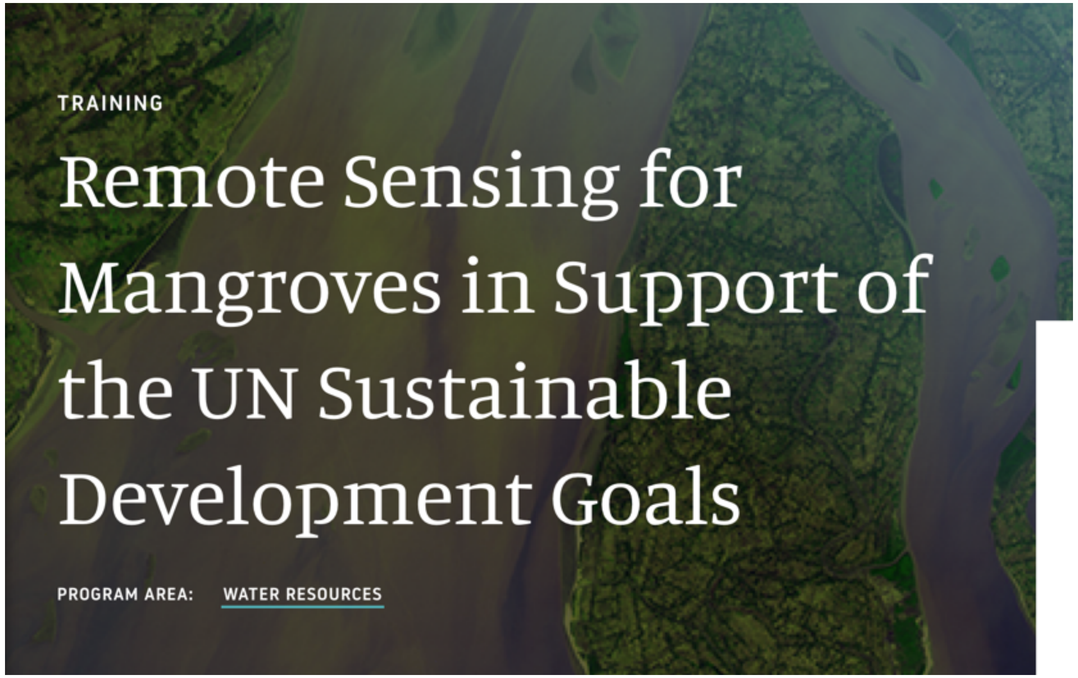
Part 1: Intro to SDG 6.6 and Remote Sensing Techniques for Mangroves

Abigail Barenblitt & Temilola Fatoyinbo

Nov 5th, 2020

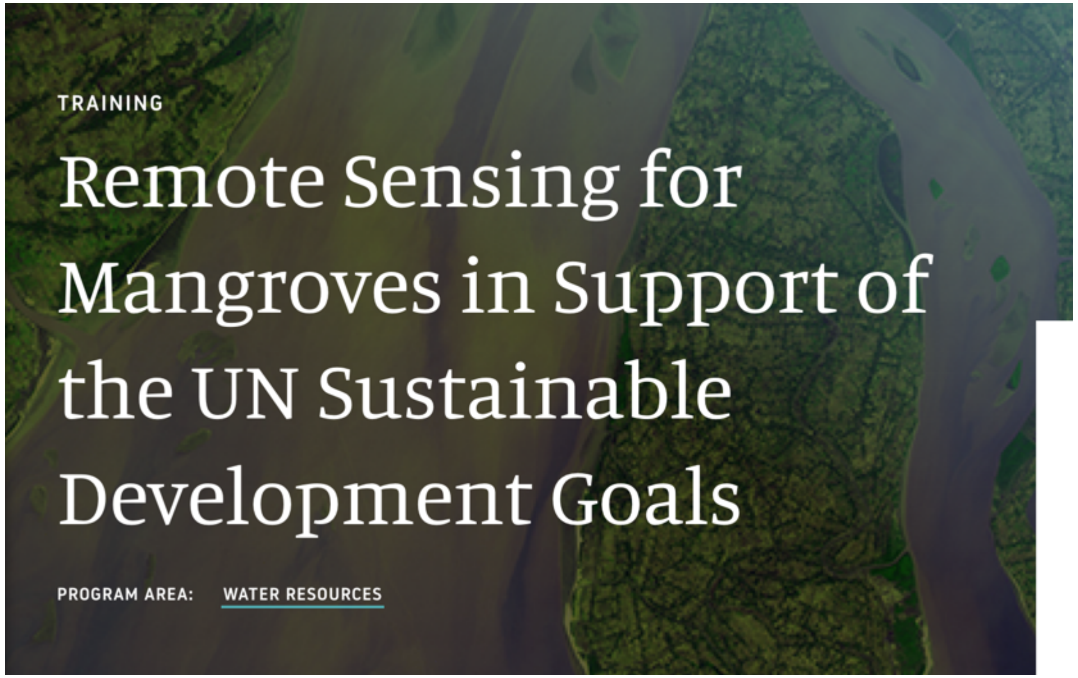
Course Structure and Materials

- 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

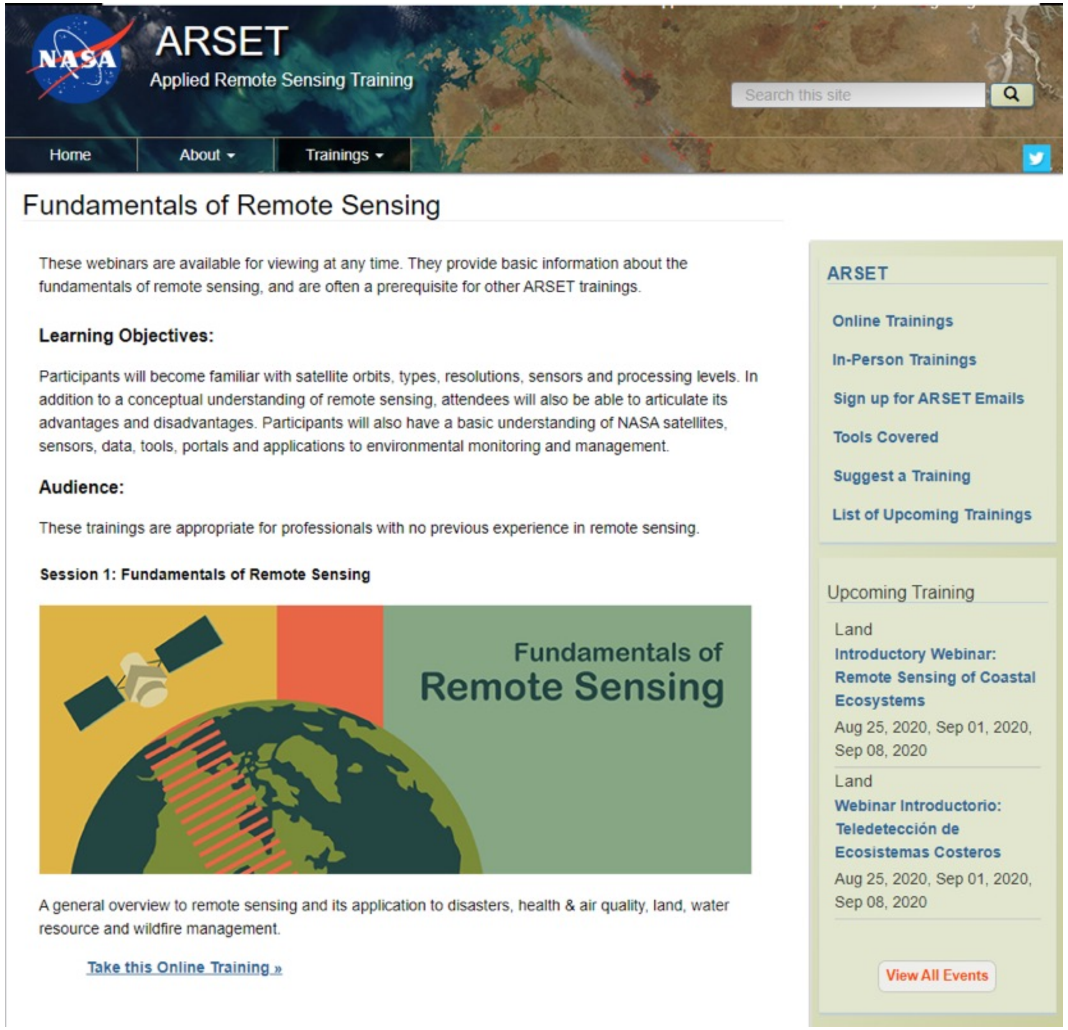
- **Certificate of Completion:**
  - Attend all three live webinars
  - Complete the homework assignments by the deadline (access from ARSET website)
  - You will receive certificates approximately two months after the completion of the course from: marines.martins@ssaihq.com

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



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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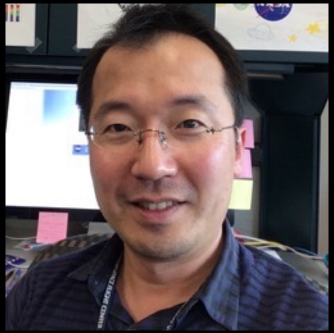
Celio Souza


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

Image Credit: NASA

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.

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.

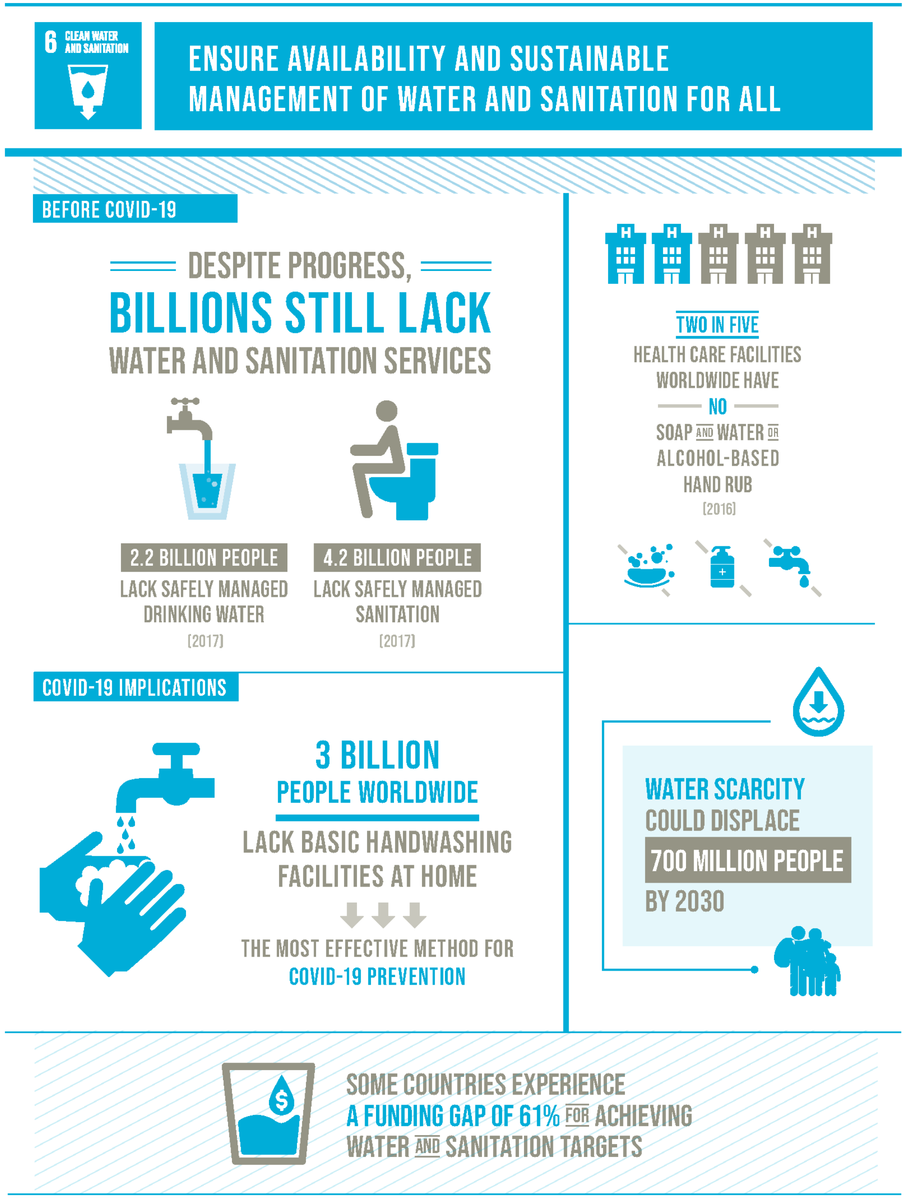


Image Credit: United Nations

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

UN environment
United Nations Environment Programme

UN HABITAT
FOR A BETTER URBAN FUTURE

unicef

UNECE

Food and Agriculture Organization of the United Nations

UNESCO
United Nations Educational, Scientific and Cultural Organization

World Health Organization

WMO

With support from:

SWEDEN

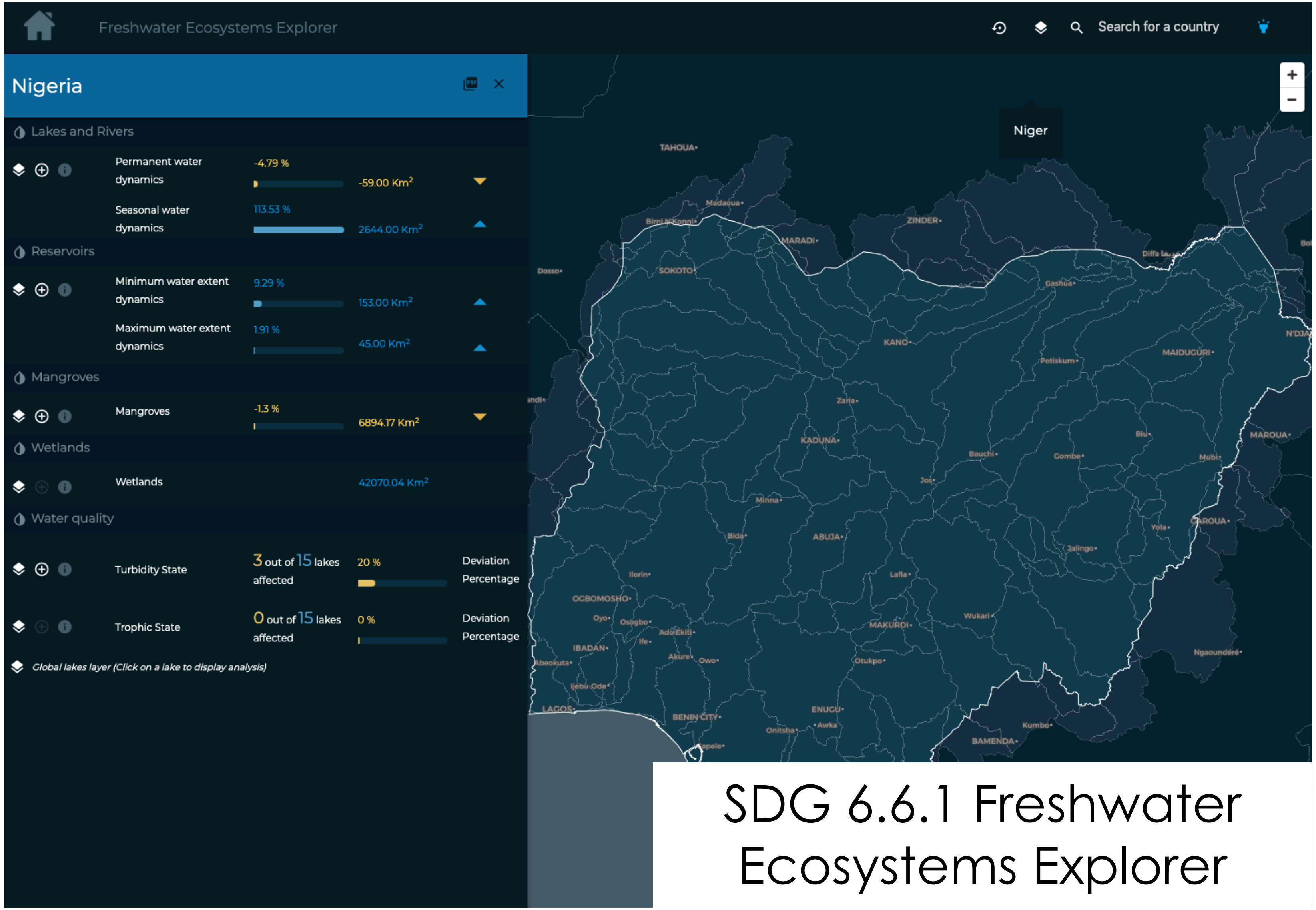
Schweizerische Eidgenossenschaft
Confédération suisse
Confederazione Svizzera
Confederaziun svizra

Swiss Agency for Development and Cooperation SDC

Federal Ministry for Economic Cooperation and Development

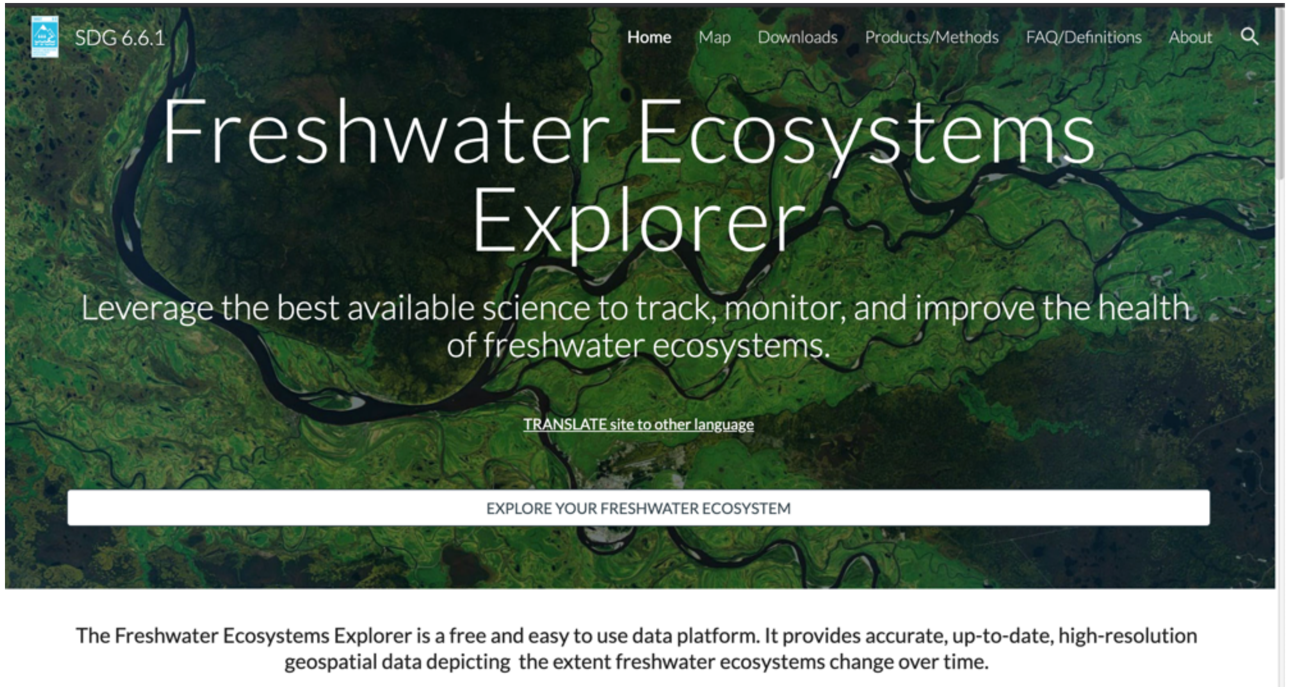
Ministry of Infrastructure and the Environment

UN WATER



SDG 6.6.1 Freshwater Ecosystems Explorer

https://www.sdg661.app/



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+ scheme[1] (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 and 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

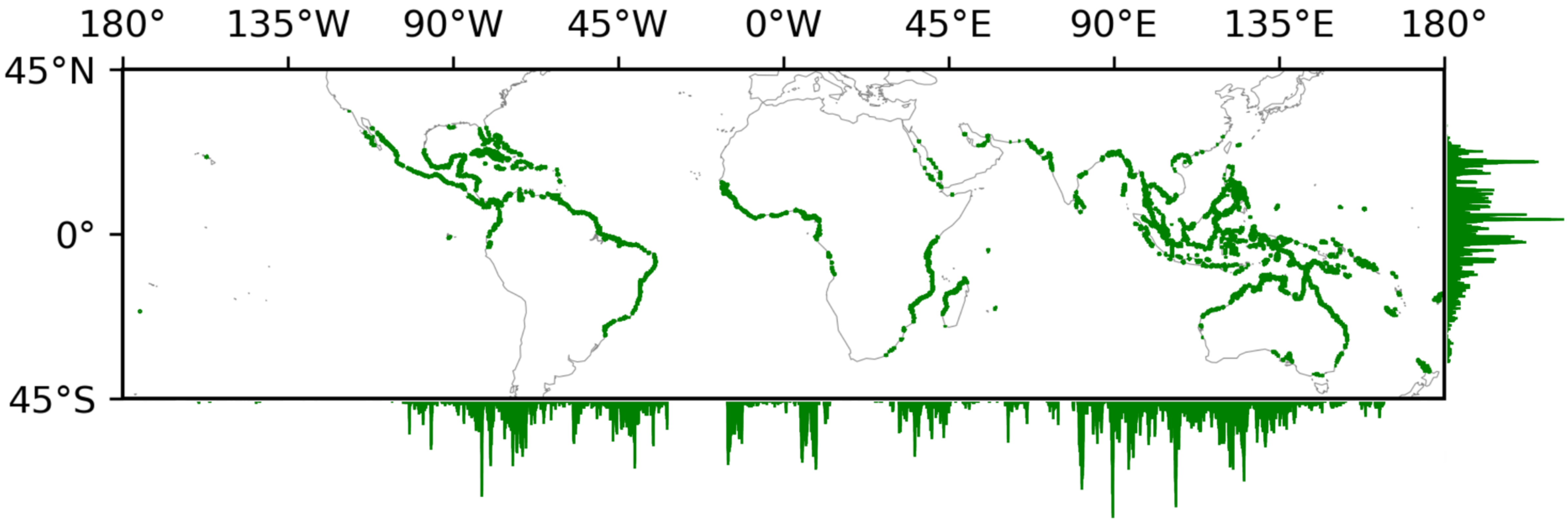
- SDG 1: No Poverty
- SDG 2: Zero Hunger
- SDG 8: Decent Work and Economic Growth
- SDG 12: Responsible Consumption and Production
- SDG 13: Climate Action
- SDG 14 : Life Below Water
- SDG 15: Life on Land

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.

Image Credit: NASA

Remote Sensing of Mangroves

Remotely Sensing Mangroves

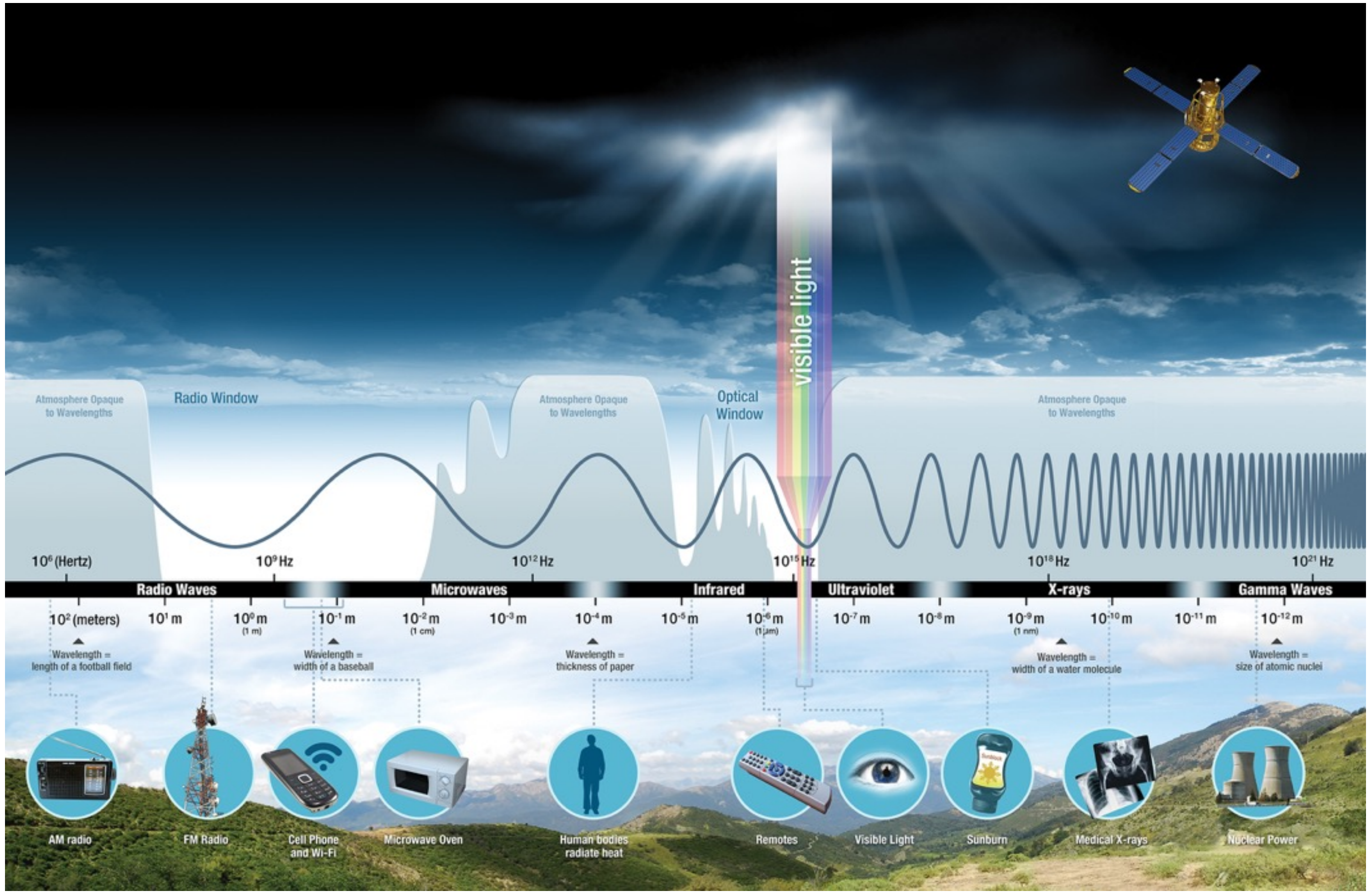
- We can measure extent, change height, biomass, and carbon stock using:
  - Passive Optical
  - Synthetic Aperture Radar
  - LiDAR

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

Passive Optical

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

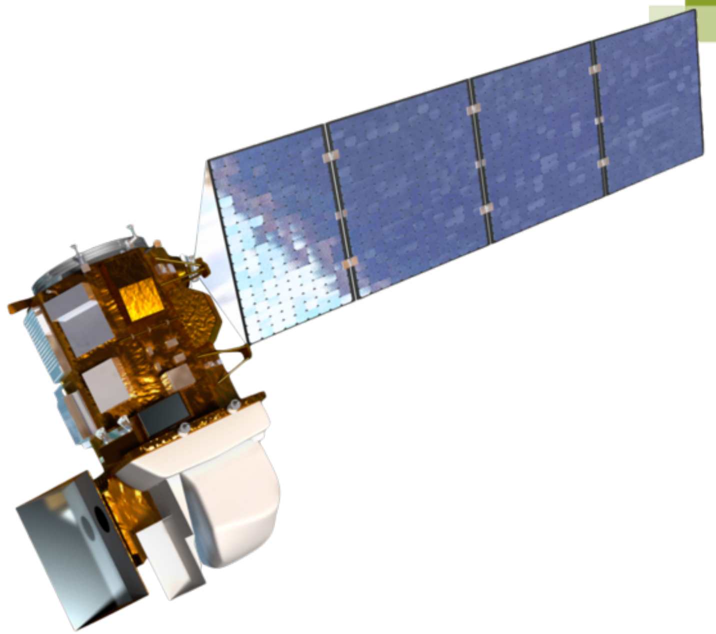
$$NDVI = \frac{(NIR - VIS)}{(NIR + VIS)}$$



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

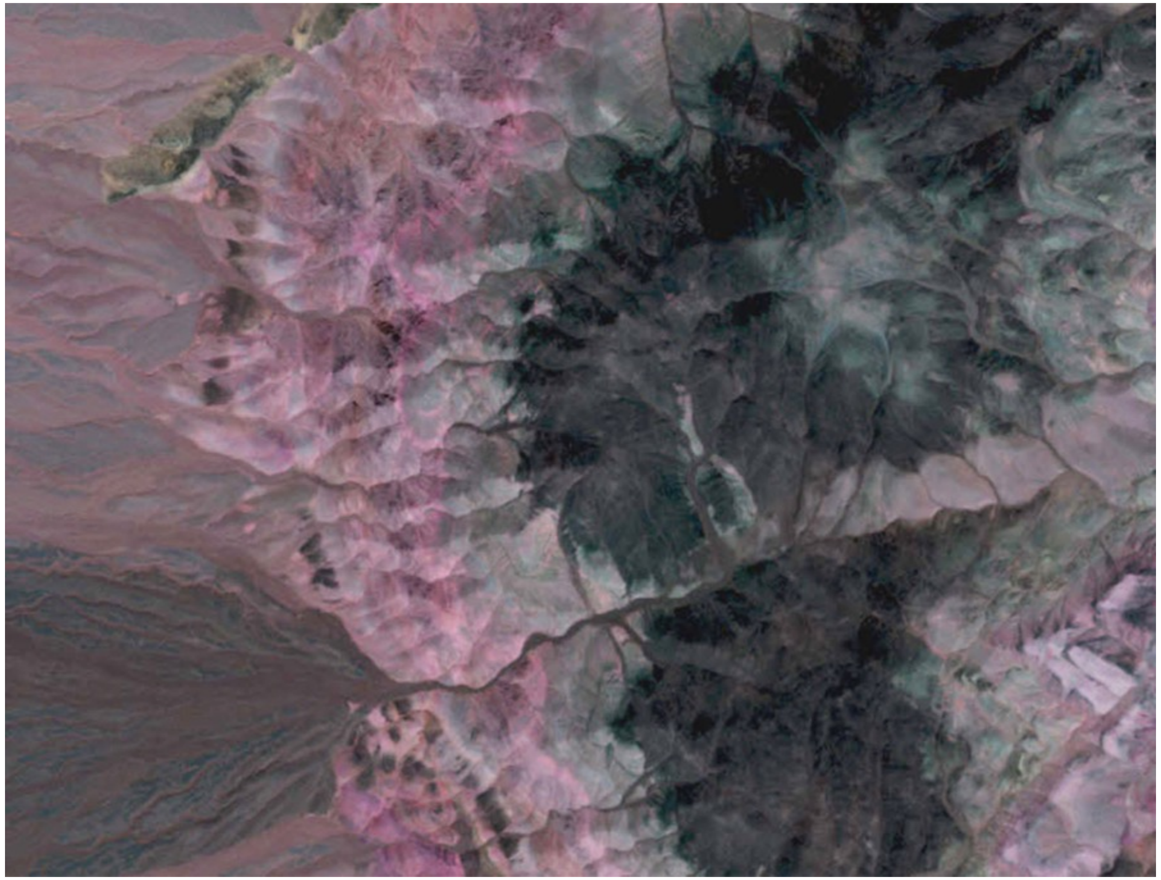


Image Credit: Digital Globe

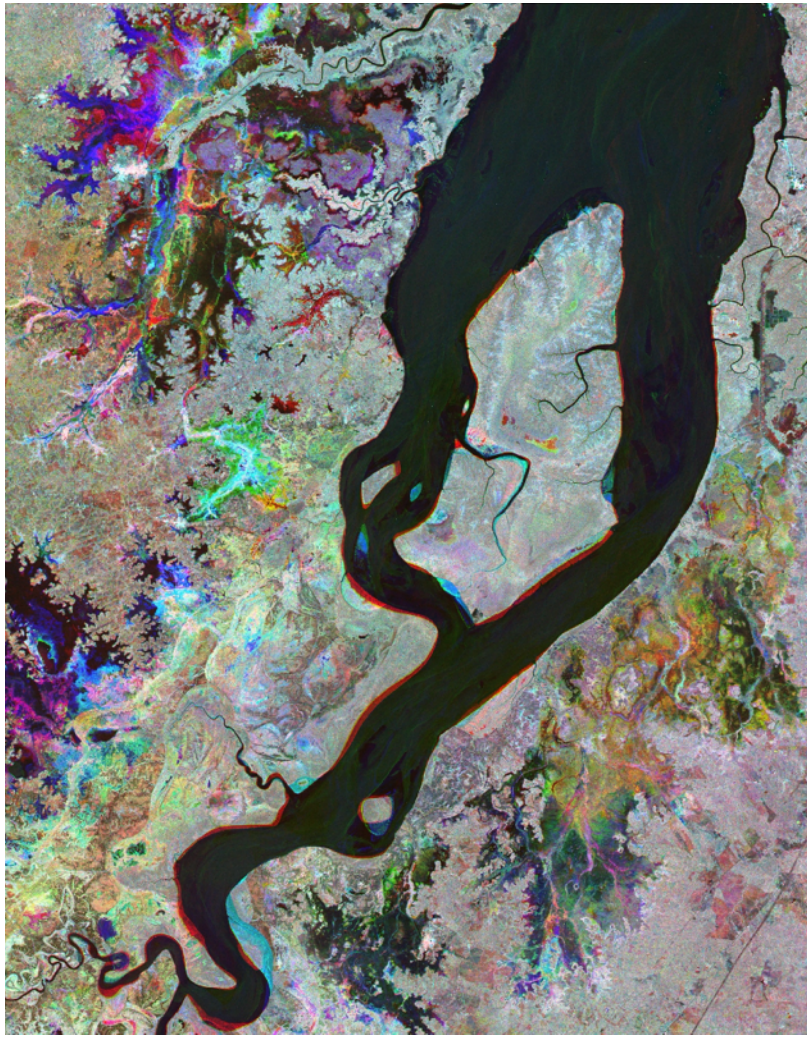
Synthetic Aperture Radar

- 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

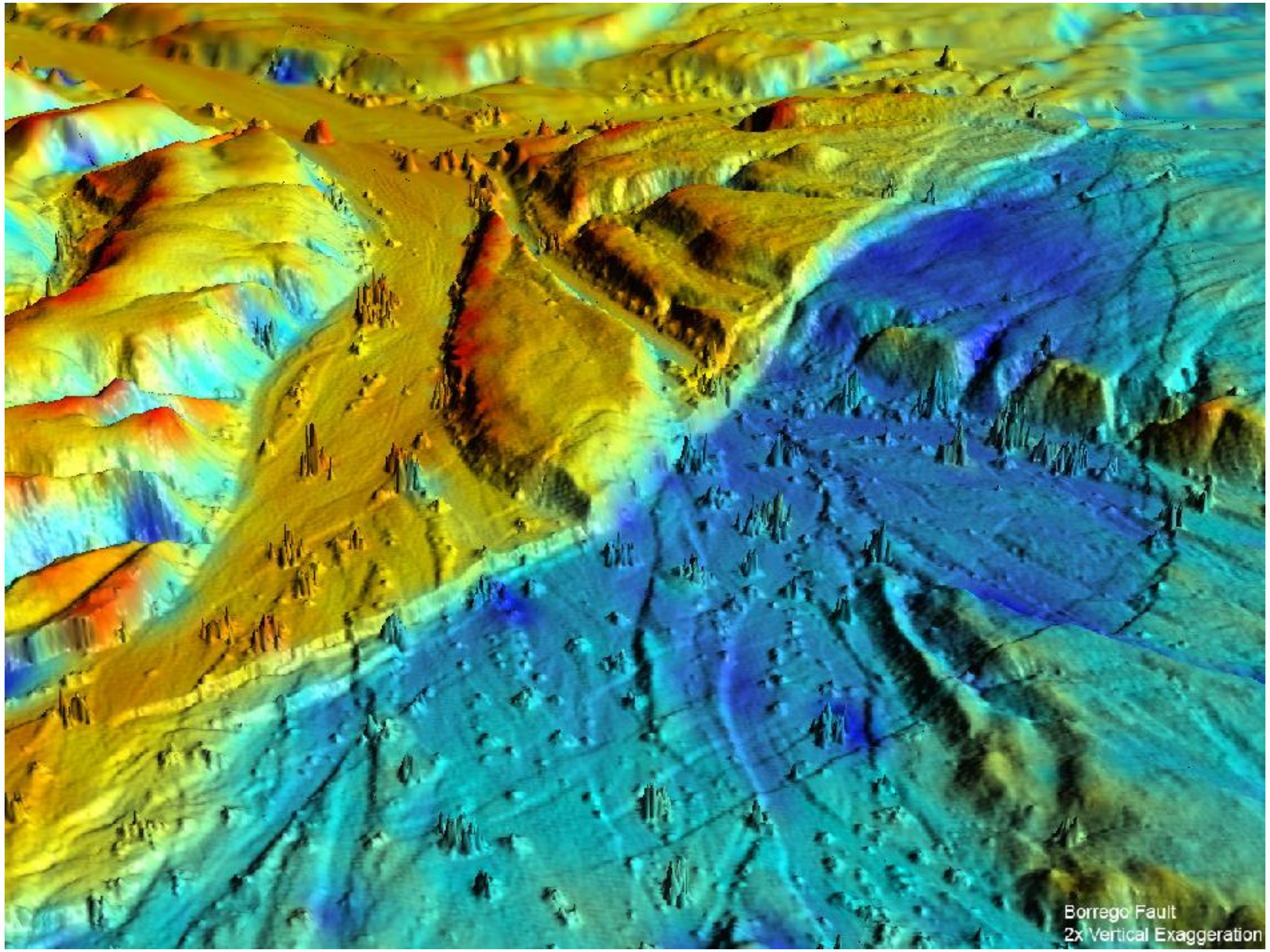
- Senses water volume in vegetation
- Can be used to estimates forest biomass from backscatter
- Can be used to measure topography, changes in elevation and canopy height
- Can be used to improve Land cover extent maps, particularly water related ecosystems and flooded forests.



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



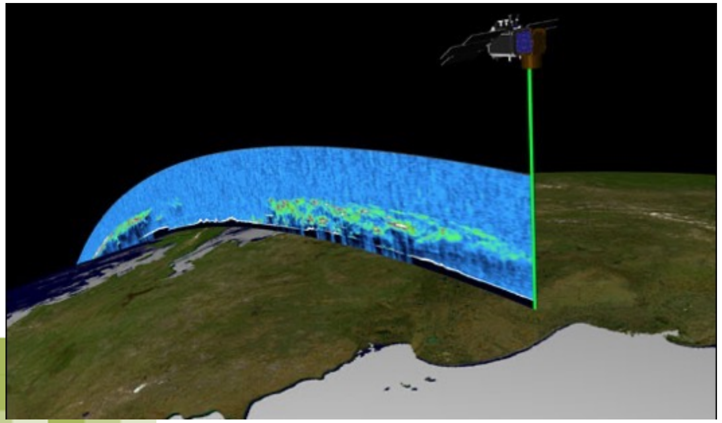
3D visualization of Borrego Fault, Image Credit: NASA

Example Research

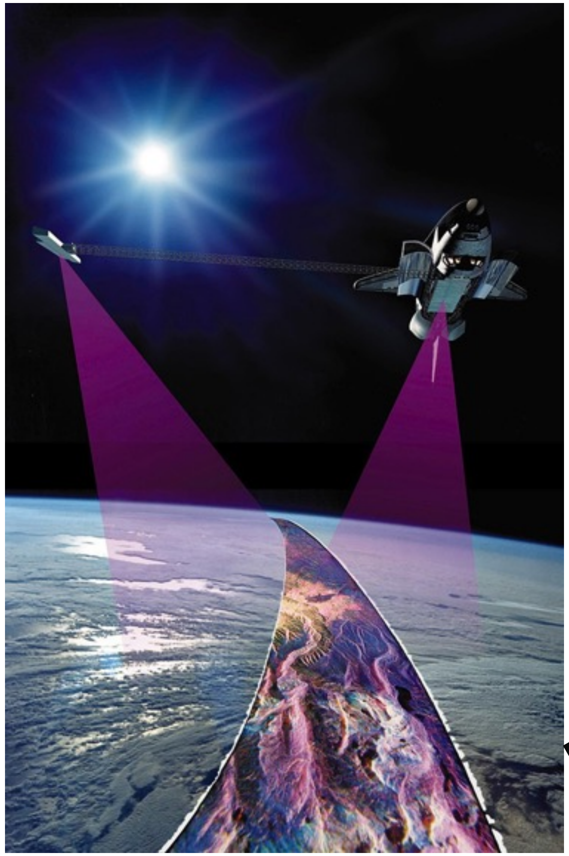
Radar/Lidar Fusion for Mangrove 3D Structure

TanDEM-X Digital Elevation Modal

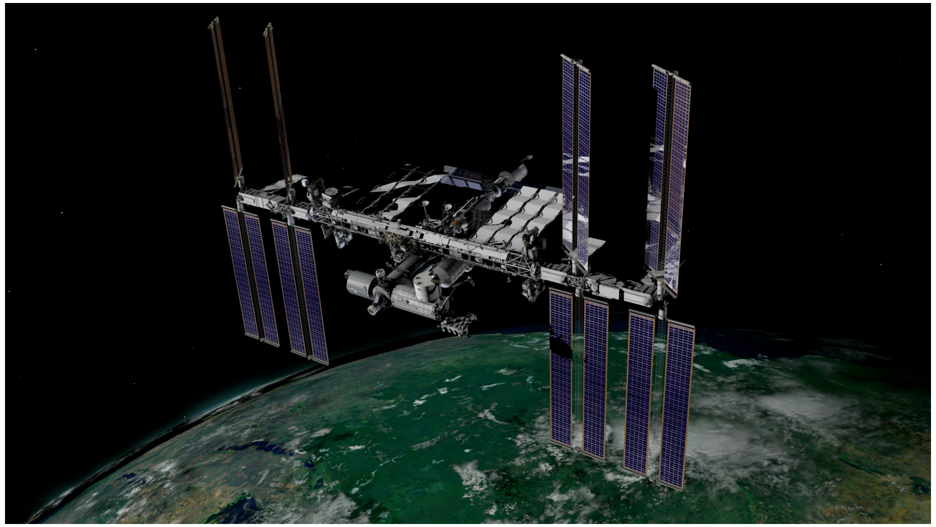
IceSat/GLAS



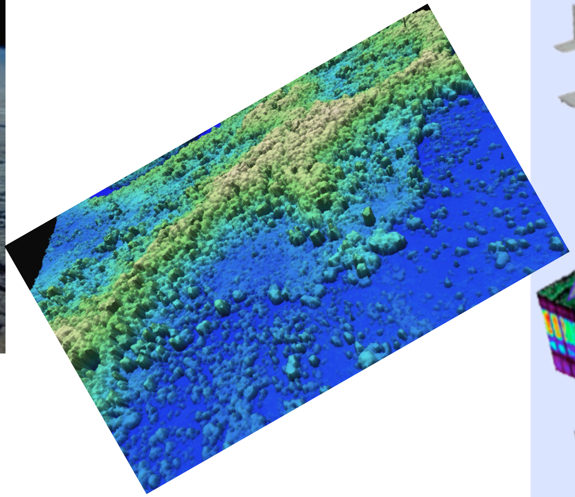
SRTM DEM

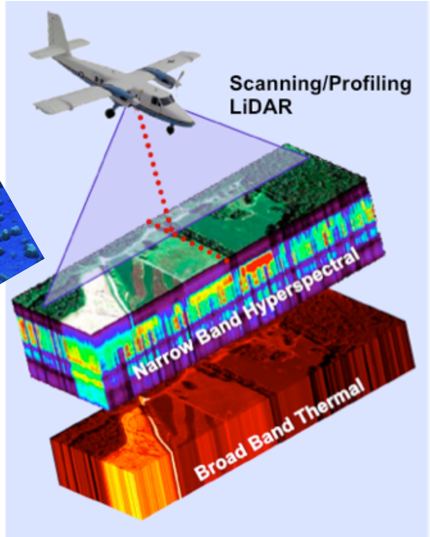


Global Ecosystem Dynamics Investigation (GEDI) Lidar

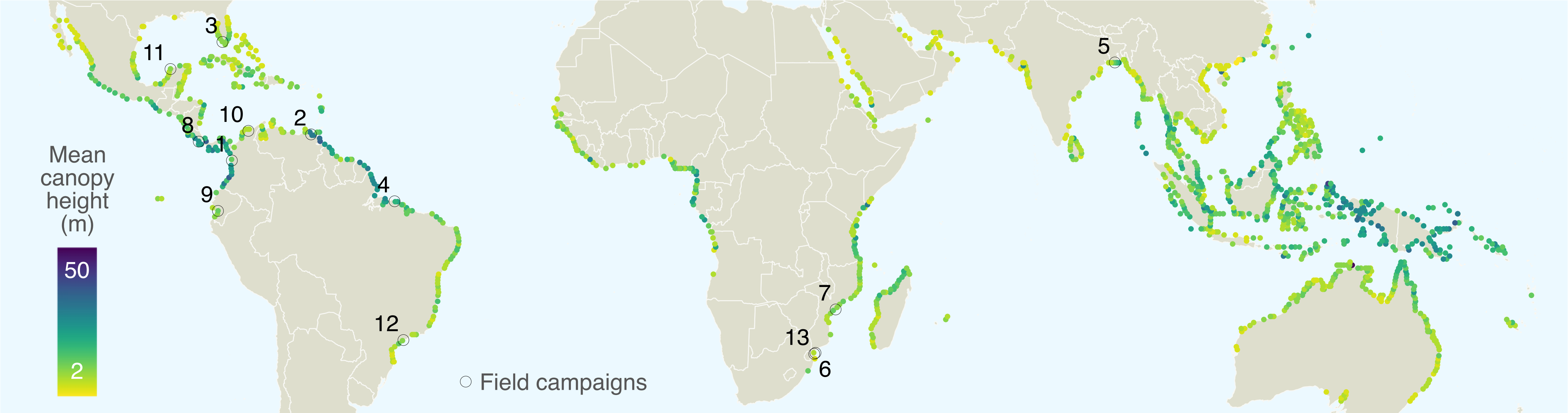


Airborne Lidar

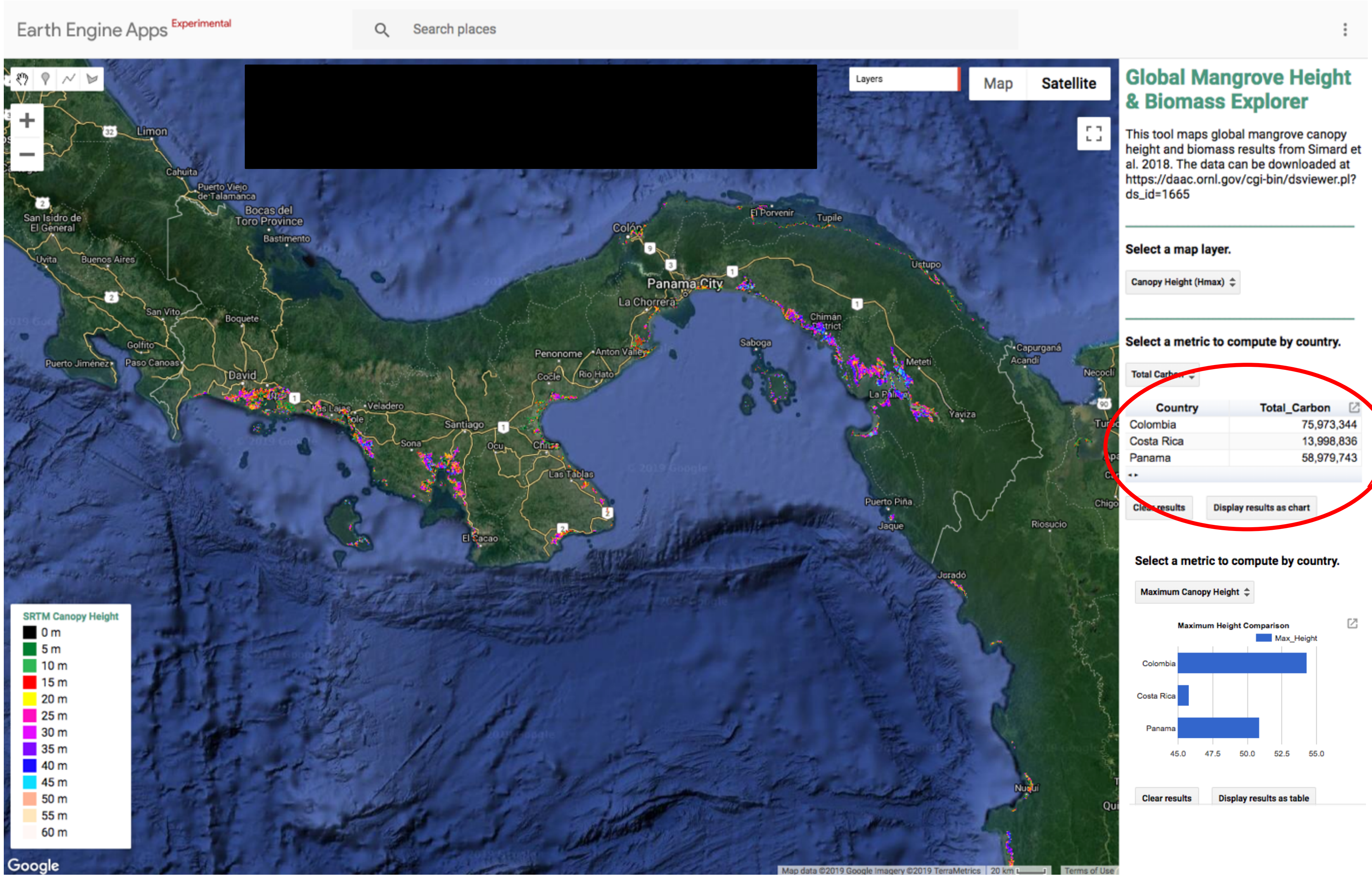




Global Mangrove Height, AGB, and Carbon 2000



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



Here we can provide relevant results as table or bar chart

Mangrove Loss Drivers

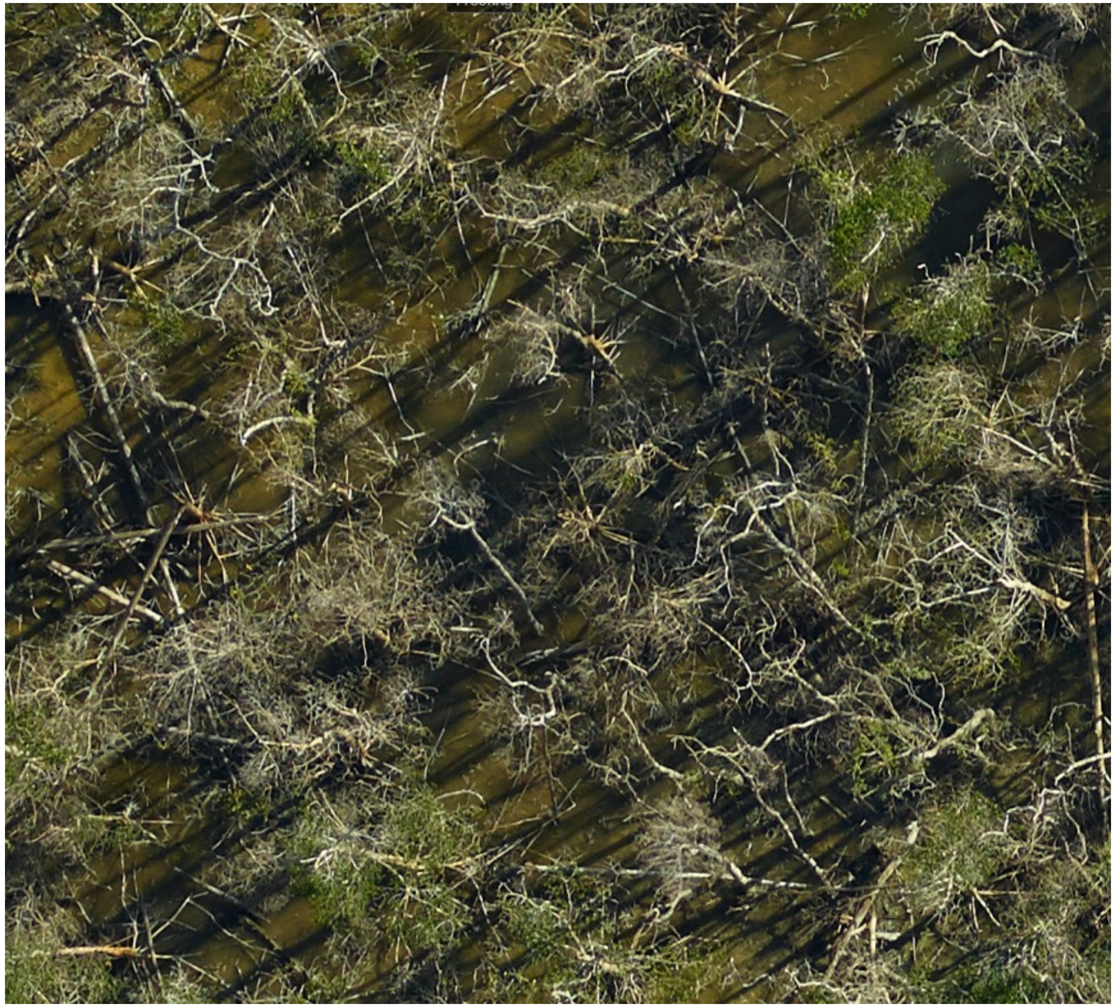


Image Credit: NASA G-LiHT

Gulf of Carpentaria, Australia

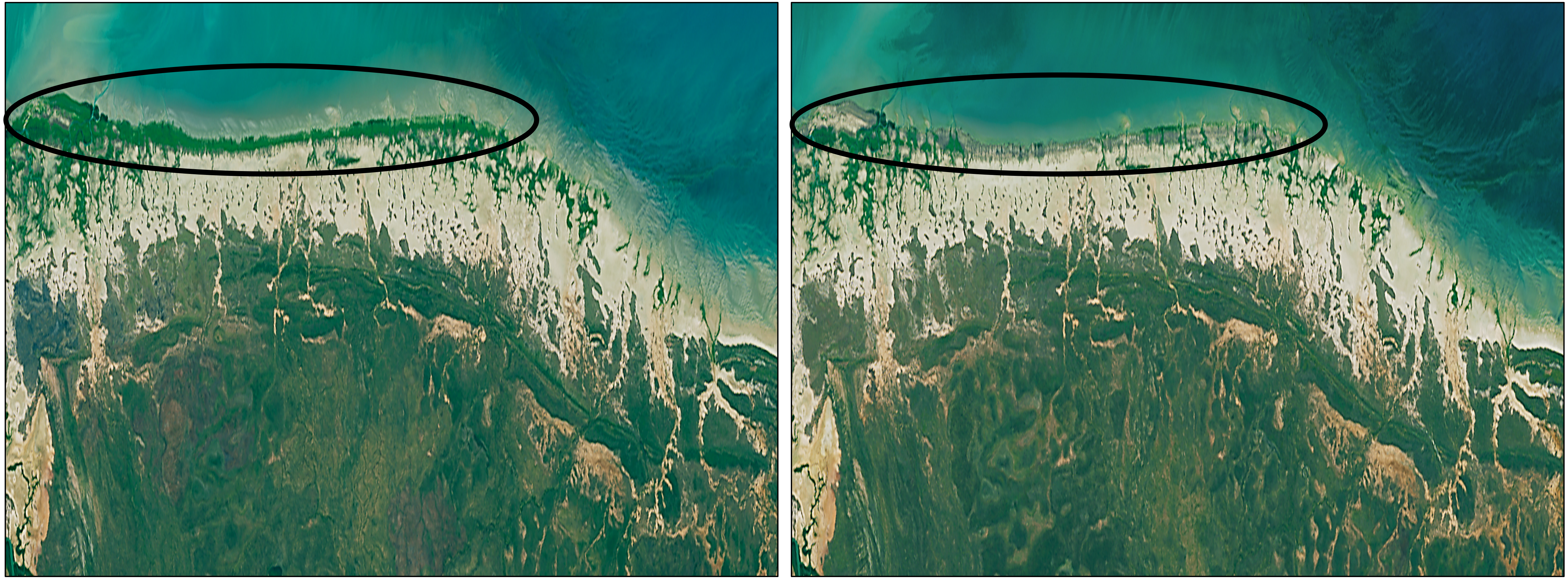
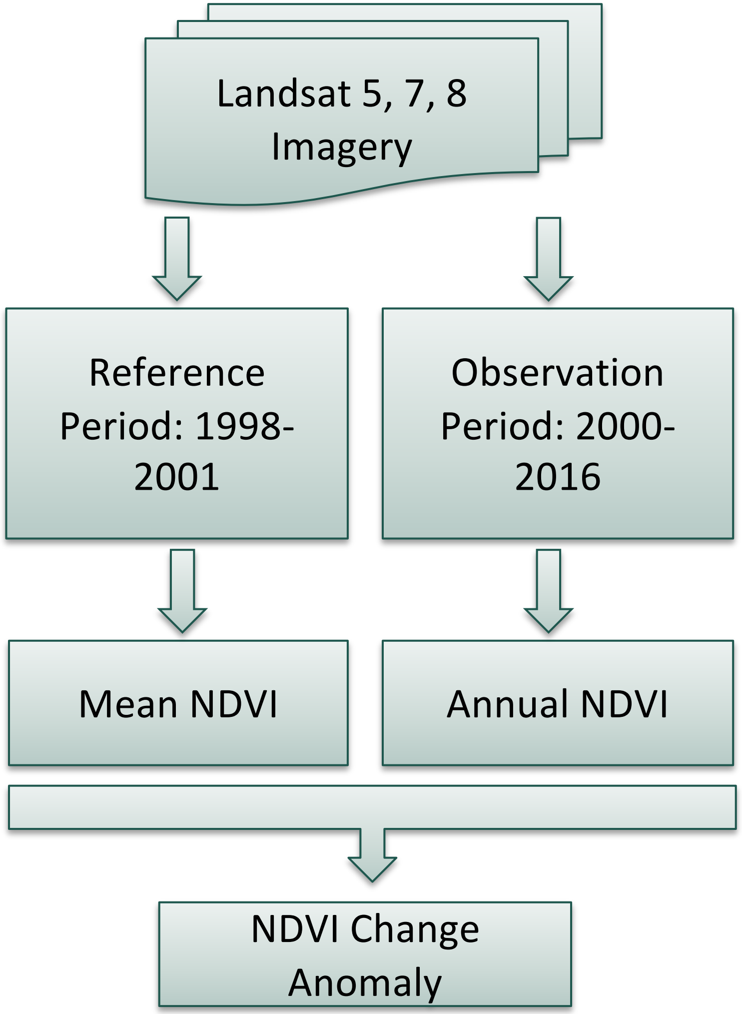
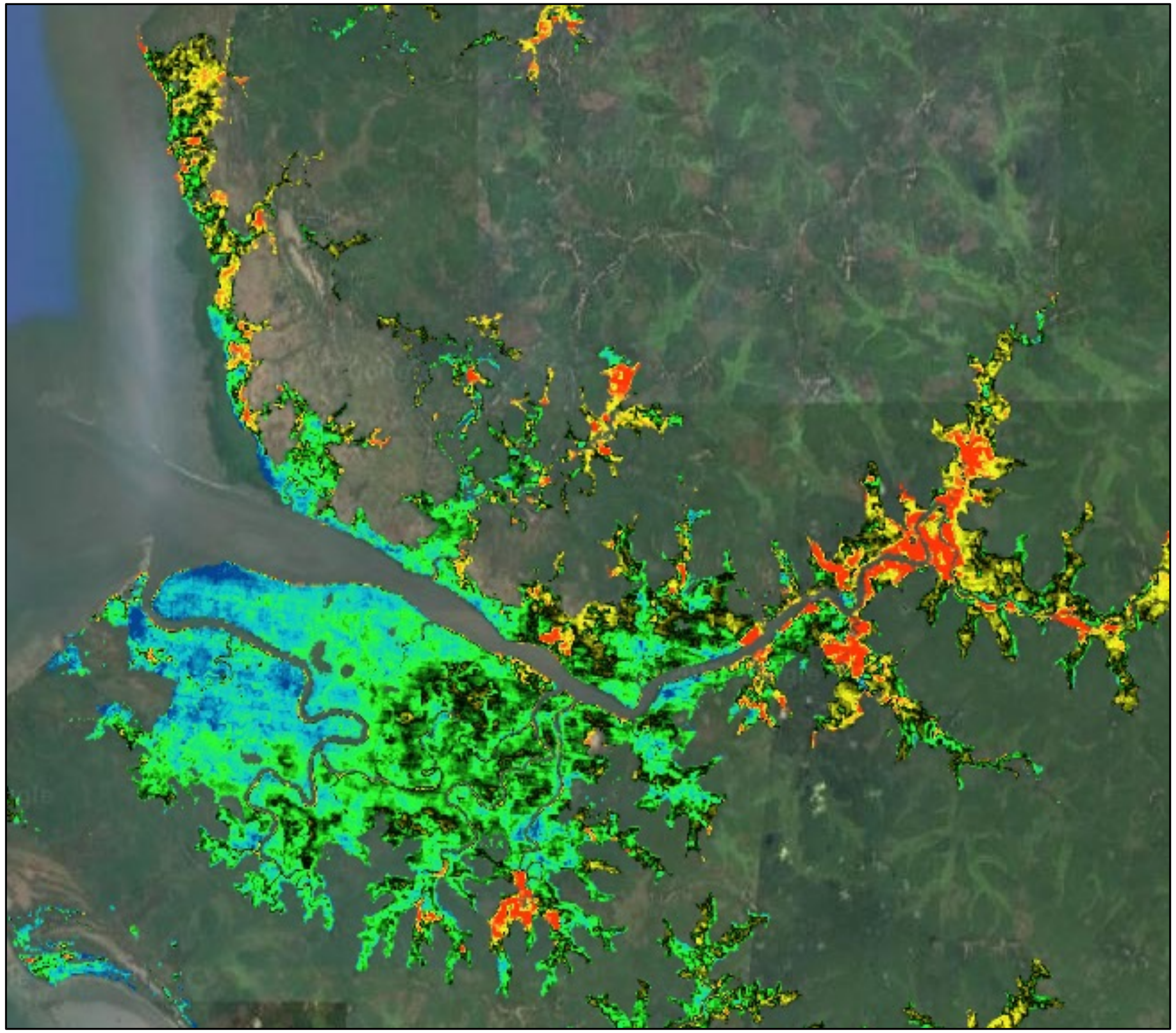


Image Credit: Liza Goldberg

Loss Extent Mapping





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

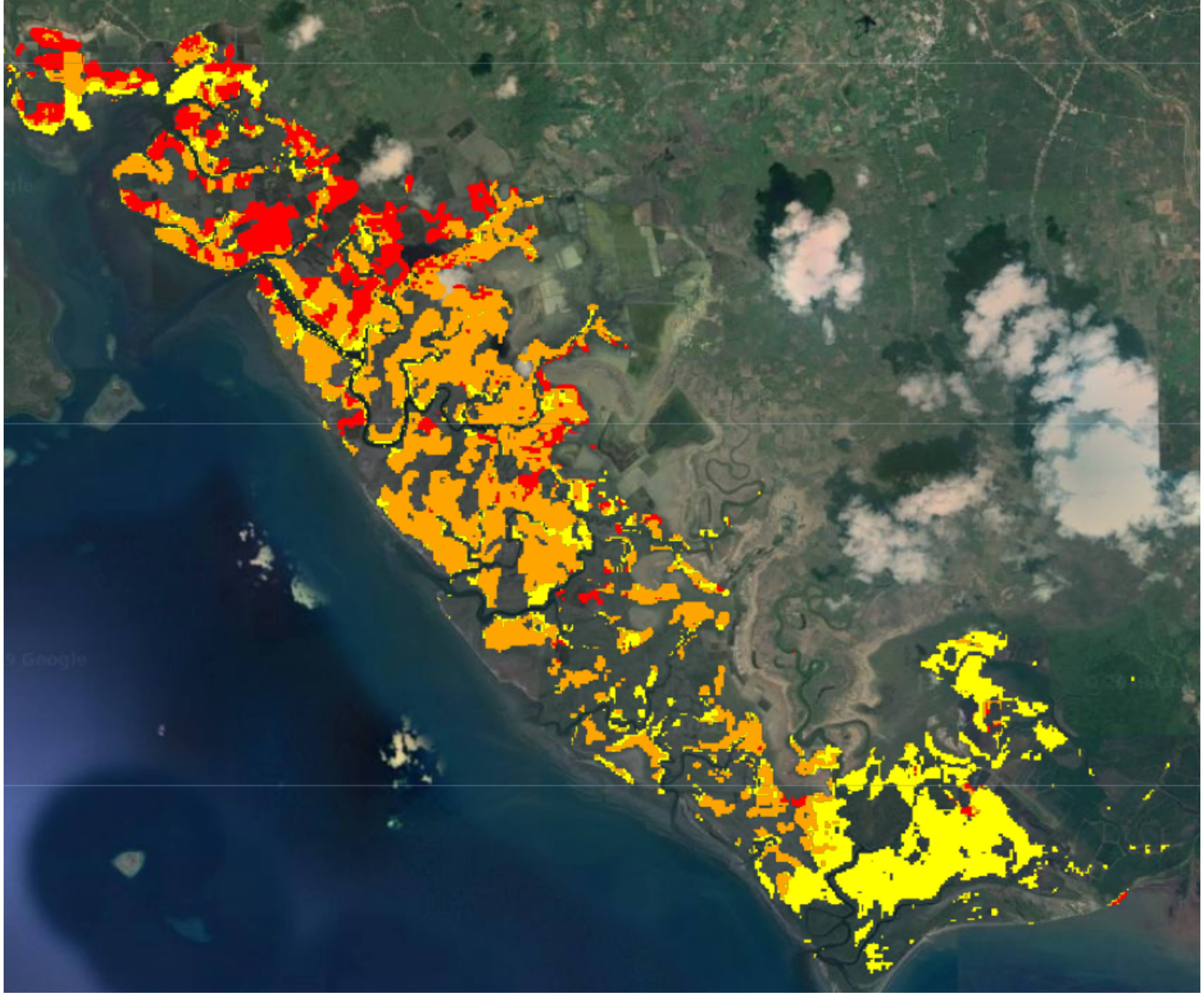
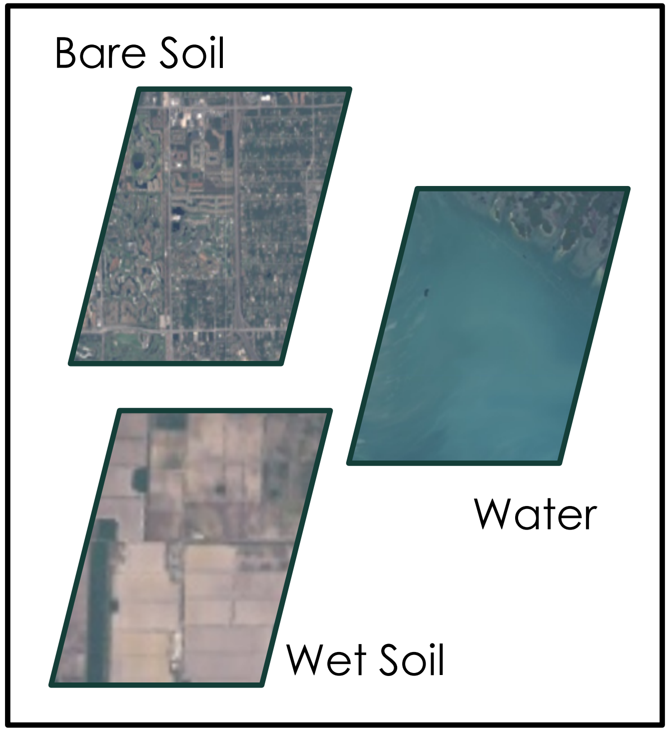
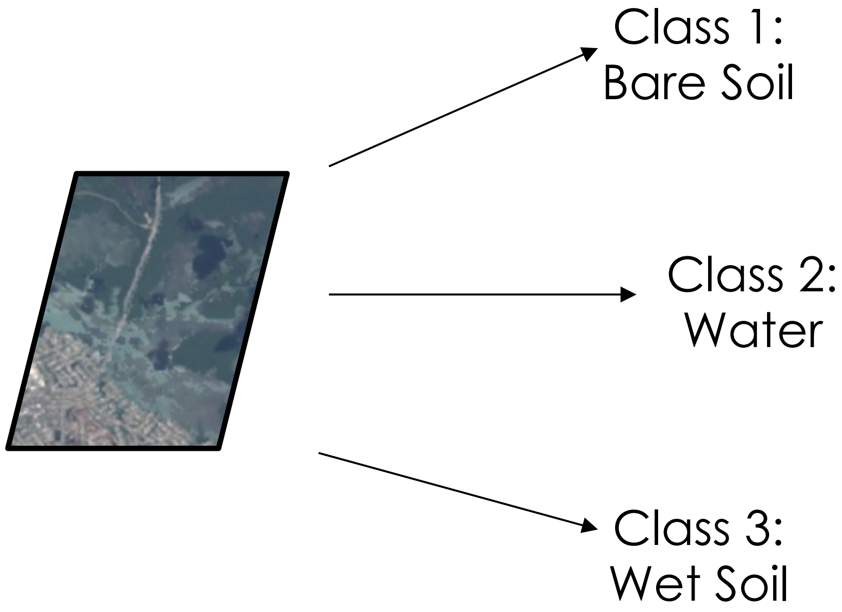


Image Credit: Liza Goldberg

Random Forest Land Cover Change Classification



Training Data:
Landsat 7,8 imagery in classified regions

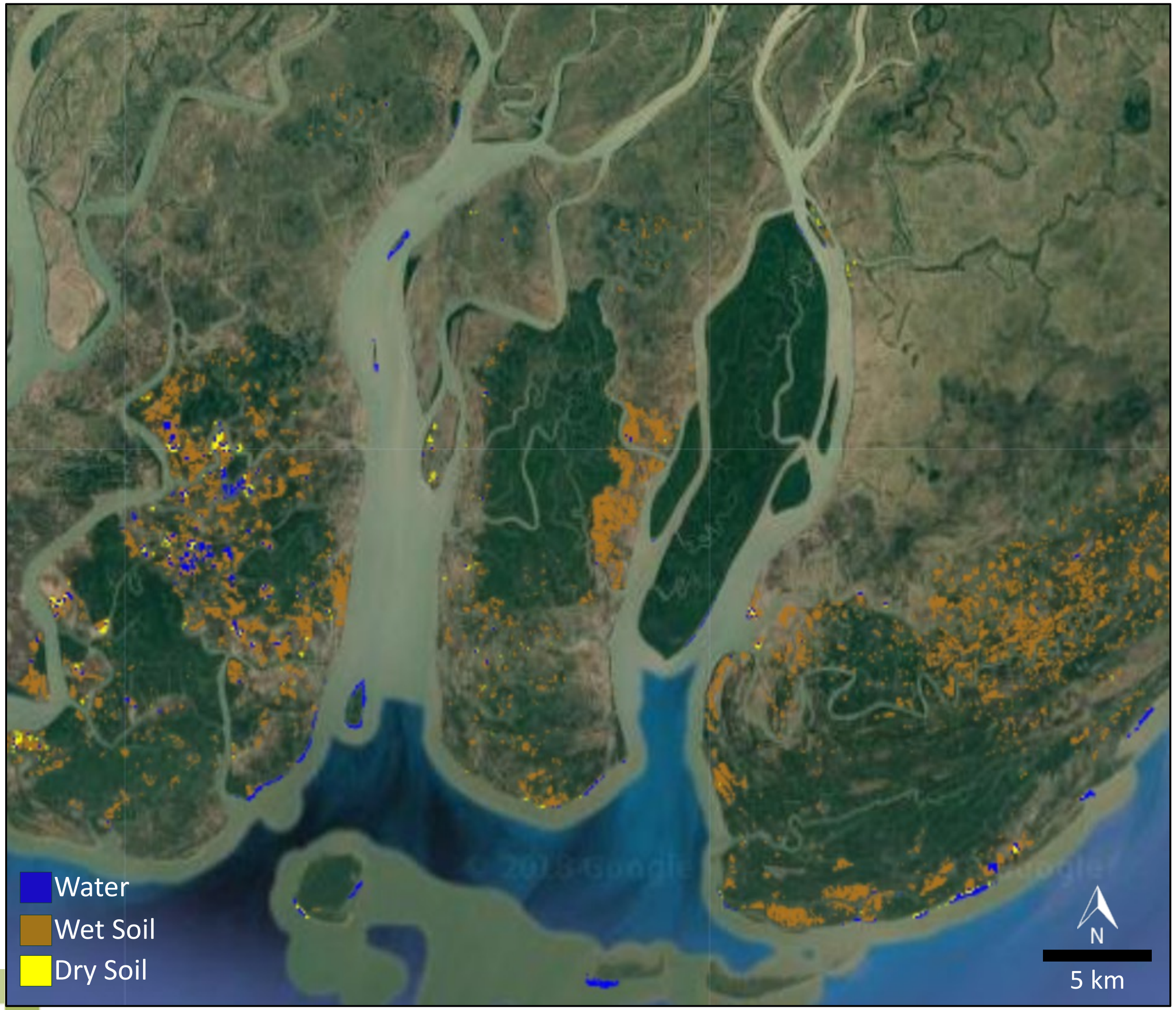


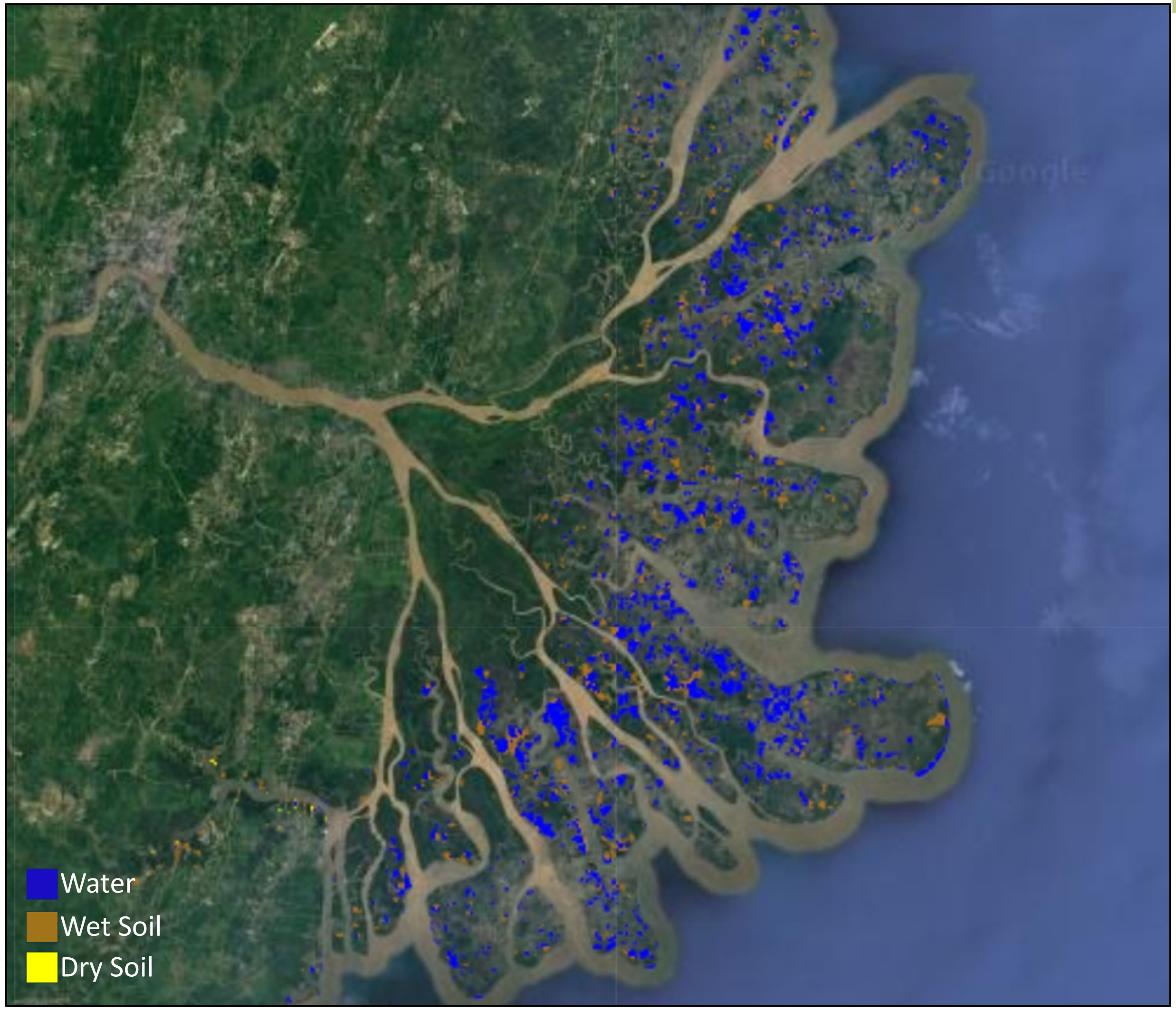
RF Classification:
Landsat 7,8 imagery in all mangrove loss regions

Land Cover Change Classification

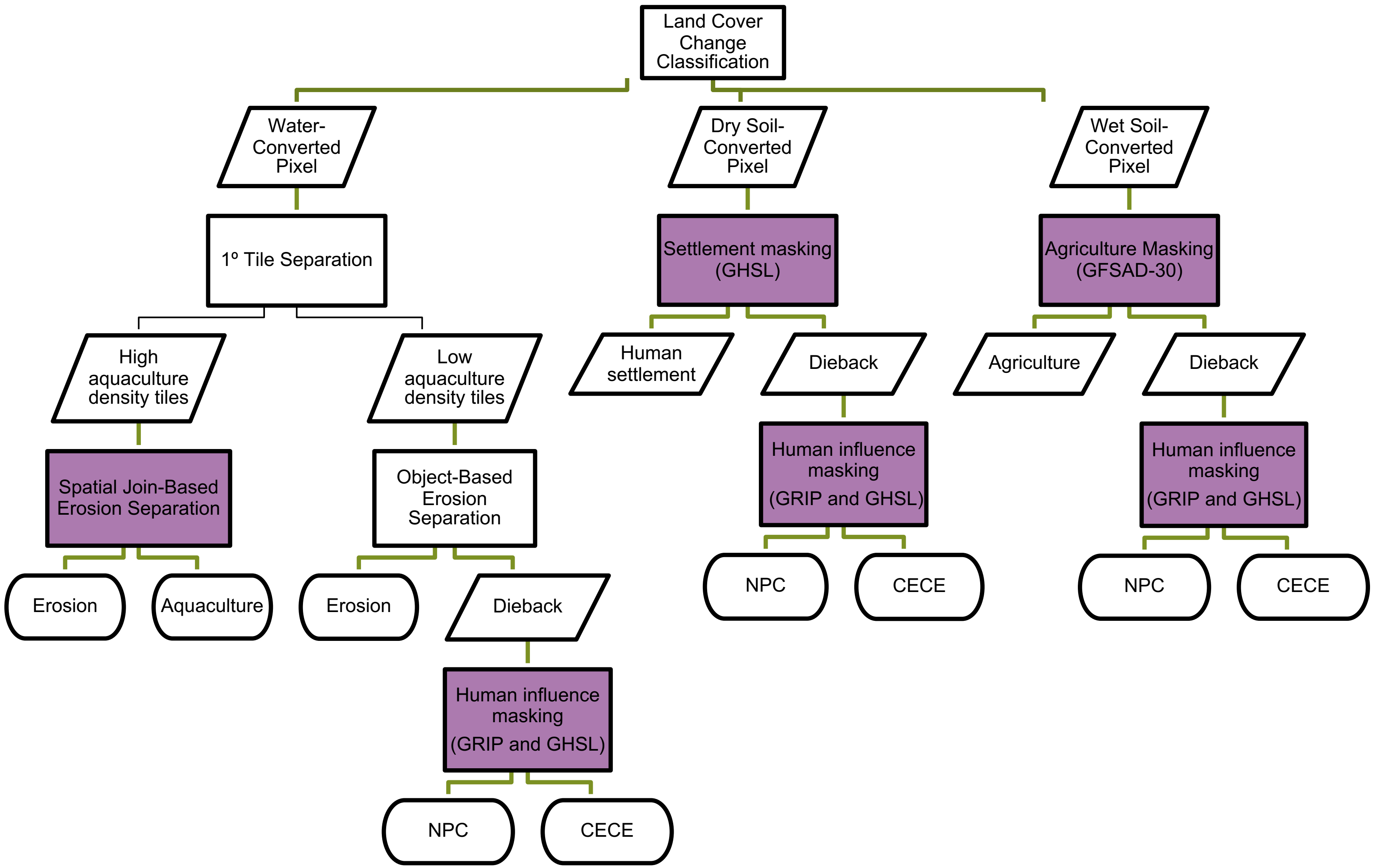
Image Credit: Liza Goldberg

Random Forest Land Cover Change Classification





Land Uses Change Decision Trees



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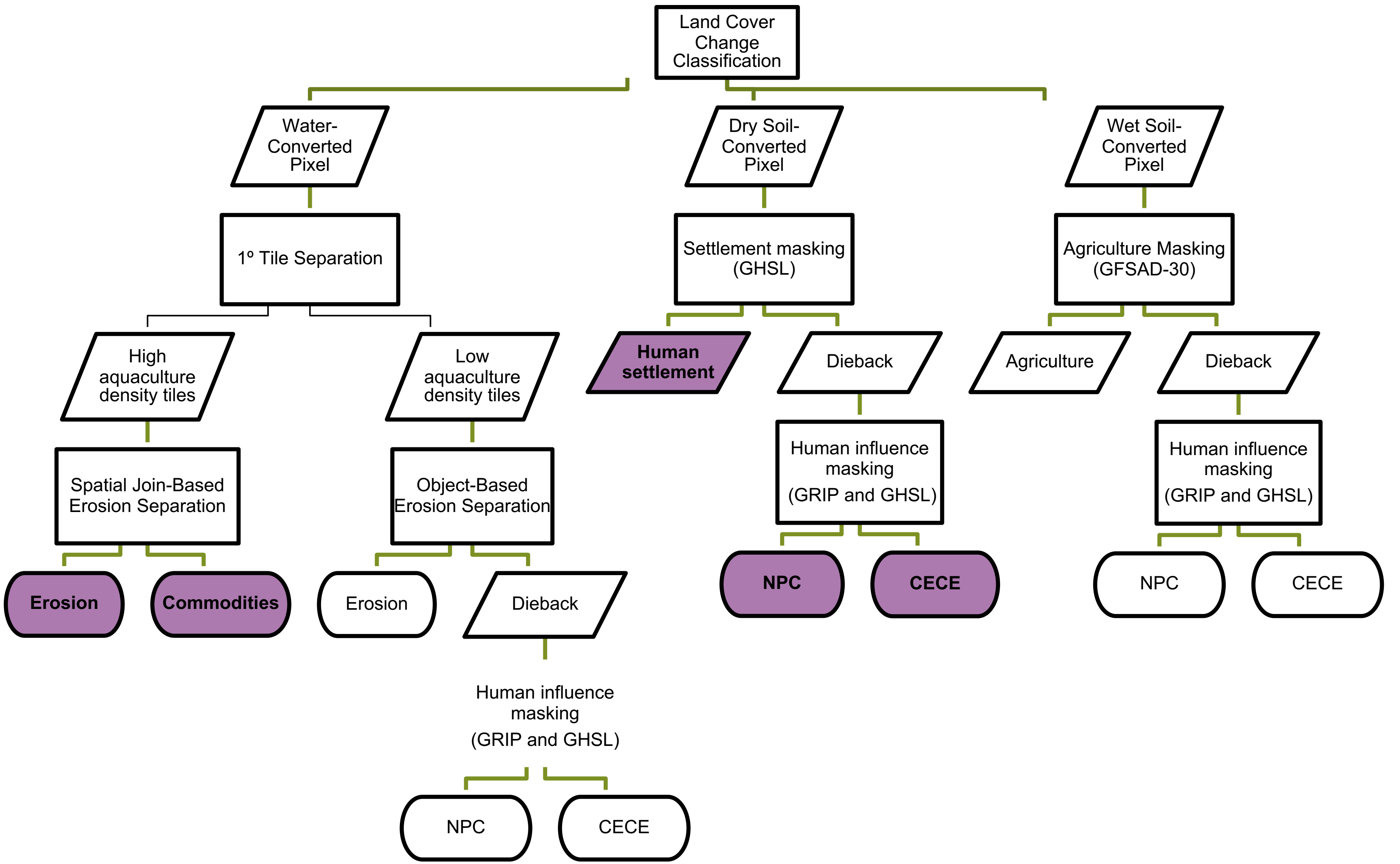
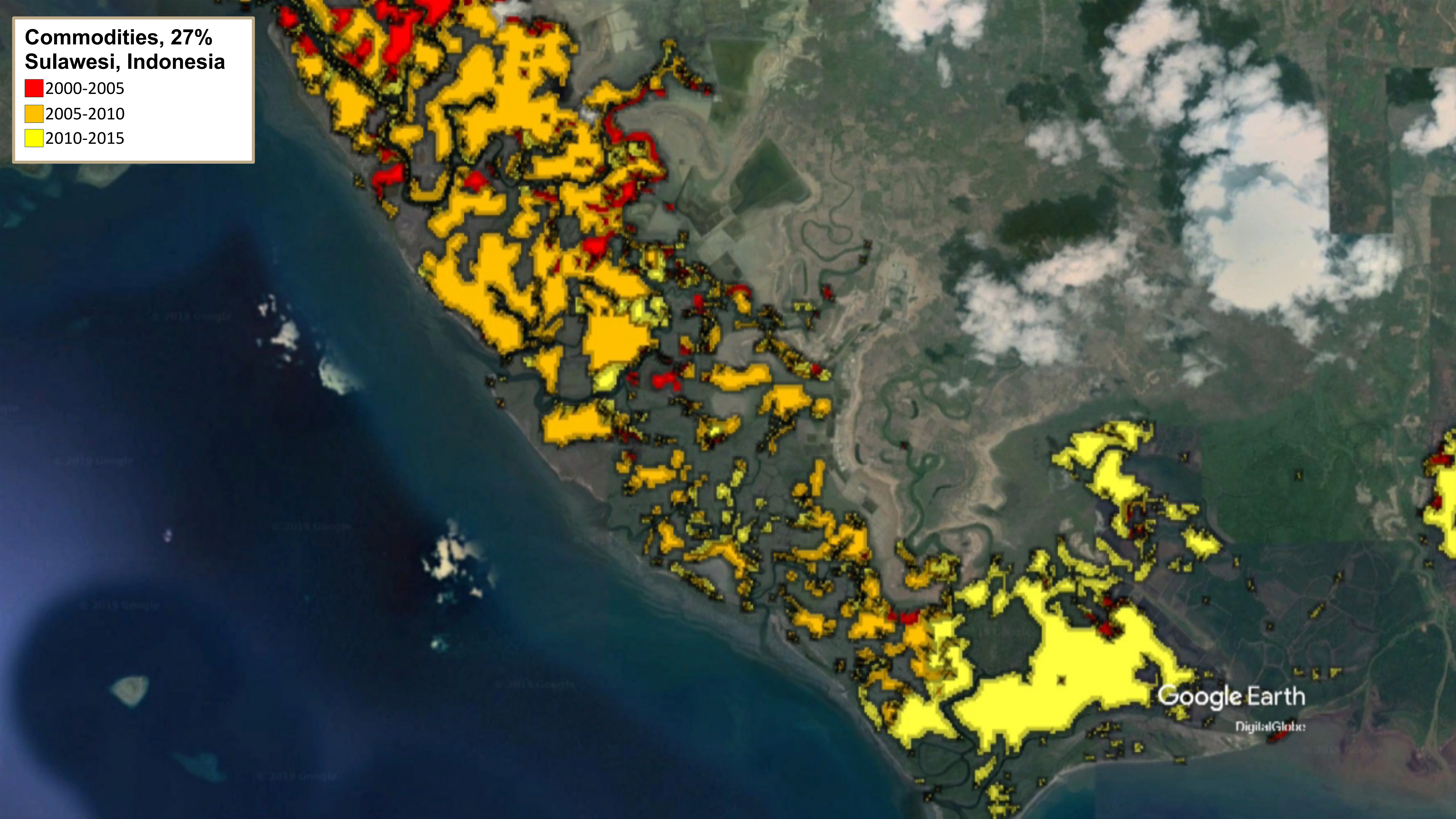



Commodities, 27%
Sulawesi, Indonesia
2000-2005
2005-2010
2010-2015
Google Earth
DigitalGlobe

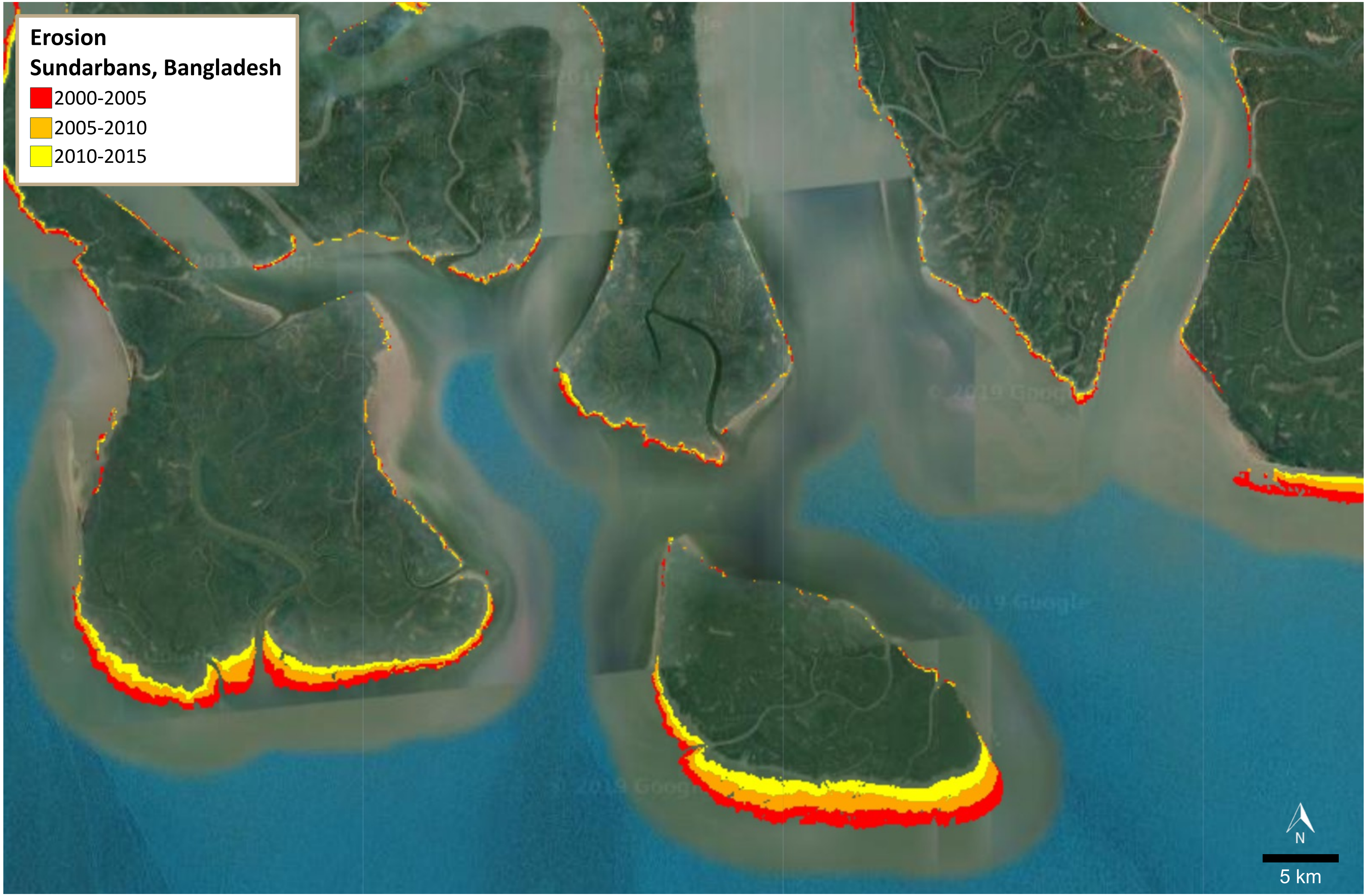


Image Credit: Liza Goldberg

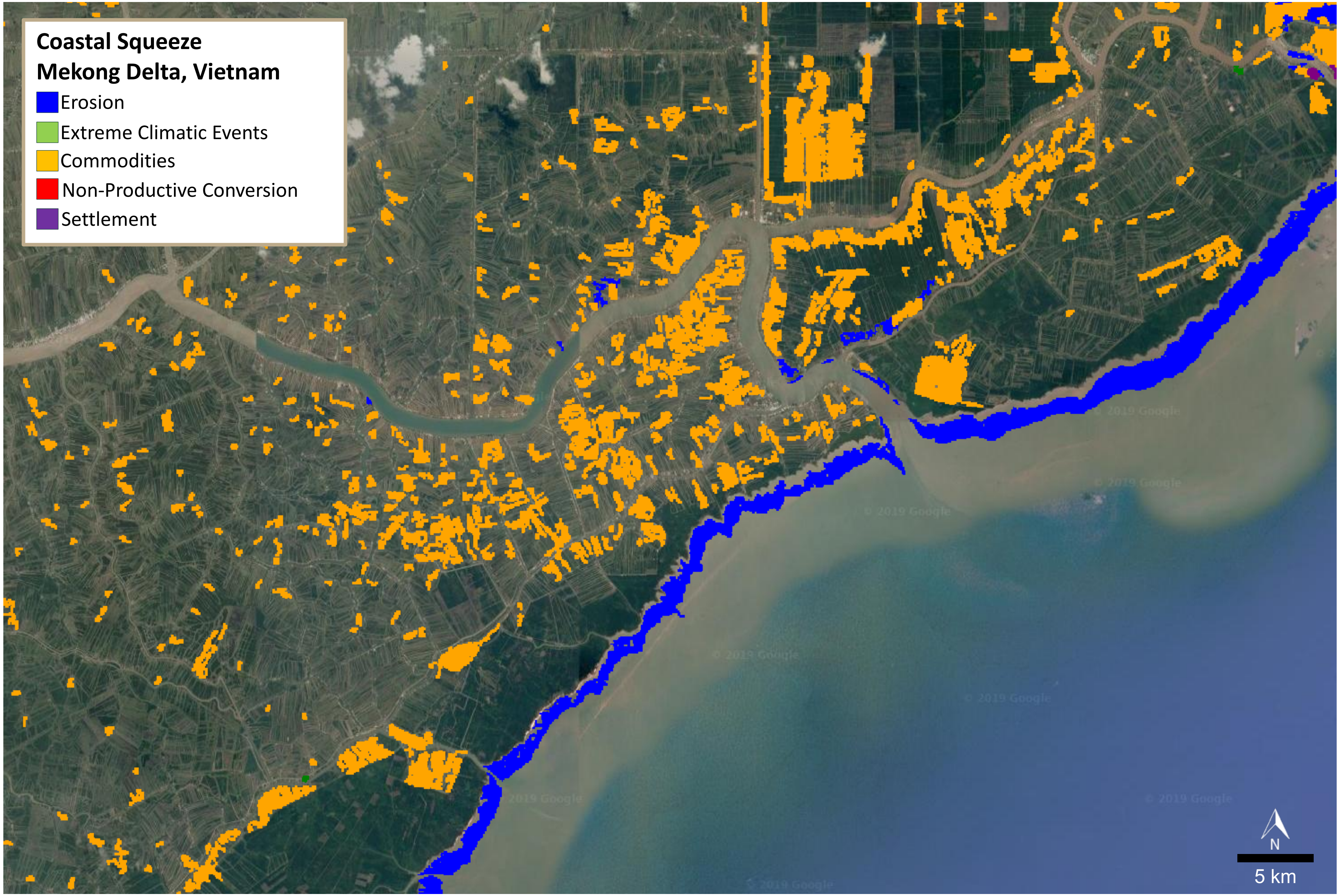


Image Credit: Liza Goldberg

National Loss Driver Trends – 2000-2016

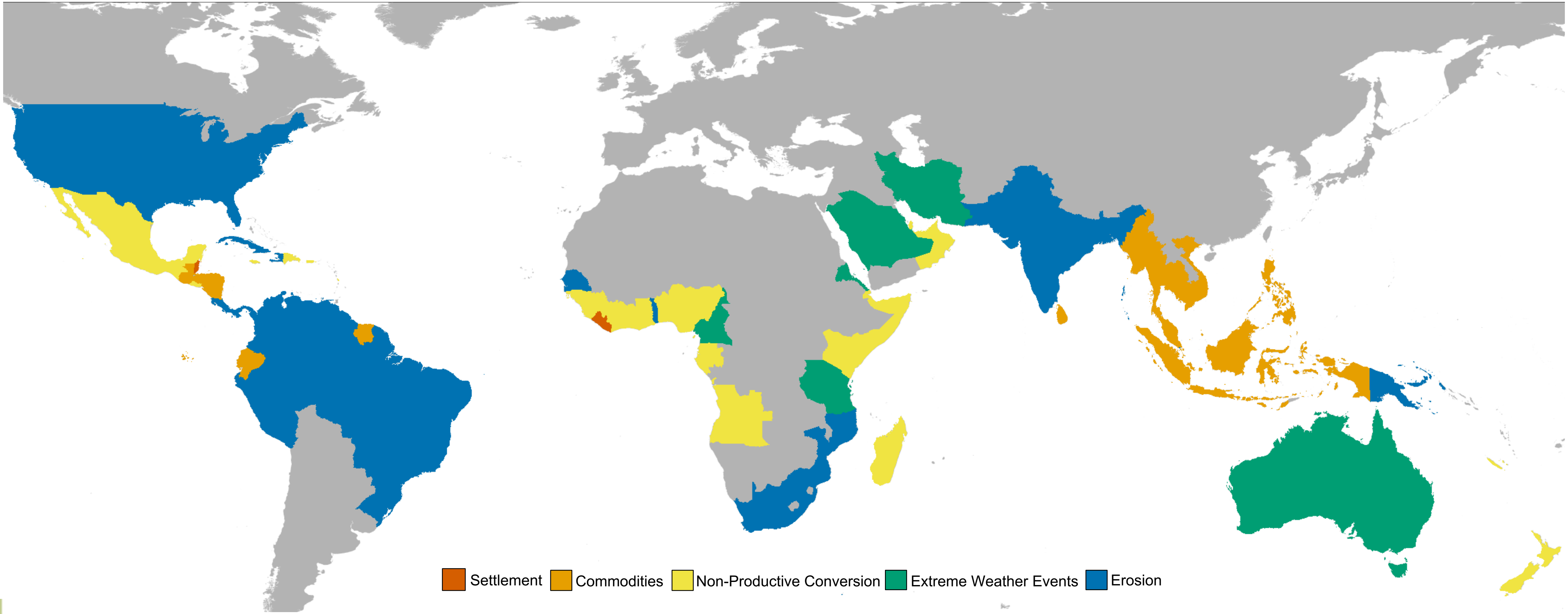


Image Credit: Liza Goldberg

National Loss Driver Trends – 2000-2016

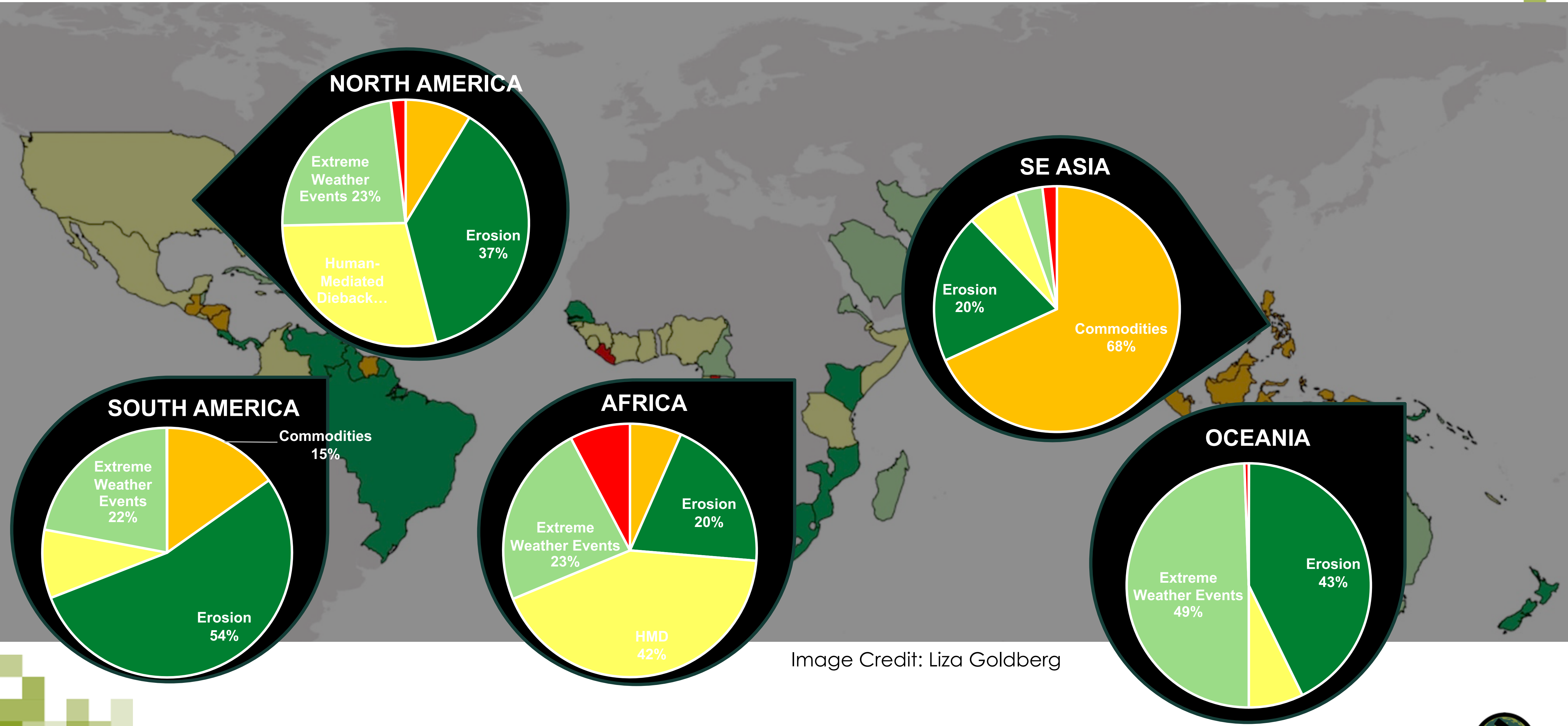


Image Credit: Liza Goldberg

National Loss Driver Trends – 2000-2016

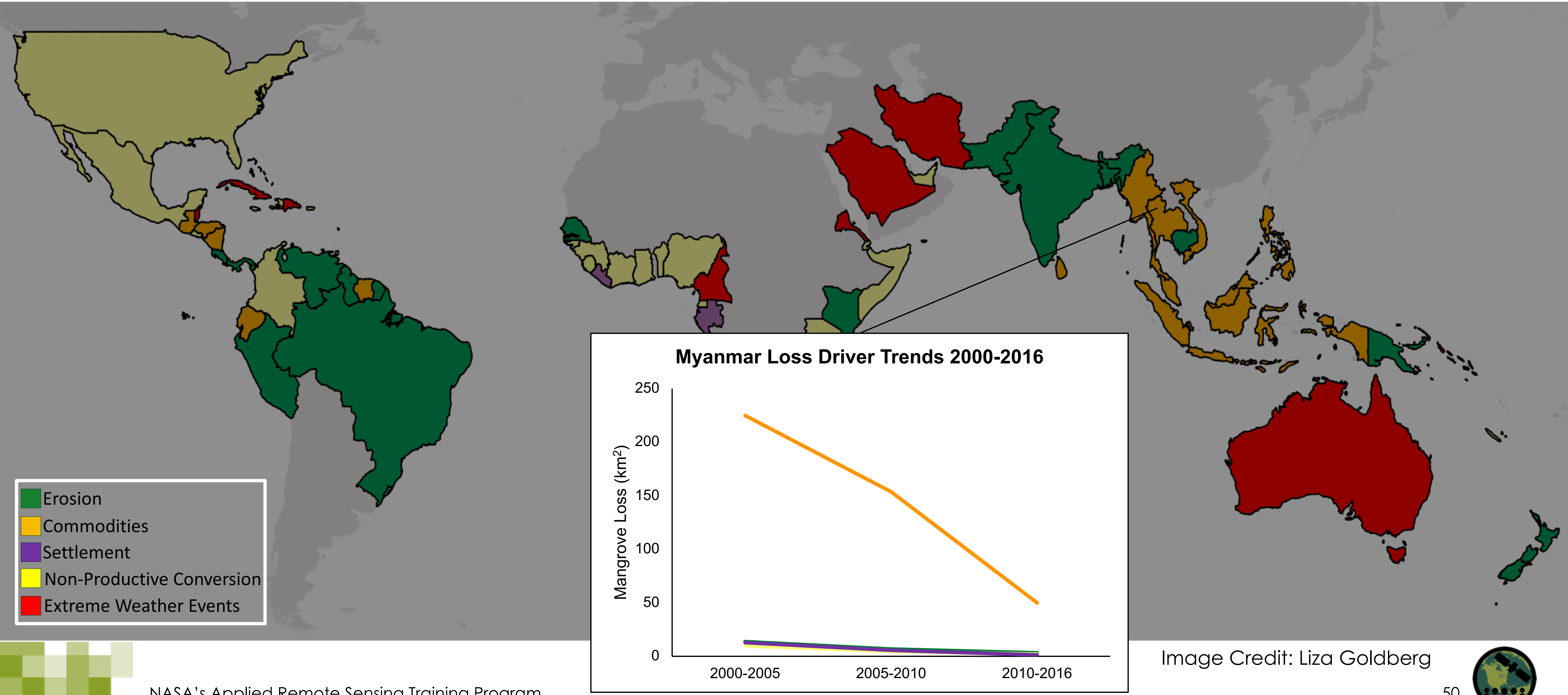
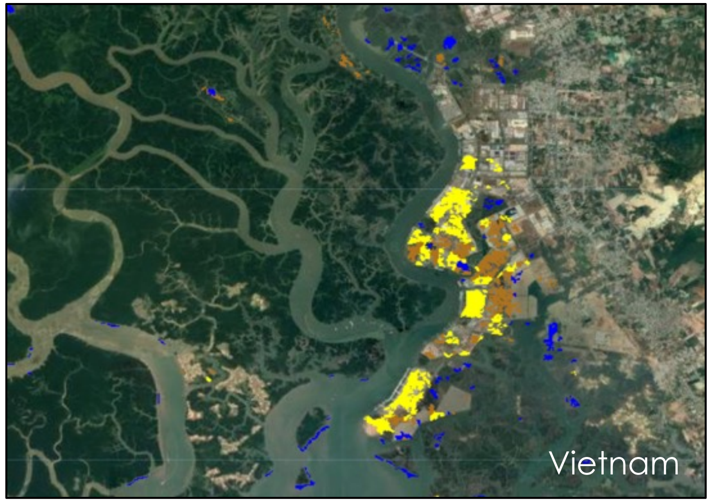


Image Credit: Liza Goldberg

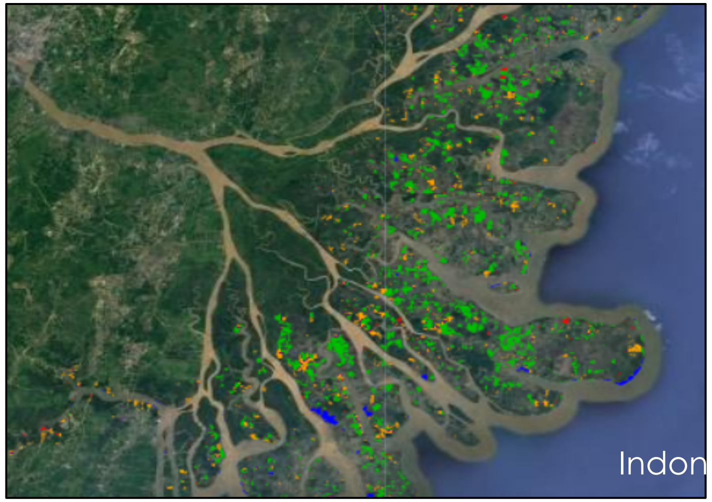
Towards Global Mangrove Vulnerability Assessment

Losses and Gains

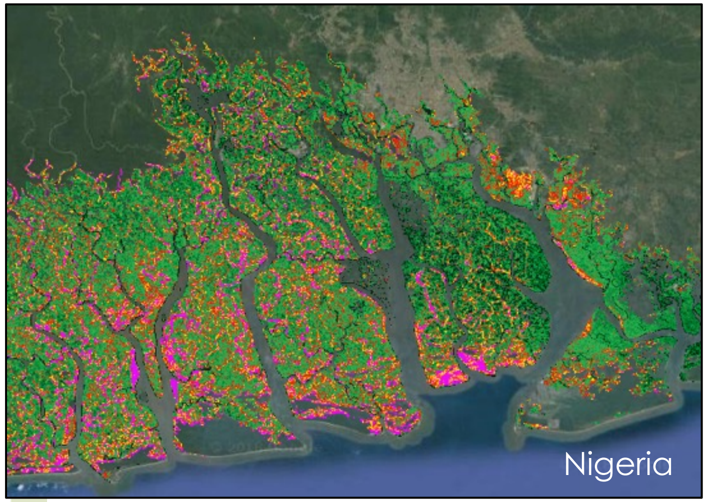
Land Cover Change



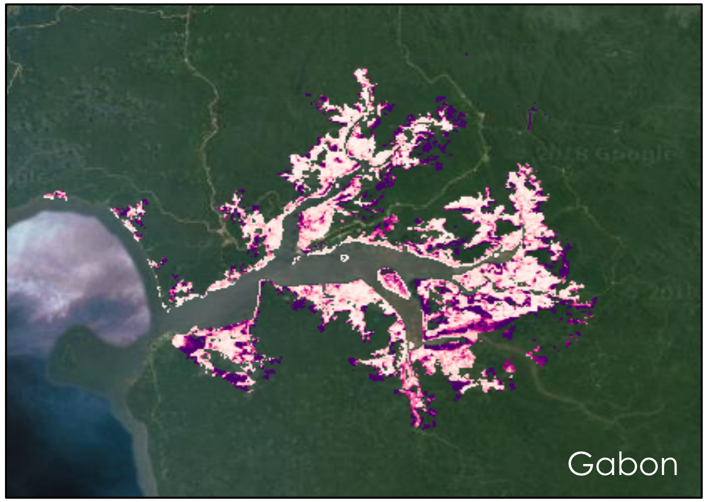
Loss Drivers



Canopy Height



Aboveground Biomass



Carbon

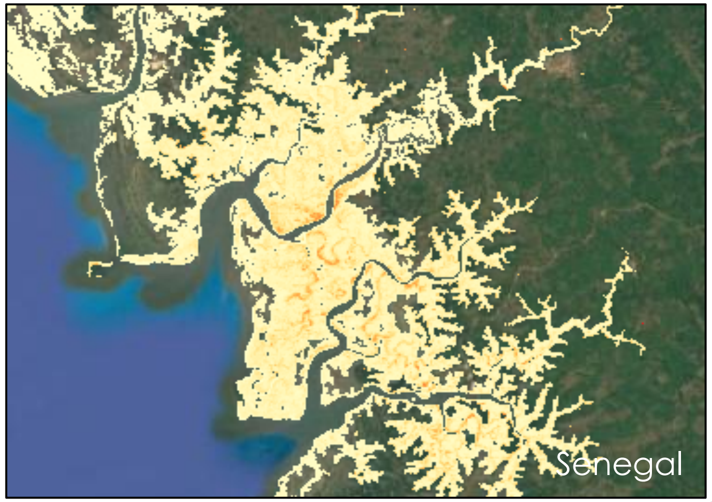
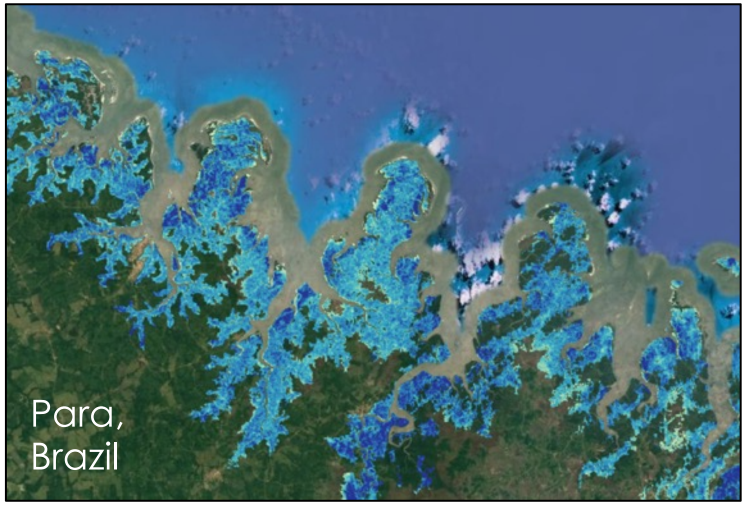
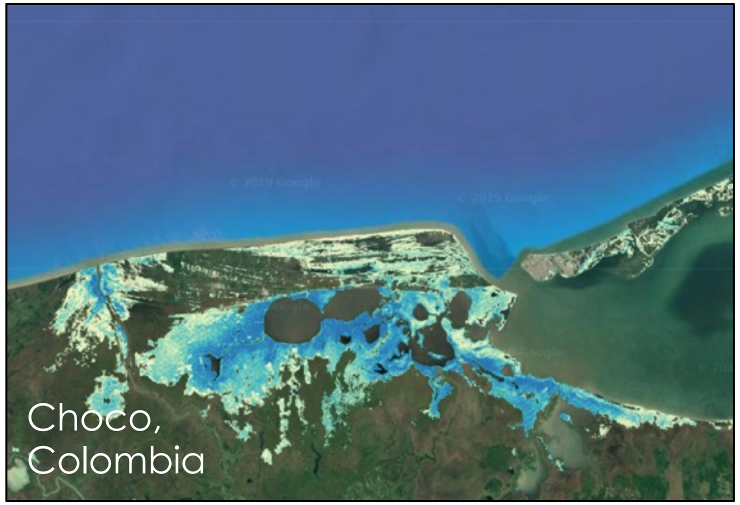


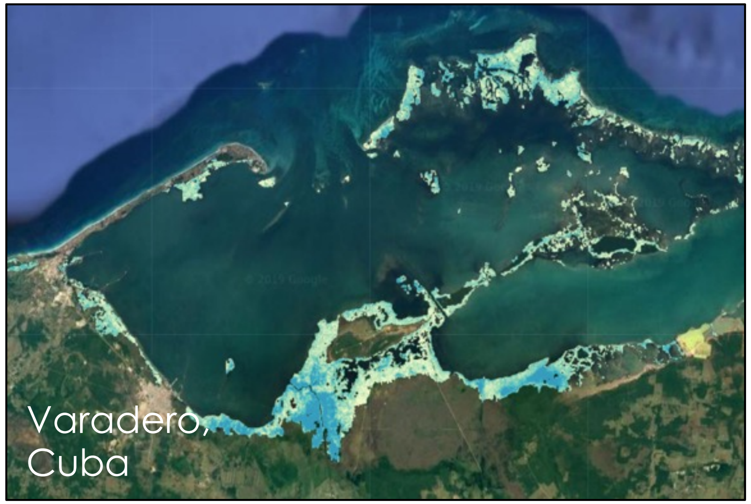
Image Credit: Liza Goldberg

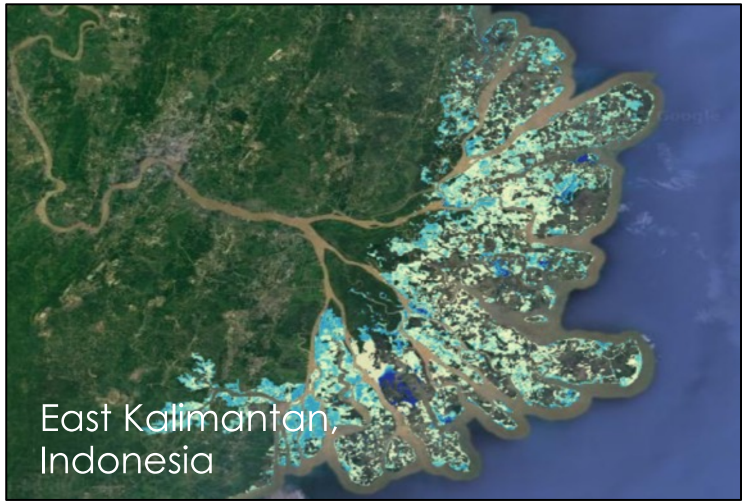
Global Mangrove Height and Biomass for 2000

Simard et al. 2019









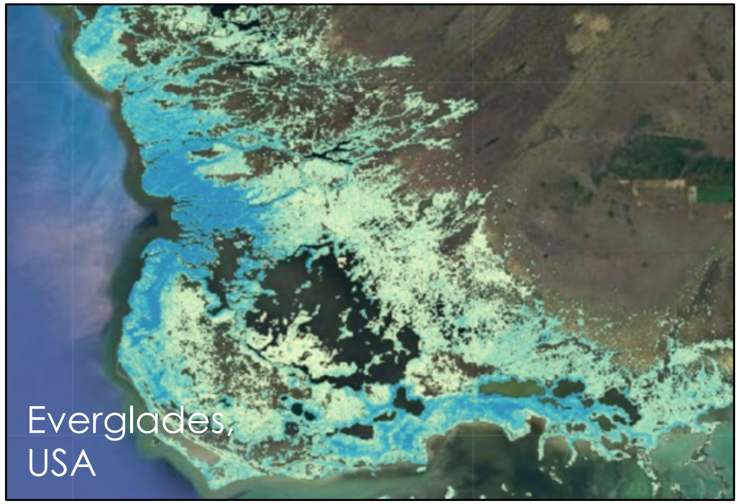


Image Credit: Liza Goldberg

Mangrove Height Trends in Commodities-Converted Regions

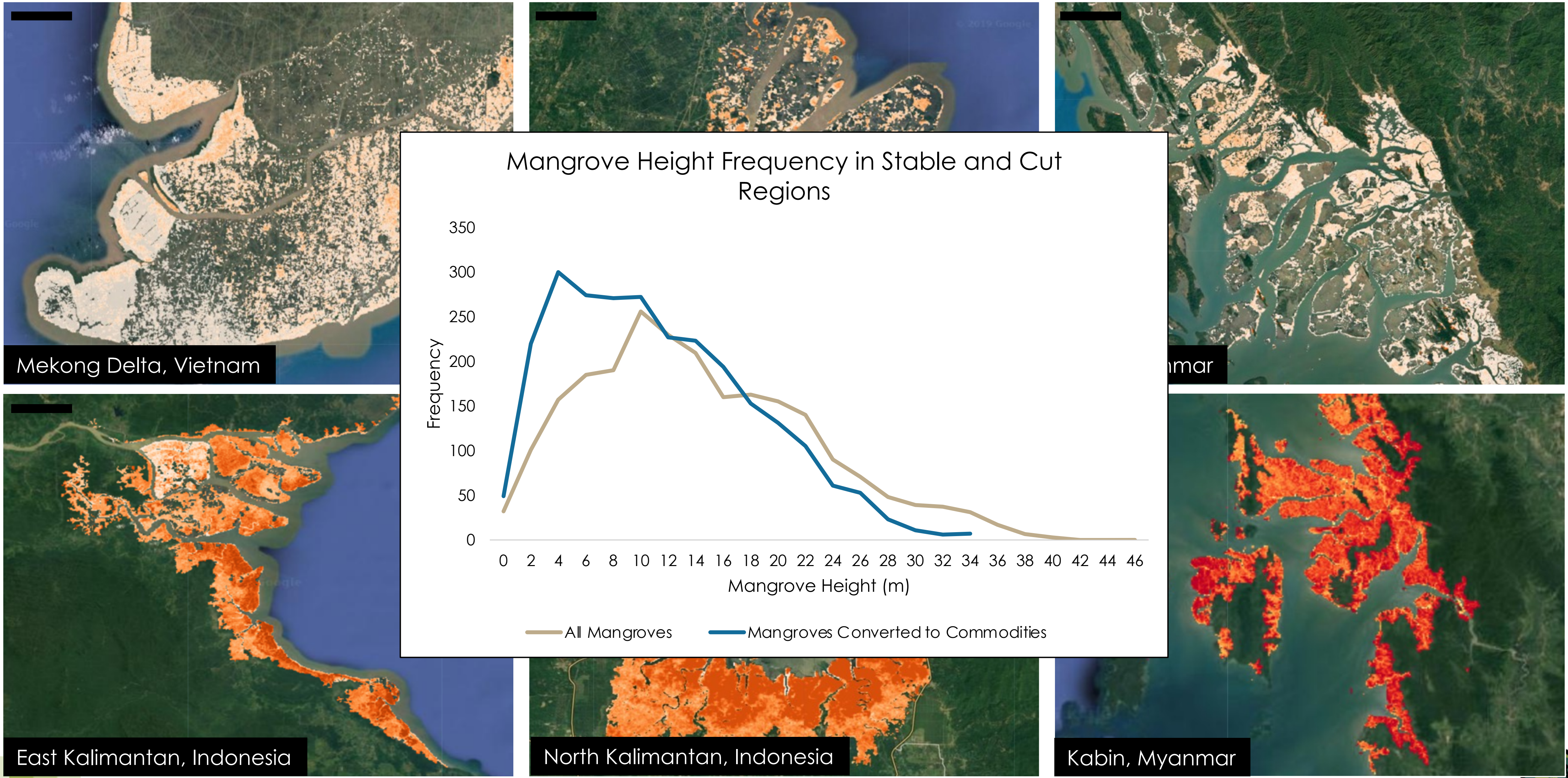


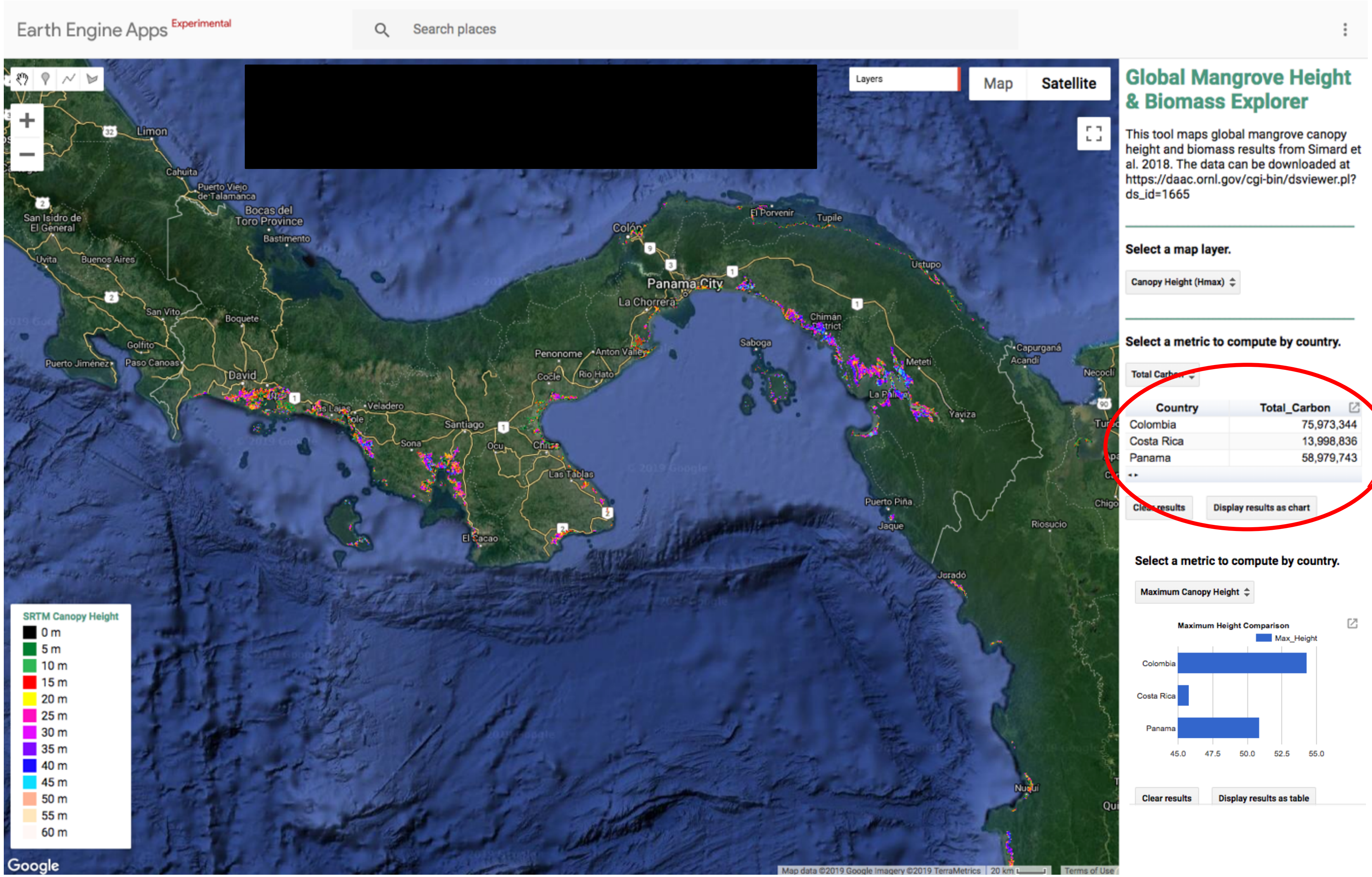
Image Credit: Liza Goldberg

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

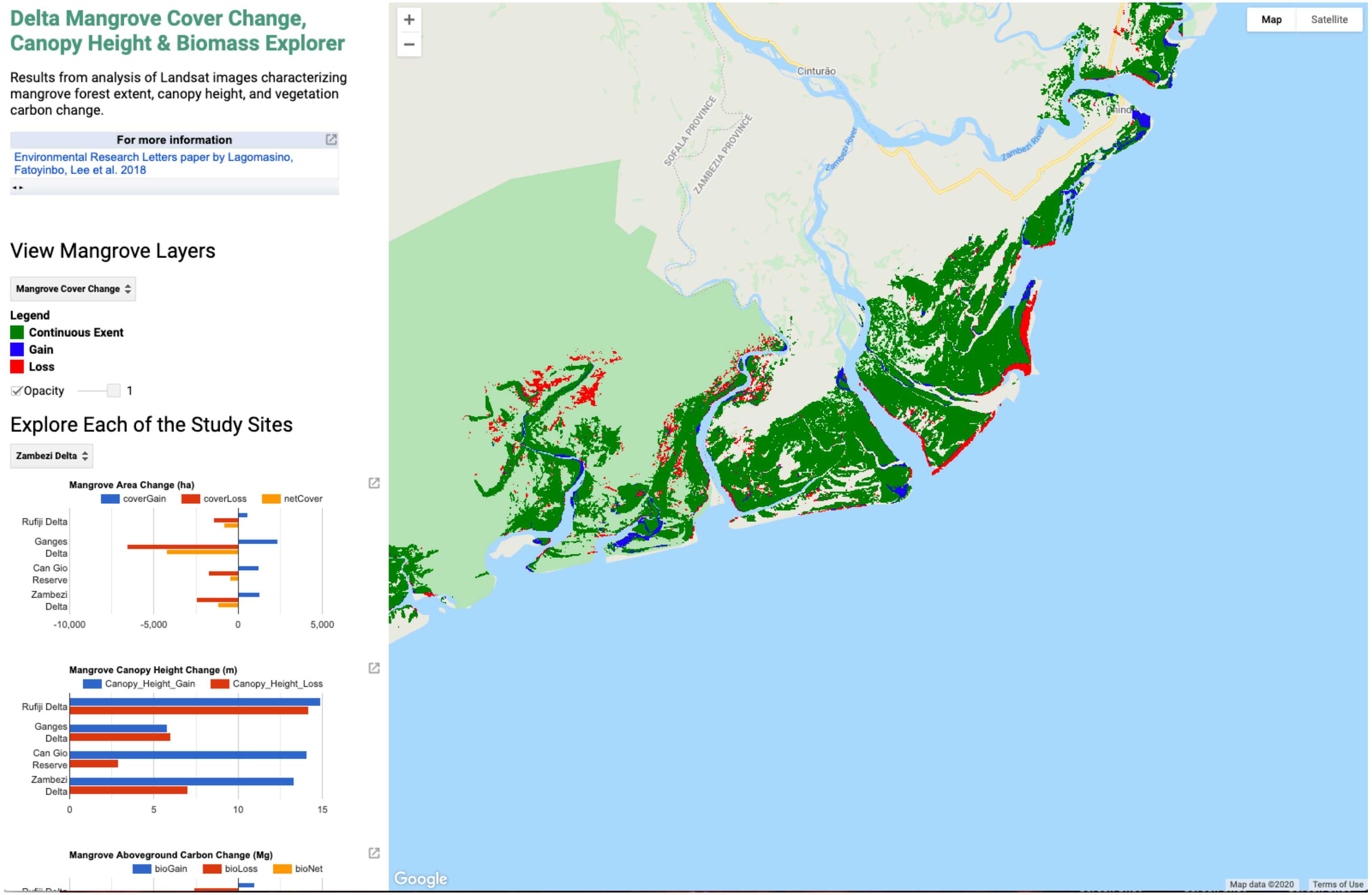


Here we can provide SDG relevant results as table or bar chart.

Mangrove Loss Drivers

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

Delta Mangrove Cover Change, Height, & Biomass



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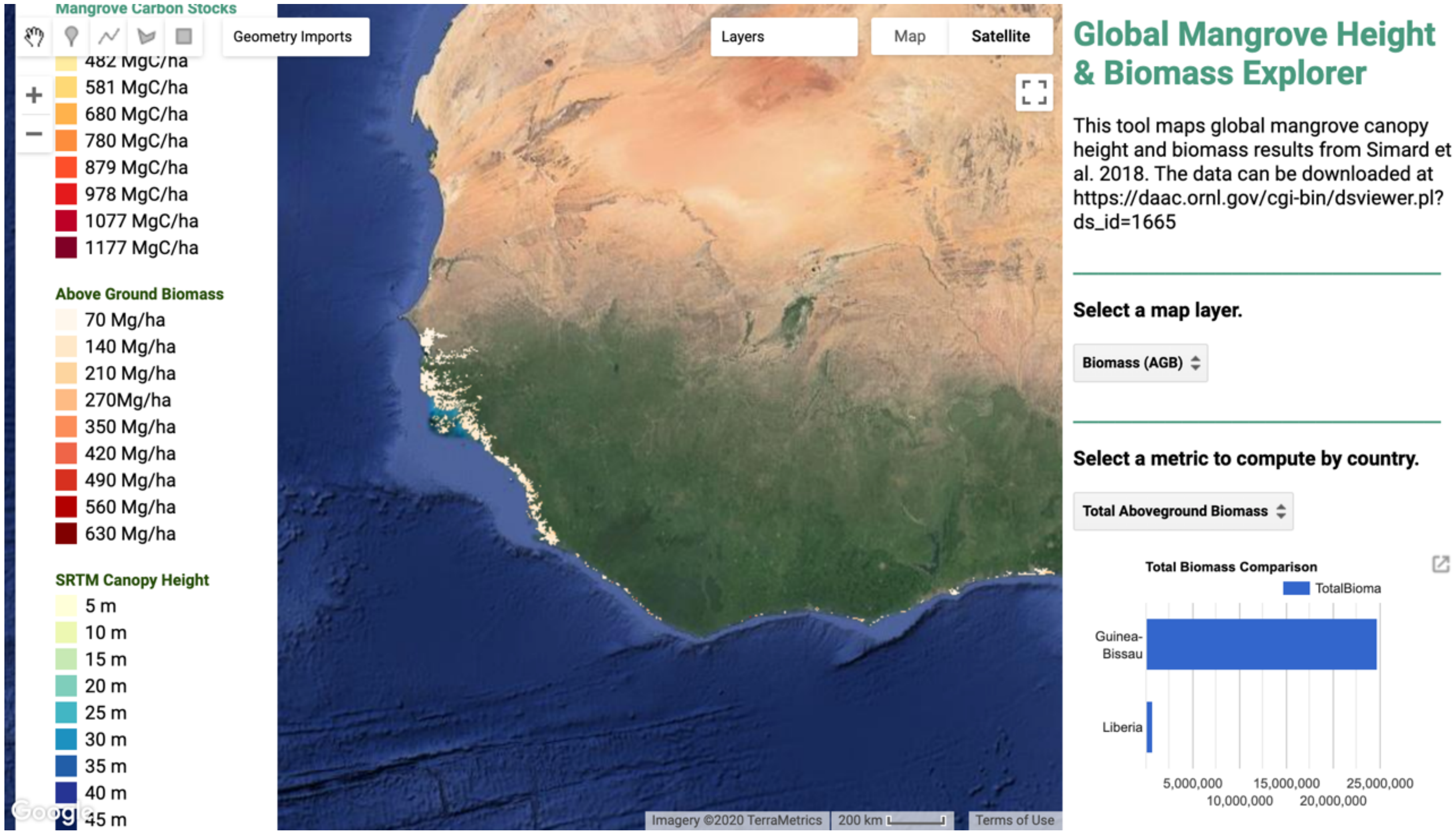
Global Mangrove Height and Biomass



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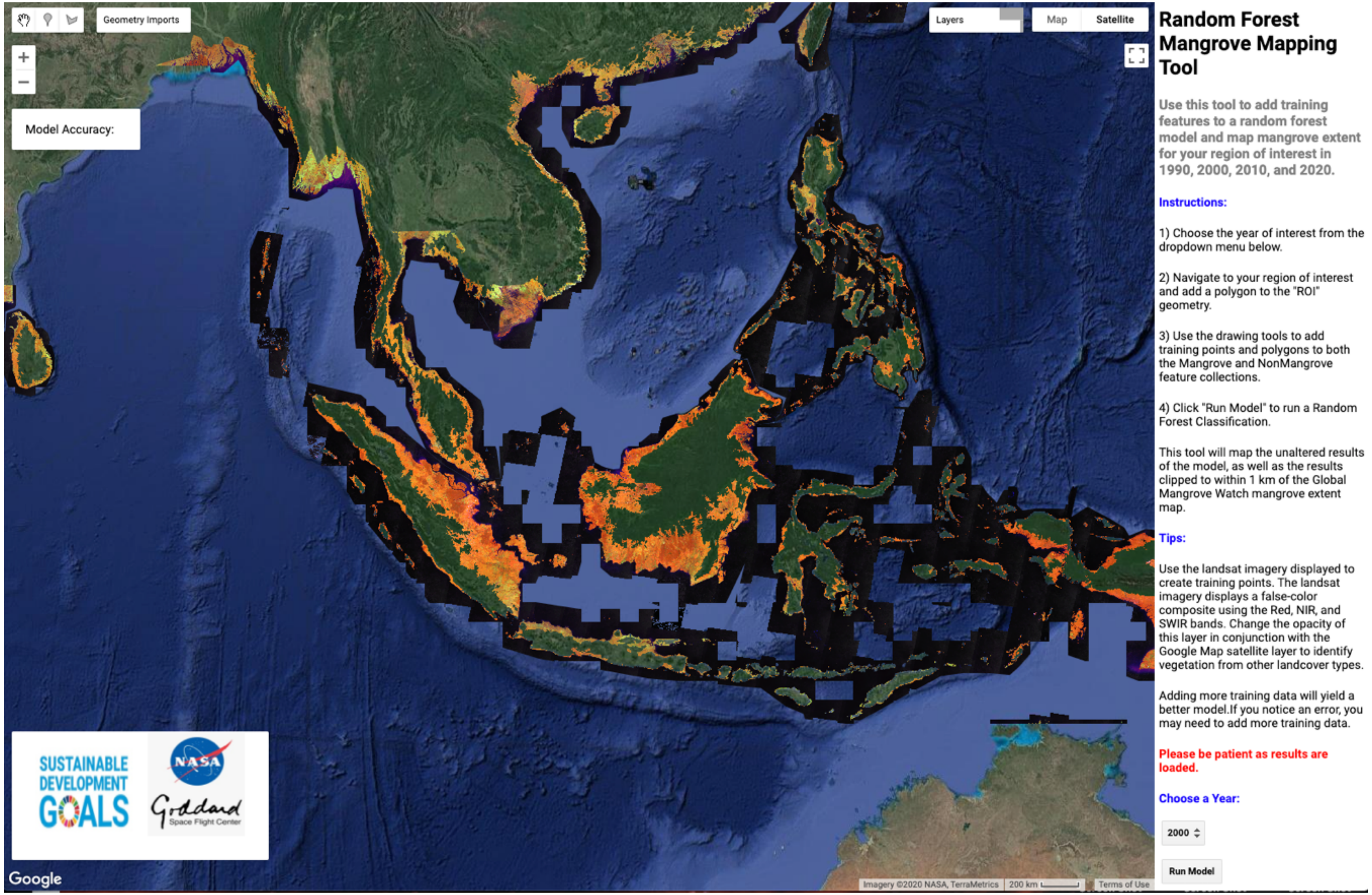
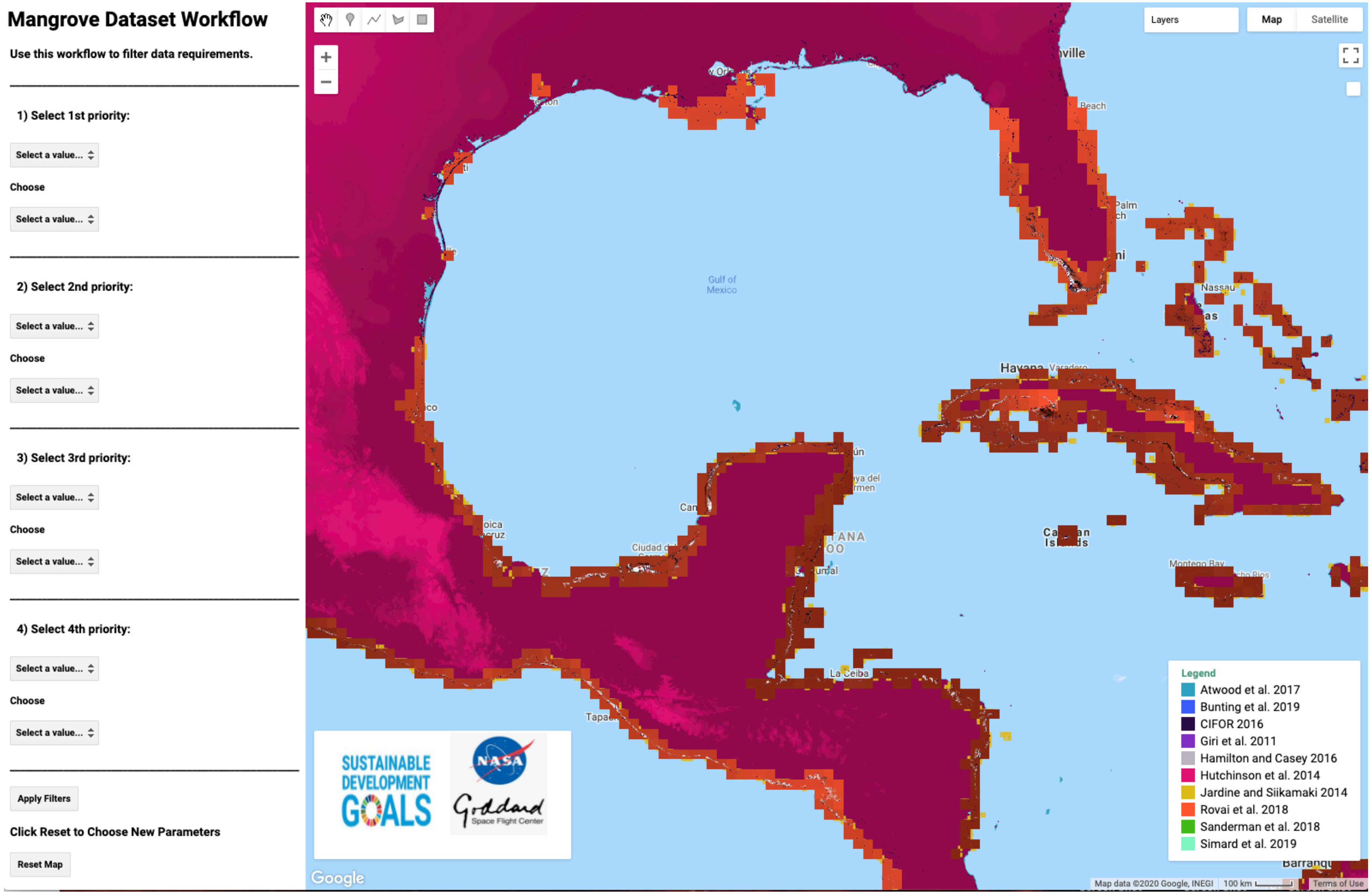
Random Forest Classification



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

Mangrove Dataset Workflow



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!