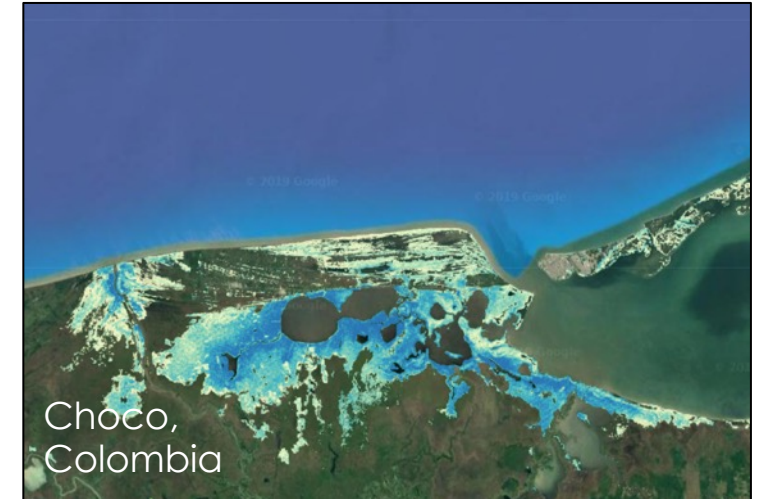
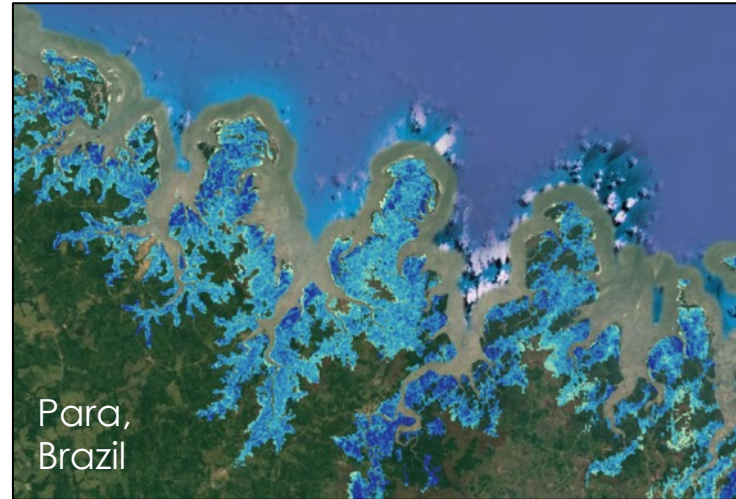


Carbon

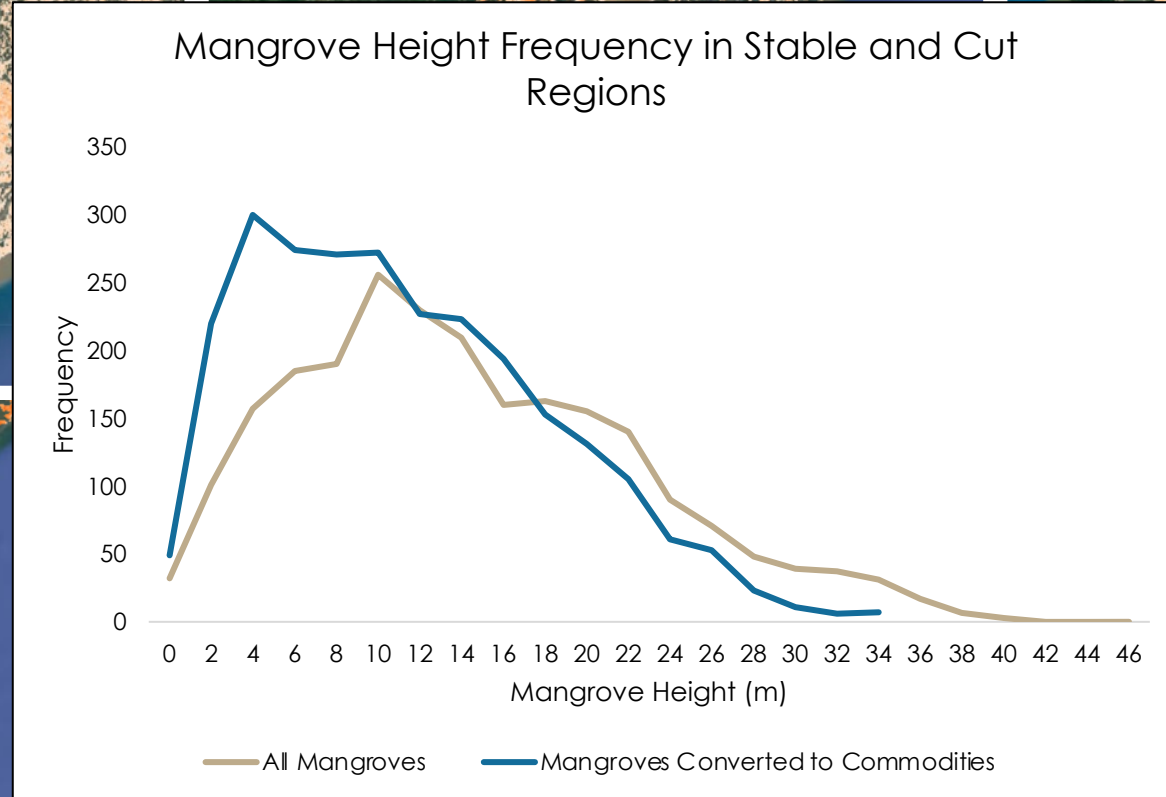
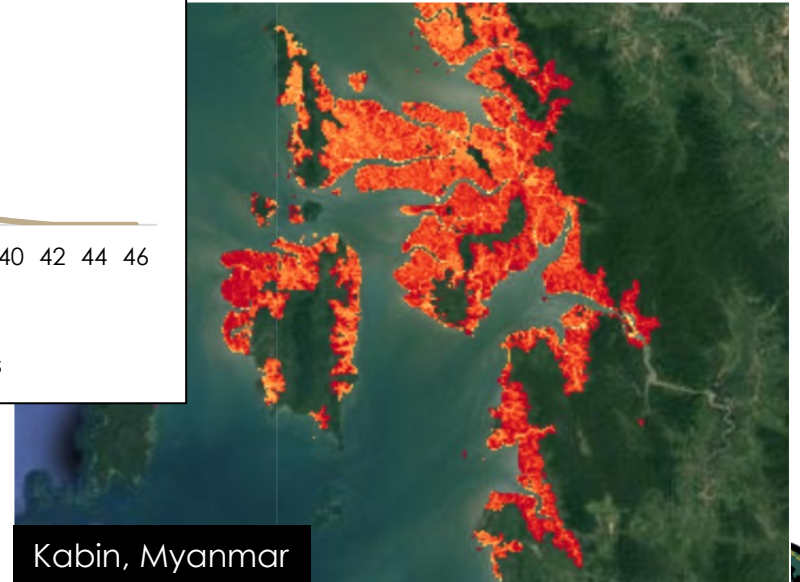
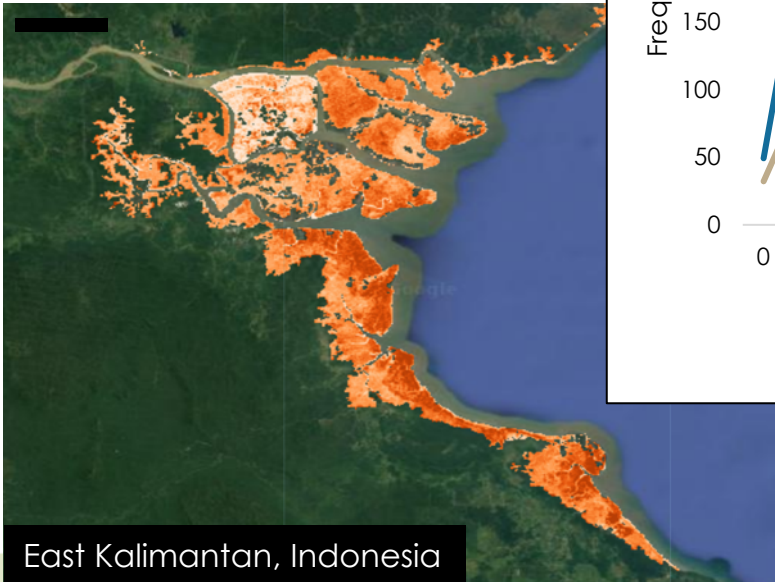
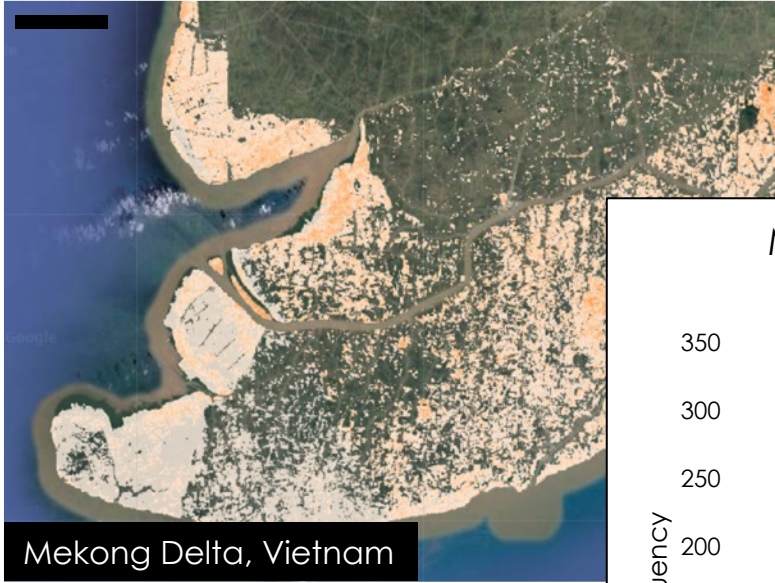


Global Mangrove Height and Biomass for 2000

Simard et al. 2019



Mangrove Height Trends in Commodities-Converted Regions





Communicating Results With GEE Apps

Communicating Results: SDG 6 Apps

- Google Earth Engine is useful for communicating results
- Allows global users to track their progress and measure mangrove extent/biomass
- Offers results that can be reported as SDG indicators



<https://mangrovescience.earthengine.app/view/mangroveheightandbiomass>

Earth Engine Apps **Experimental** Search places

Global Mangrove Height & Biomass Explorer

This tool maps global mangrove canopy height and biomass results from Simard et al. 2018. The data can be downloaded at https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1665

Select a map layer.
Canopy Height (Hmax)

Select a metric to compute by country.
Total Carbon

Country	Total_Carbon
Colombia	75,973,344
Costa Rica	13,998,836
Panama	58,979,743
..	

Clear results Display results as chart

Select a metric to compute by country.
Maximum Canopy Height

Maximum Height Comparison

Country	Max_Height
Colombia	~54.5
Costa Rica	~46.5
Panama	~51.5

Clear results Display results as table

SRTM Canopy Height

- 0 m
- 5 m
- 10 m
- 15 m
- 20 m
- 25 m
- 30 m
- 35 m
- 40 m
- 45 m
- 50 m
- 55 m
- 60 m

Map data ©2019 Google Imagery ©2019 TerraMetrics | 20 km | Terms of Use

Here we can provide SDG relevant results as table or bar chart.



Mangrove Loss Drivers

Global Mangrove Loss Drivers

This app maps the global extent of mangrove loss from 2000-2016, the epoch in which the loss occurred, the land cover change that resulted, and the ultimate driver of the loss.

See [Goldberg et al. 2020](#) for more information.

Select the map layer to view.

Epoch of Loss ▾

- 2000-2005
- 2005-2010
- 2010-2015

Select a global loss driver hotspot location.

Sundarbans, Bangladesh ▾

Observe the progression of sea level rise during each epoch as it encroaches on the seaward edge of Sundarbans National Park, a global hotspot of erosion.



<https://mangrovescience.earthengine.app/view/global-mangrove-loss-drivers>



Delta Mangrove Cover Change, Height, & Biomass

Delta Mangrove Cover Change, Canopy Height & Biomass Explorer

Results from analysis of Landsat images characterizing mangrove forest extent, canopy height, and vegetation carbon change.

For more information

Environmental Research Letters paper by Lagomasino, Fatoyinbo, Lee et al. 2018

View Mangrove Layers

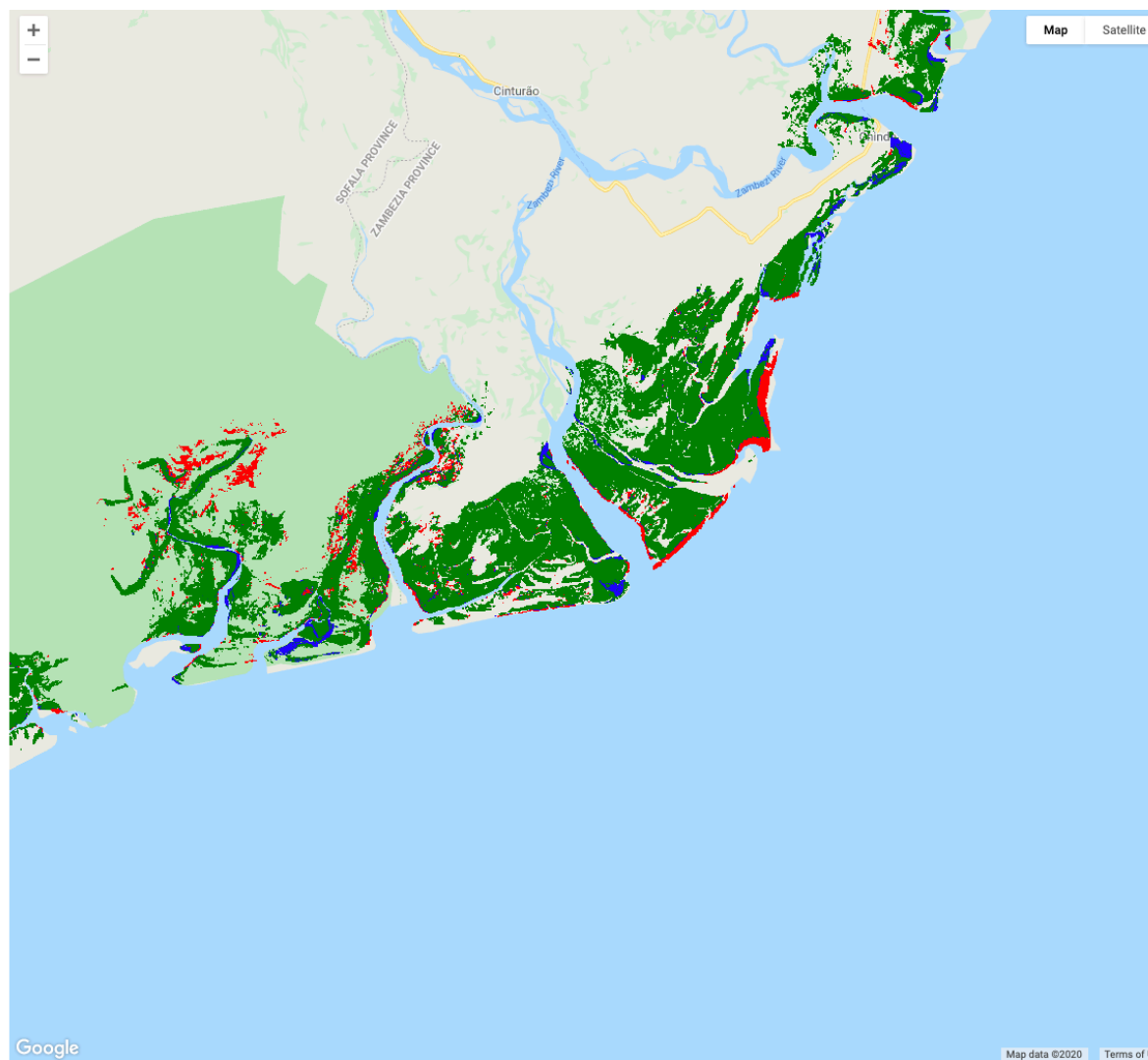
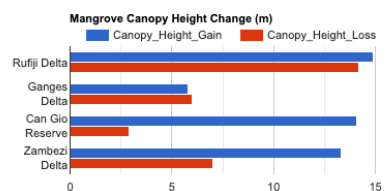
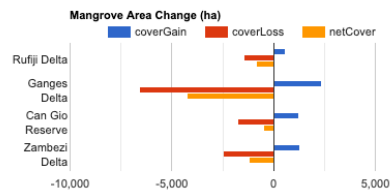
Mangrove Cover Change

- Legend**
- Continuous Exent
 - Gain
 - Loss

Opacity 1

Explore Each of the Study Sites

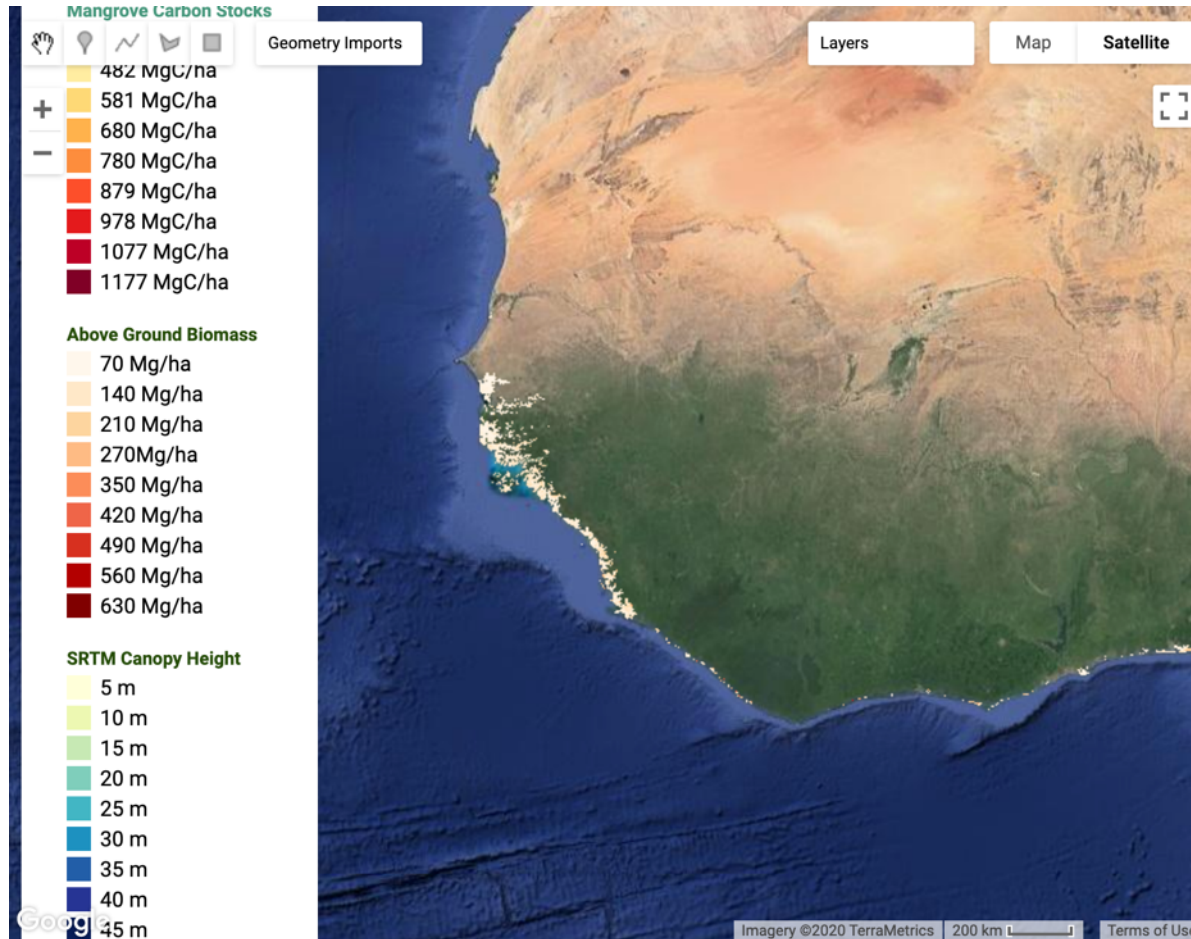
Zambezi Delta



<https://mangrovescience.earthengine.app/view/mangrovedeltas>



Global Mangrove Height and Biomass



Global Mangrove Height & Biomass Explorer

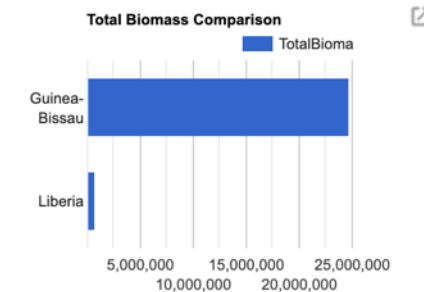
This tool maps global mangrove canopy height and biomass results from Simard et al. 2018. The data can be downloaded at https://daac.ornl.gov/cgi-bin/dsviewer.pl?ds_id=1665

Select a map layer.

Biomass (AGB) ▾

Select a metric to compute by country.

Total Aboveground Biomass ▾



<https://mangrovescience.earthengine.app/view/mangroveheightandbiomass>



Random Forest Classification

Random Forest Mangrove Mapping Tool

Use this tool to add training features to a random forest model and map mangrove extent for your region of interest in 1990, 2000, 2010, and 2020.

Instructions:

- 1) Choose the year of interest from the dropdown menu below.
- 2) Navigate to your region of interest and add a polygon to the "ROI" geometry.
- 3) Use the drawing tools to add training points and polygons to both the Mangrove and NonMangrove feature collections.
- 4) Click "Run Model" to run a Random Forest Classification.

This tool will map the unaltered results of the model, as well as the results clipped to within 1 km of the Global Mangrove Watch mangrove extent map.

Tips:

Use the landsat imagery displayed to create training points. The landsat imagery displays a false-color composite using the Red, NIR, and SWIR bands. Change the opacity of this layer in conjunction with the Google Map satellite layer to identify vegetation from other landcover types.

Adding more training data will yield a better model. If you notice an error, you may need to add more training data.

Please be patient as results are loaded.

Choose a Year:

2000

Run Model

SUSTAINABLE DEVELOPMENT GOALS NASA Goddard Space Flight Center

Google Imagery ©2020 NASA, TerraMetrics 200 km Terms of Use

<https://mangrovescience.earthengine.app/view/randomforest>



Mangrove Dataset Workflow

Mangrove Dataset Workflow

Use this workflow to filter data requirements.

1) Select 1st priority:

Select a value... ▾

Choose

Select a value... ▾

2) Select 2nd priority:

Select a value... ▾

Choose

Select a value... ▾

3) Select 3rd priority:

Select a value... ▾

Choose

Select a value... ▾

4) Select 4th priority:

Select a value... ▾

Choose

Select a value... ▾

Apply Filters

Click Reset to Choose New Parameters

Reset Map

Legend

- Atwood et al. 2017
- Bunting et al. 2019
- CIFOR 2016
- Giri et al. 2011
- Hamilton and Casey 2016
- Hutchinson et al. 2014
- Jardine and Siikamaki 2014
- Rovai et al. 2018
- Sanderman et al. 2018
- Simard et al. 2019

Map data ©2020 Google, INEGI 100 km

<https://mangrovescience.earthengine.app/view/mangroveworkflow>



Questions

- Please enter your questions into the Q&A box.
- We will post the questions and answers to the training website following the conclusion of the course.



Contacts

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Thank You!

