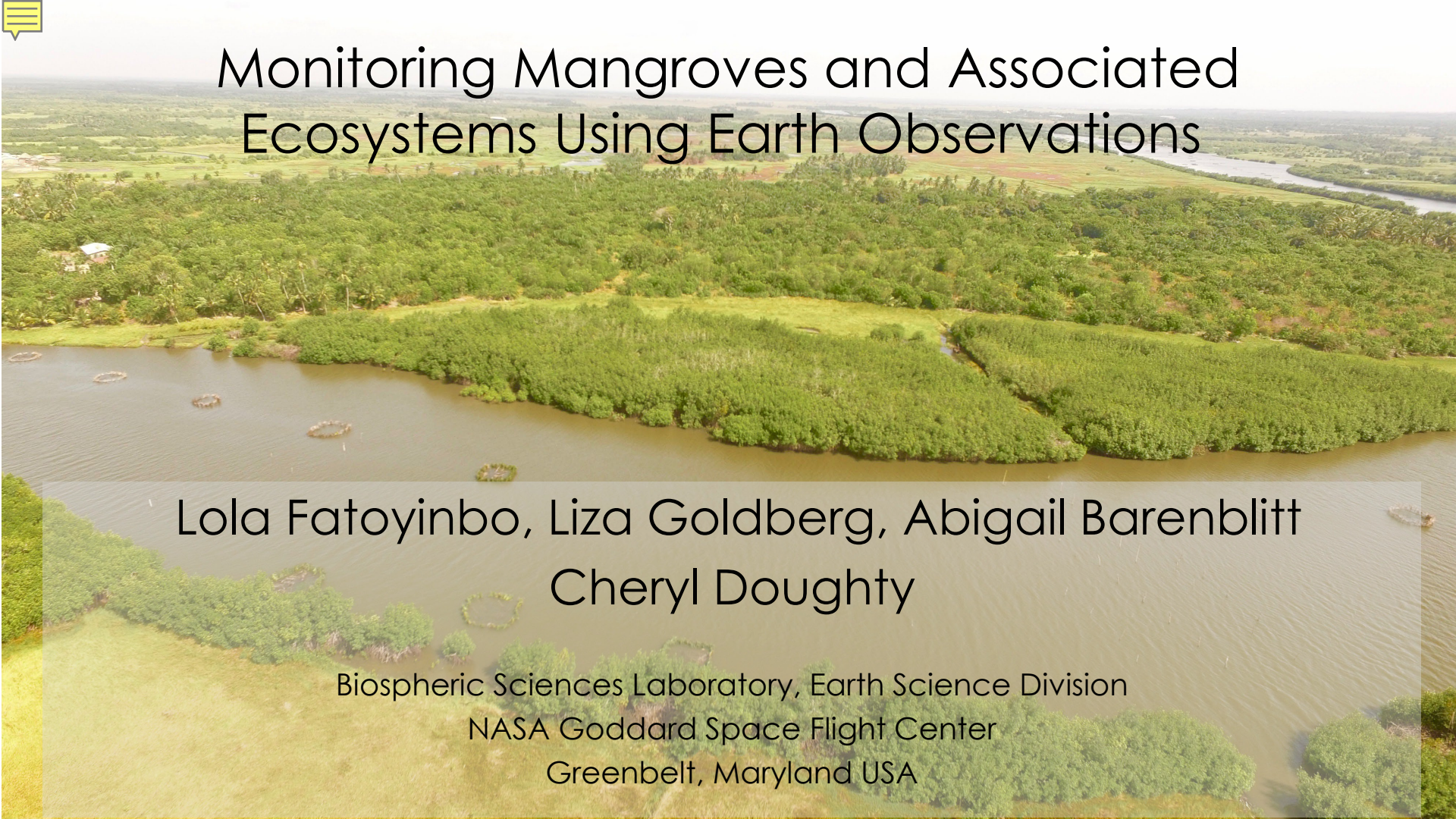
Monitoring Mangroves and Associated Ecosystems Using Earth Observations



Lola Fatoyinbo, Liza Goldberg, Abigail Barenblitt

Cheryl Doughty

Biospheric Sciences Laboratory, Earth Science Division

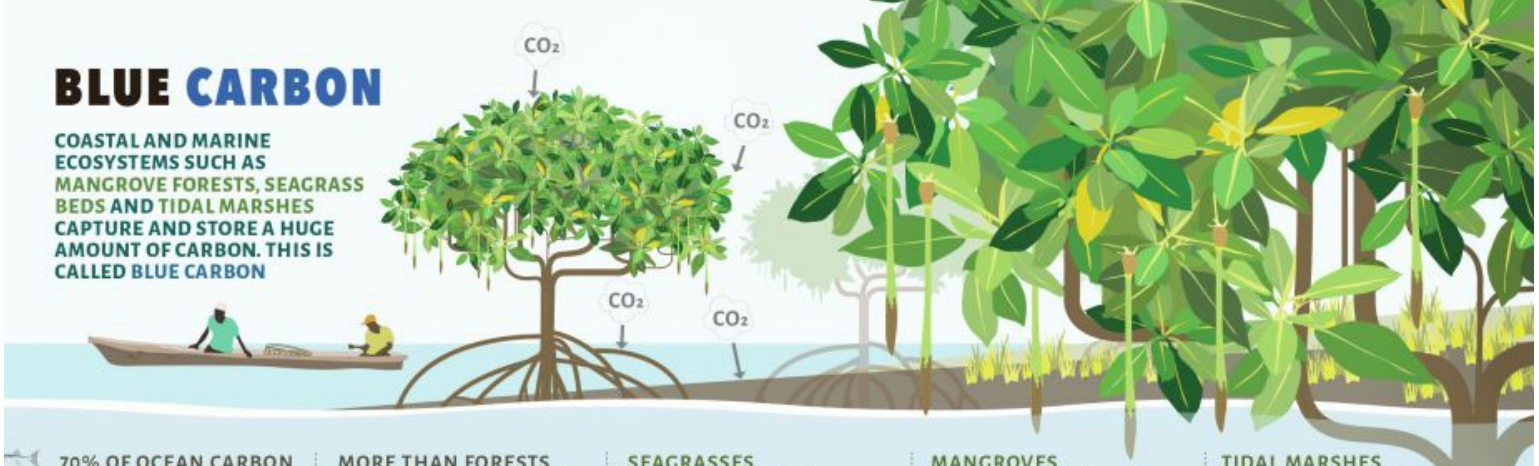
NASA Goddard Space Flight Center

Greenbelt, Maryland USA

Improved Mapping and Monitoring of Blue Carbon Ecosystems

BLUE CARBON

COASTAL AND MARINE ECOSYSTEMS SUCH AS MANGROVE FORESTS, SEAGRASS BEDS AND TIDAL MARSHES CAPTURE AND STORE A HUGE AMOUNT OF CARBON. THIS IS CALLED BLUE CARBON



70% OF OCEAN CARBON

Coastal ecosystems occupy less than 0.5% of the global ocean surface area, yet store around 70% of total carbon sequestered by the world's oceans.

MORE THAN FORESTS

Mangroves, seagrass and tidal marshes store more carbon per unit area than terrestrial forests and play a crucial role in mitigating climate change.

SEAGRASSES

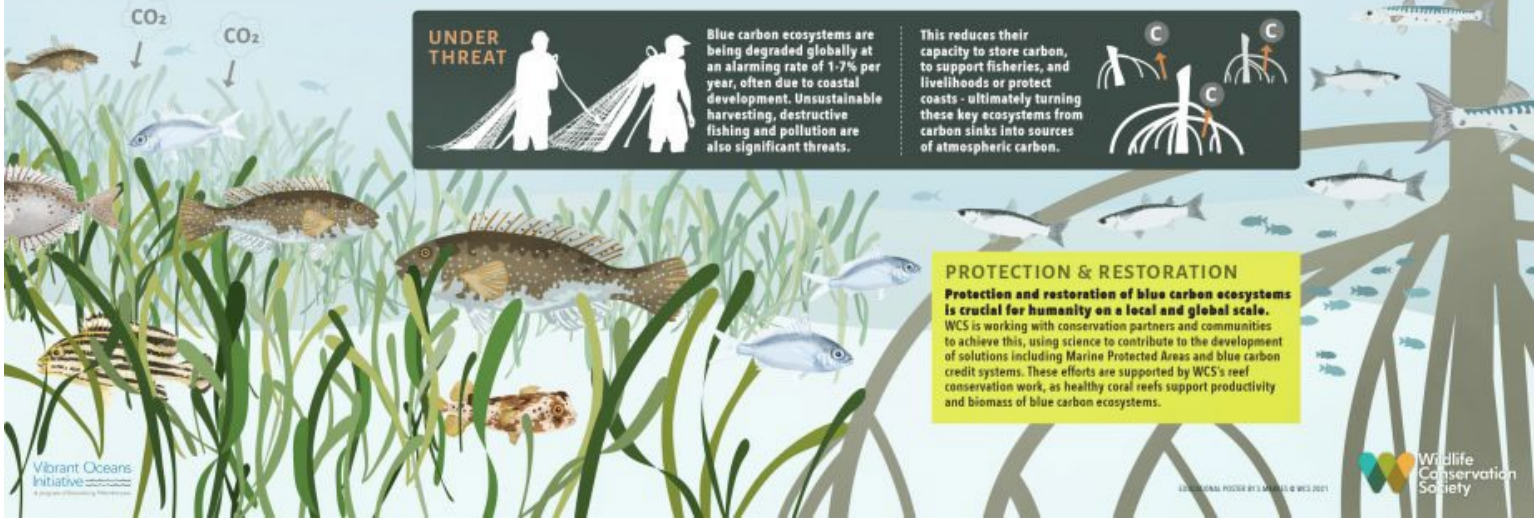
grow very fast, absorbing carbon from sea water to build their leaves and roots. Seagrass beds secure sediment and dead organic matter, storing a significant amount of carbon in the soil.

MANGROVES

absorb carbon dioxide from the atmosphere to photosynthesize. They are extremely effective at storing carbon in their leaves, wood and roots as well as in the sediments they hold in place.

TIDAL MARSHES

are home to numerous vegetation types that store carbon in addition to securing sediments and creating carbon-rich soil.



UNDER THREAT

Blue carbon ecosystems are being degraded globally at an alarming rate of 1-7% per year, often due to coastal development. Unsustainable harvesting, destructive fishing and pollution are also significant threats.

This reduces their capacity to store carbon, to support fisheries, and livelihoods or protect coasts - ultimately turning these key ecosystems from carbon sinks into sources of atmospheric carbon.

PROTECTION & RESTORATION

Protection and restoration of blue carbon ecosystems is crucial for humanity on a local and global scale. WCS is working with conservation partners and communities to achieve this, using science to contribute to the development of solutions including Marine Protected Areas and blue carbon credit systems. These efforts are supported by WCS's reef conservation work, as healthy coral reefs support productivity and biomass of blue carbon ecosystems.

Vibrant Oceans Initiative

Wildlife Conservation Society

Example: Global Mangrove Biomass and Carbon Stocks from space

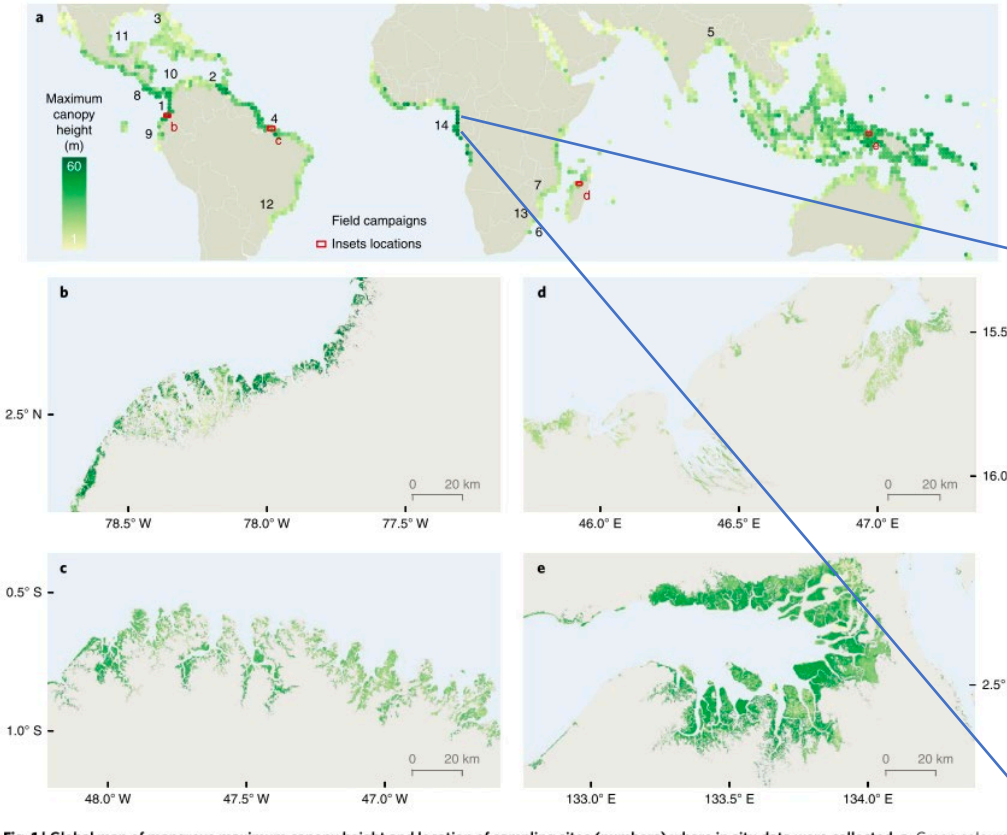
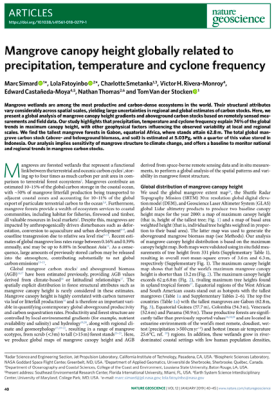


Fig. 1 | Global map of mangrove maximum canopy height and location of sampling sites (numbers) where in situ data were collected. a, Green colours show tallest maximum mangrove canopy height found within 1° cells. The map also shows the locations of the field sites and the locations of the high-resolution insets in **b**–**e**. **b**, Coastal Nariño and Cauca (Colombia). **c**, Coastal Pará (Brazil). **d**, Bombetoka Bay (Madagascar). **e**, Bintuni Bay (West Papua, Indonesia).



ARTICLES

nature geoscience

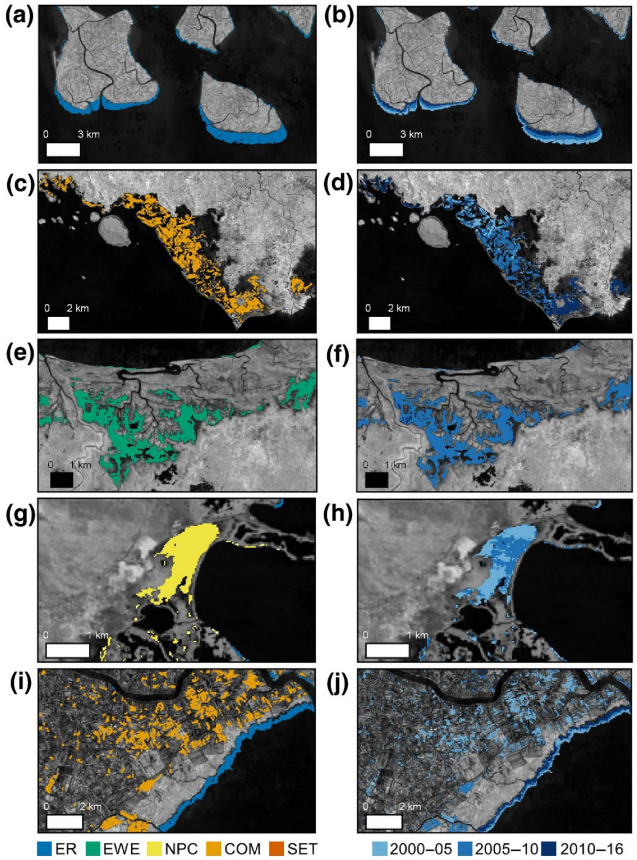
Mangrove canopy height globally related to precipitation, temperature and cyclone frequency

Marc Simard, Lola Fatoyinbo, Charlotte Smetanka, Victor H. Rivera-Monroy, Edward Castañeda-Moya, Nathan Thomas and Tom Van der Stocken

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 map of global mangrove canopy height at 1 km spatial resolution, developed from machine learning, remote sensing measurements and field data. Our study highlights that precipitation, temperature and cyclone frequency explain 70% 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 42.8 m. The total global mangrove carbon stock (above- and belowground biomass, and soil) is estimated at 8.55 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.

Simard, M., **Fatoyinbo, L.**, Smetanka, C., Rivera-Monroy, V.H., Castañeda-Moya, E., Thomas, N. and Van der Stocken, T., 2019. Mangrove canopy height globally related to precipitation, temperature and cyclone frequency. Nature

Example Application: Global Drivers of Forest Loss



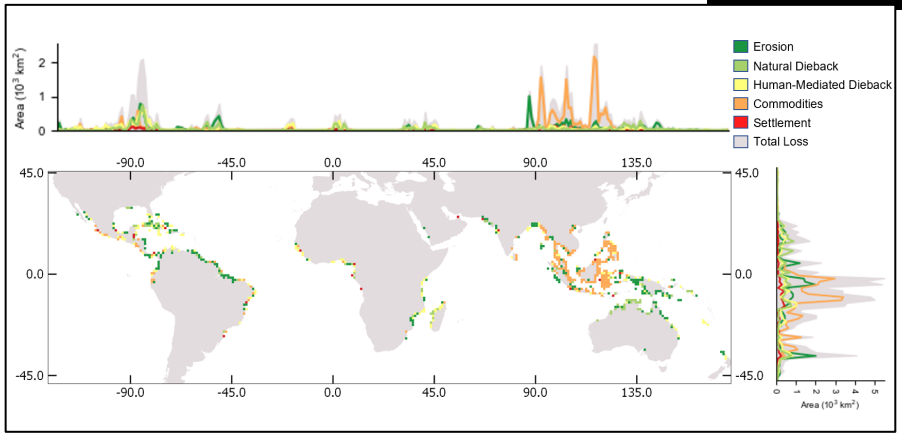
Shoreline Erosion

Commodities

Extreme Weather Events

Non-Productive Conversion

Coastal Squeeze

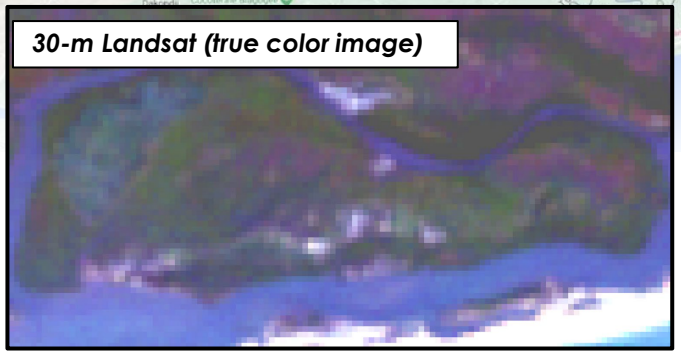


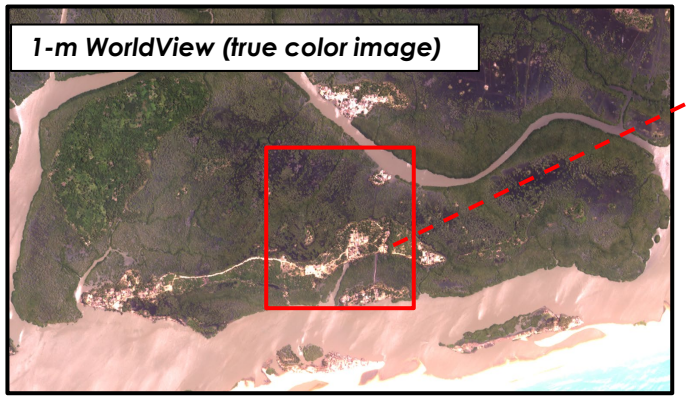
- 62% of global losses from 2000-2016 resulted from land-use change.
- 80% of these human-driven losses occurred within six Southeast Asian nations (Indonesia, Myanmar, Malaysia, the Philippines, Thailand, and Vietnam)

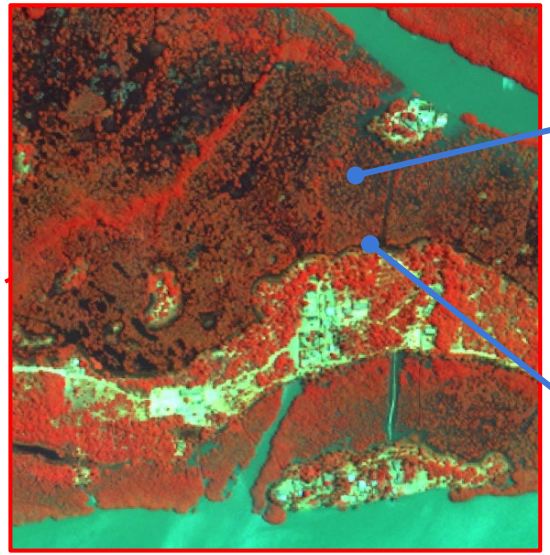
Goldberg, L., Lagomasino, D., Thomas, N. and Fatoyinbo, T. (2020), Global declines in human-driven mangrove loss. Glob Change Biol. doi:10.1111/gcb.15275

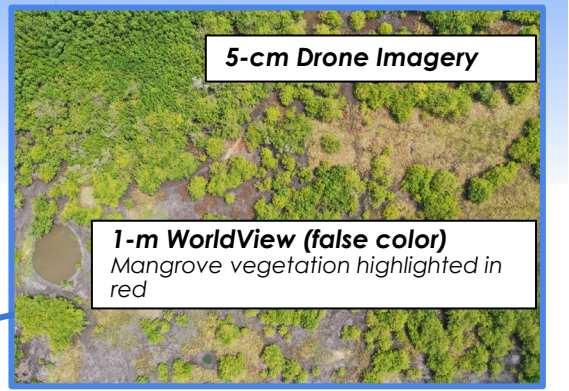
Mapping mangroves with multiple sensors

Reserve de Biosphere Transfrontiere du Mono - *Site de la Bouche du Roy*









In-Country Engagement

- SDG targets & Indicators:
  - SDG6 'Water for all' target 6.6.1,
  - SDG 15 'Life on Land', target 15.1.1, 15.1.2,
  - SDG13 ' Climate Action', target: 13.2.1, 13.2.2, 13.b1, 13.1
- Key Stakeholders and Partners:
  - **GEO Wetlands**
  - **Countries:** Benin, Nigeria, Senegal, West Africa Wide
  - **Government:** Ministries of Finance Benin, Direction of Water and Forests Benin, Ministry of State of the Niger Delta, Nigeria
  - **NGOs:** UNEP, IUCN, World Bank Group, The AFR100 Secretariat/African Union Development Agency (AUDA-NEPAD), Ecobenin, SDN and Oceanium

ECO-BENIN
BENIN ECOTOURISM CONCERN

CSE
Centre de Suivi Ecologique

IUCN

UN environment programme

afr100

AUDA-NEPAD
AFRICAN UNION DEVELOPMENT AGENCY

WeForest
Making Earth Cooler

Green Keeper Africa

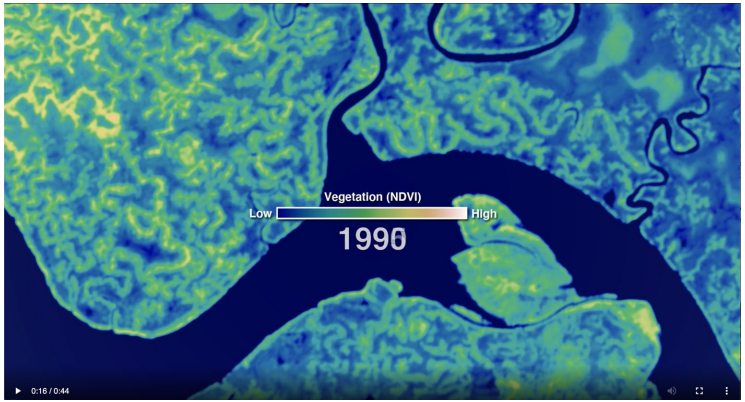
OCEANIUM
DAKAR

SDN

Senegal

- Key Stakeholders and Partners:
  - Oceanium, WeForest, IUCN, Centre de Suivi Ecologique
- Data being used:
  - Mangrove extent and change maps/ Landsat
  - Mangrove restoration potential/ Landsat (to be developed)
- Engagement:
  - Mangrove restoration sites visit and mapping/modeling needs assessments
- Anticipated Impact:
  - Use of data for restoration planning by NGO partners

Field work in the Saloum Delta with NASA GSFC and Oceanium NGO. Visit included mangrove field data collection, participation in mangrove reforestation and drone/GPS and field photo collection.



SVS Animation of Senegal mangrove Change

Benin:

- Key Stakeholders and Partners:
  - Ministry of Finance, Dept. of Water and Forests, EcoBenin, Benin National Water Institute, Greenkeeper Africa
- Data being used:
  - Mangrove extent and change maps/ Landsat
  - Carbon stock and change estimates/ Landsat
- Engagement:
  - Technical analysis of mangrove extent and carbon change from 1990
  - Planning Mapping training
- Anticipated Impact:
  - Use of NASA data for the implementation of National mangrove and National forest restoration efforts, policies, and COP 27

Benin Mangrove Cover 2020 with Loss since 1990

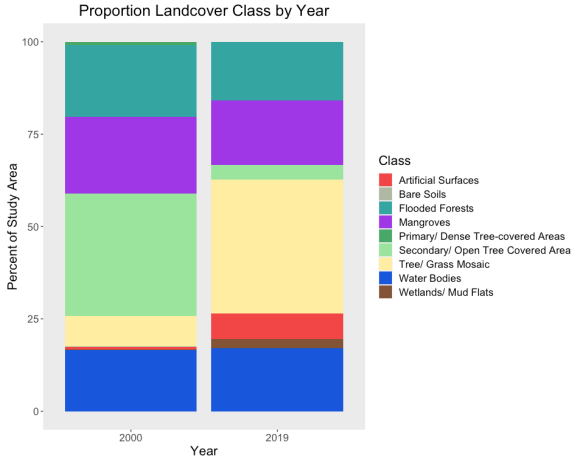
Meeting at National Water Institute

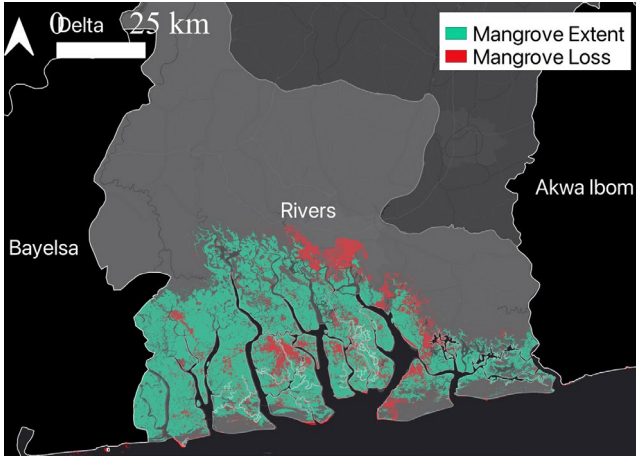
Diapaga
Togo
Ana
Ibad
Lagos
Lekki

DC
ECO-BENIN
BENIN ECOTOURISM CONCERN

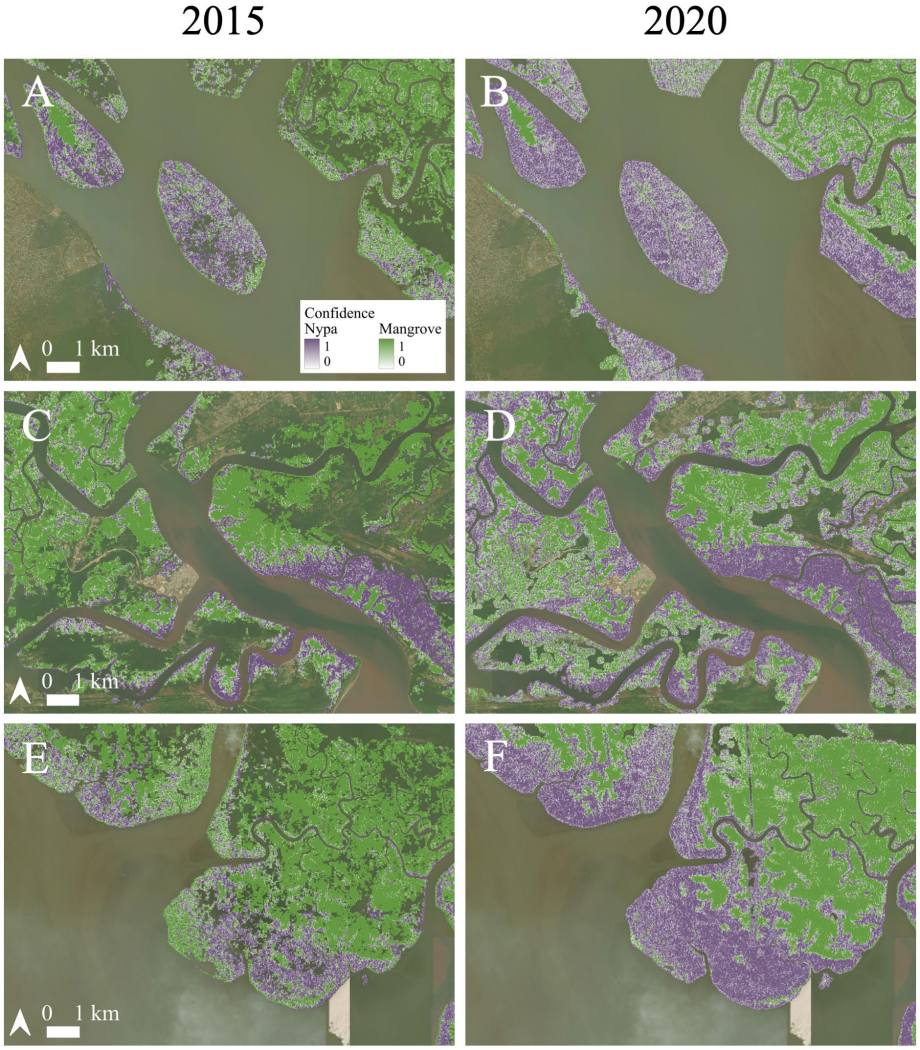
Nigeria

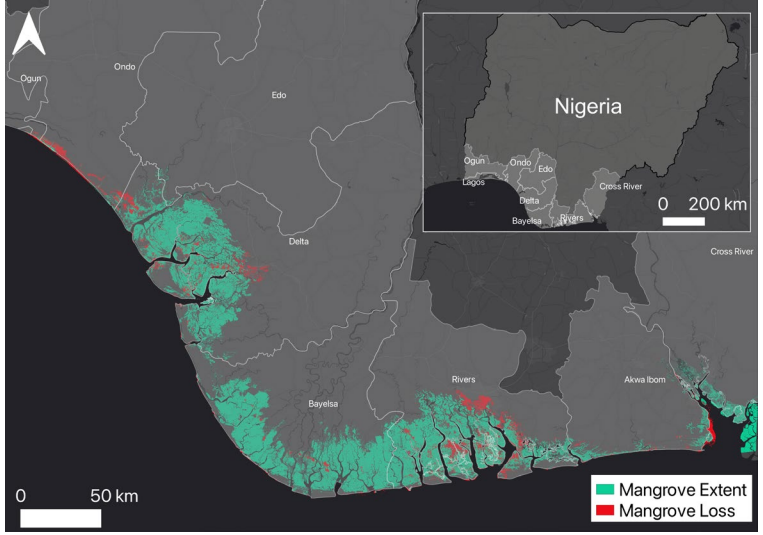
- Key Stakeholders and Partners:
  - UNEP, WorldBank, Stakeholder Democracy Network (SDN), African Nature Investors (ANI), Ministry of Environment, Ministry of State for Niger Delta Affairs
- Data being used:
  - Coastal/ mangrove extent, change and drivers of change maps 1990 -2019 (Landsat)
  - Invasive Species extent/ change(Landsat, GEDI, S1)
- Engagement:
  - Presentation package on mangrove status and importance for Ministry of State for Niger Delta Affairs
- Anticipated Impact:
  - Development of mangrove policy for Nigeria
  - Support establishment of mangrove protected

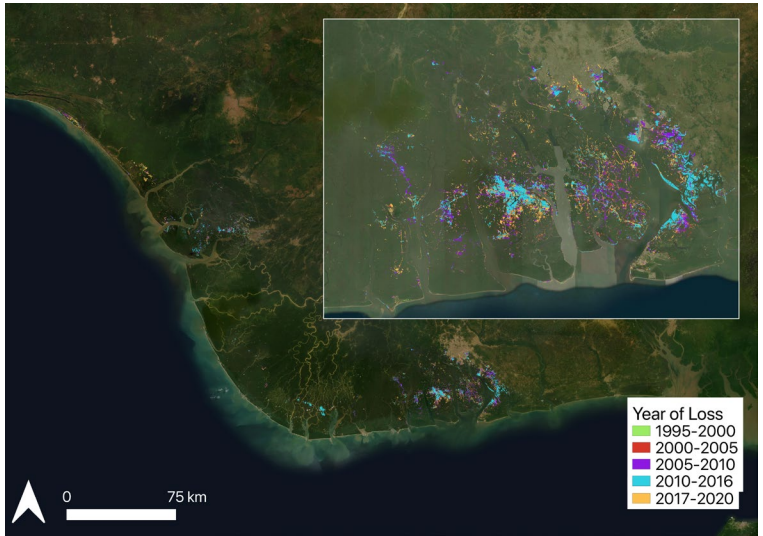




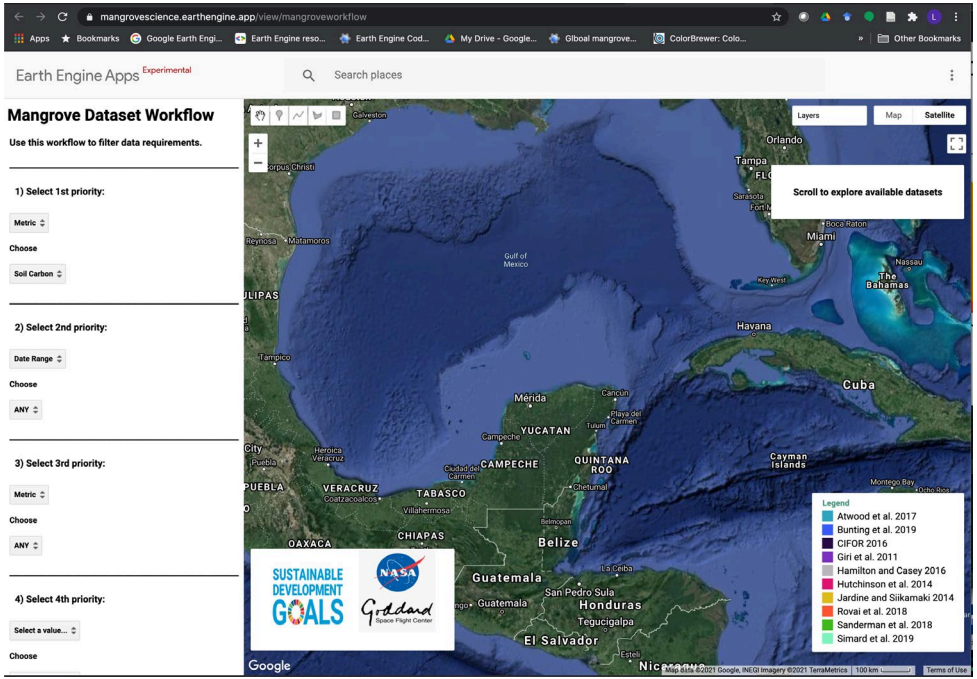
Mangrove extent and loss maps from 1990 - 2020 for Nigeria from Landsat, shared with Nigerian partners

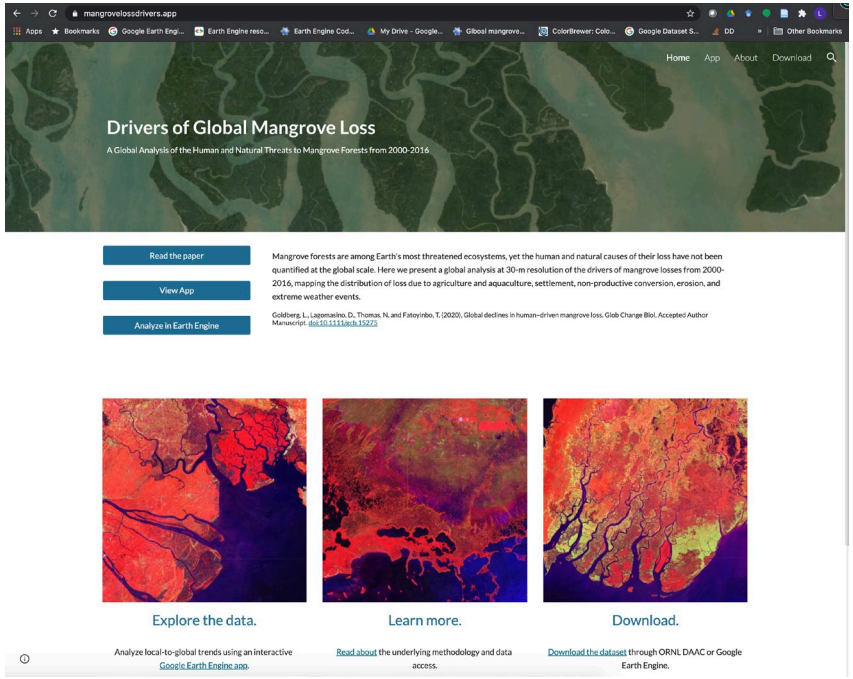

2015
2020
A
B
C
D
E
F
Confidence
Nypa
Mangrove
1
0
1
0
0 1 km
0 1 km
0 1 km


Ogun
Ondo
Edo
Delta
Bayelsa
Rivers
Akwa Ibom
Cross River
Nigeria
Lagos
0 200 km
0 50 km
Mangrove Extent
Mangrove Loss


0 75 km
Year of Loss
1995-2000
2000-2005
2005-2010
2010-2016
2017-2020

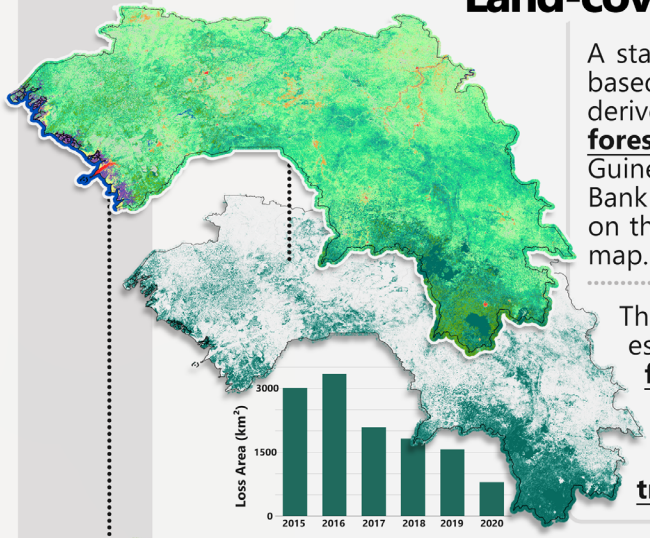
Data Dissemination





Guinea

Land-cover and Forests

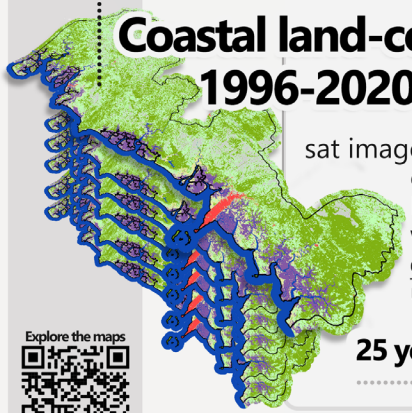


A state-of-the-art remote sensing classifying approach based on machine learning algorithms was used to derive a **30-m resolution 13-class land cover map and forest cover for the year 2014**, the first of its kind for Guinea. Our team has worked closely with the World Bank Task team - our intermediate end-user - to agree on the thematic content and class nomenclature of the map.

Guinea forests in 2014 and beyond

The forest classes in the LCM (and subsequent forest/non-forest map) followed Guinea's adopted **forest definition of 10% canopy cover and at least 5 meters of height**. The yearly forest extent losses for subsequent years were computed based on the 2014 forest/non-forest map, using a **spectral index anomaly-based** approach.

Coastal land-cover 1996-2020



In order to monitor the historical land cover changes for the coastal zone in Guinea, we combined the LandTrendr algorithm with Landsat imagery to produce annual (1996-2020) land cover and forest map for the coastal prefectures of Boffa, Boké, Conakry, Coyah, Dubréka and Forécariah. The **annual changes** were compiled using error matrices which highlighted, for example, the **downward trend in mangrove extent** led primarily by **conversion into rice fields** and the steady urbanization of the Conakry region.

25 years of land extent accounts

Land cover extent account

Area (km²)								
Opening stocks	**398.26**	**105.34**	**452.16**	**5.31**	**5,096.42**	**10,254.24**	**2,424.01**	**7,636.08**
Reduction	16.94	2.36	133.02	8.90	2,356.09	3,688.75	445.19	1,600.22
Addition	21.73	84.17	315.96	4.08	639.56	3,502.25	263.64	3,410.43
Net change	*4.79*	*81.81*	*182.94*	*-4.82*	*-1,716.52*	*-186.51*	*-181.55*	*1,810.22*
Closing stocks	**403.05**	**187.14**	**635.10**	**10.13**	**3,379.89**	**10,067.73**	**2,242.46**	**9,446.29**

Explore the maps

Helping to inform decisions

The Guinea Land Cover Mapping project initiated in January, 2021 as a **joint venture between the World Bank, the Universities Space Research Association (USRA) and NASA Goddard Space Flight Center.**

The results summarized here were developed using Google Earth Engine (GEE), a **web-based and free cloud-computing platform** that revolutionized time-consuming remote sensing processes, allowing for rapid land cover classification at large scales.

We took advantage of GEE's programming language to develop **online self-paced tutorials** covering all the information and processes used to derive the results, maps and layers **aiming to build capacity in Guinea to ensure the continuity of the monitoring of the land-cover in the future.**

The maps are now being used by the government of Guinea to **plan for 17 new National Parks** – and it's **being used** for the **Guinea's Nationally Determined Contributions (NDC) report.**

TRAINING

ARSET - Remote Sensing for Mangroves in Support of the UN Sustainable Development Goals

PROGRAM AREA: ECOLOGICAL FORECASTING

0
SHARES

NASA
Goddard
SPACE FLIGHT CENTER