SOCODEVI

# COLLOQUE SUR LES ECOSYSTEMES DE MANGROVES

## Partager des expériences pour une gestion durable

## The Google Earth Engine Mangrove Mapping Methodology (GEM)

**Présentée:** Awa Rane Ndoye

Blue Venture

IUCN NDRODAY Casades CAREM REFEPAS IISD TAYO

En partenariat avec Canada

# The Google Earth Engine Mangrove Mapping Methodology (GEM)

Natur'ELLES, Dakar, Senegal
July 2025



1. **Mangrove mapping**

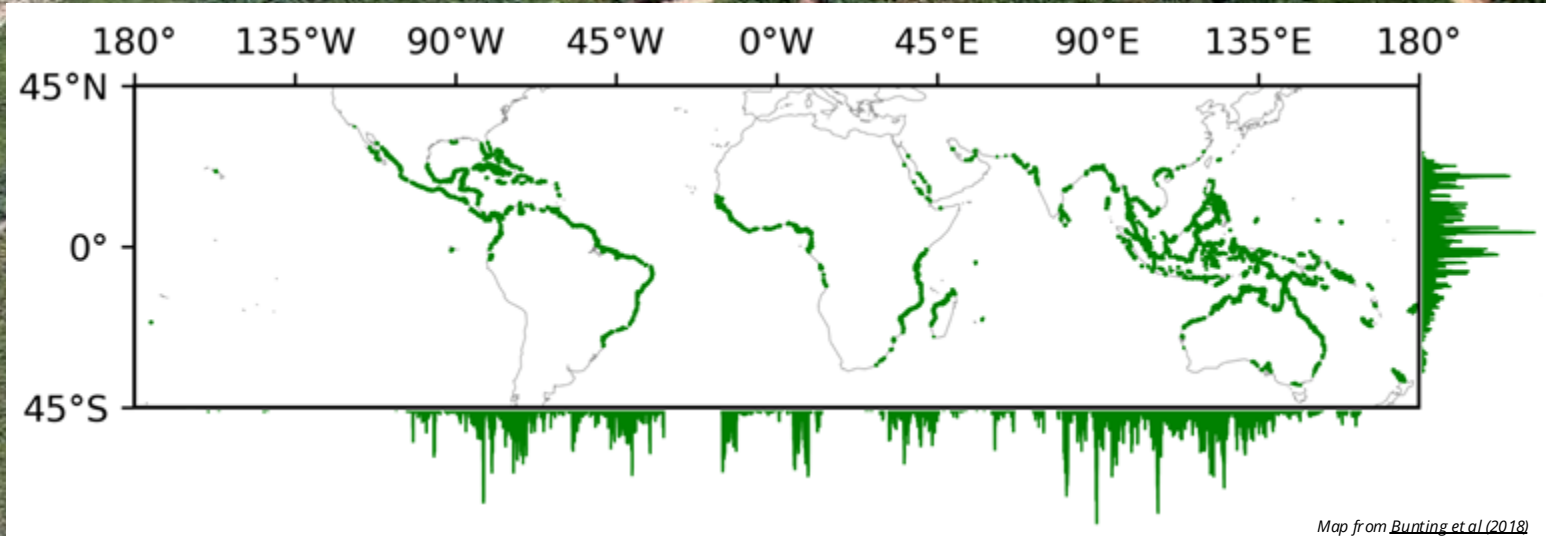
1. **GEM**

1. **CRAs**

1. **Next steps**

# Mangrove ecosystems (blue forests)

- Inter-tidal areas within >120 countries
- Ecosystem goods and services
- Floral and faunal biodiversity
- Carbon dense

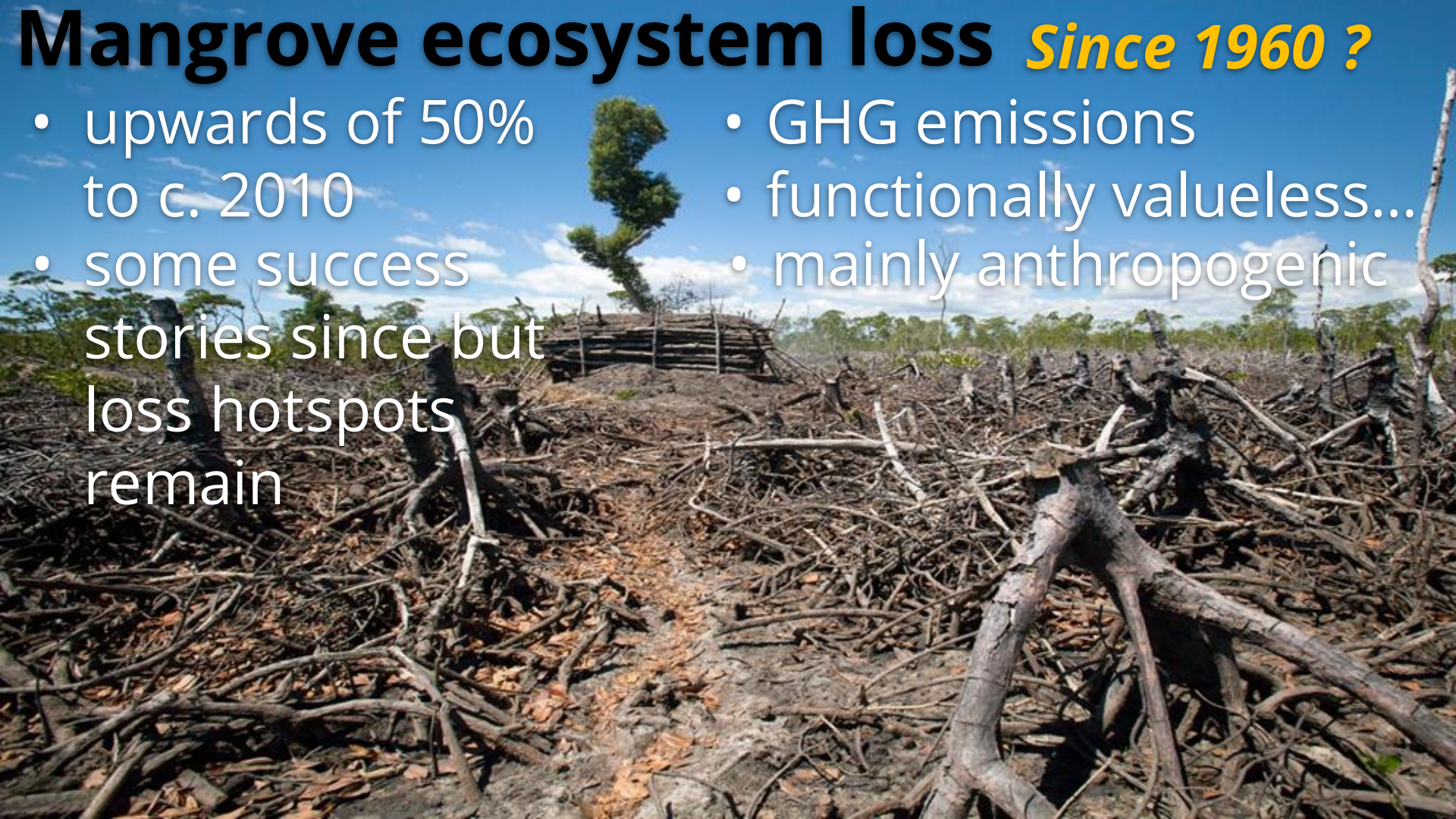



*Map from Bunting et al (2018)*

# Mangrove ecosystem loss *Since 1960 ?*

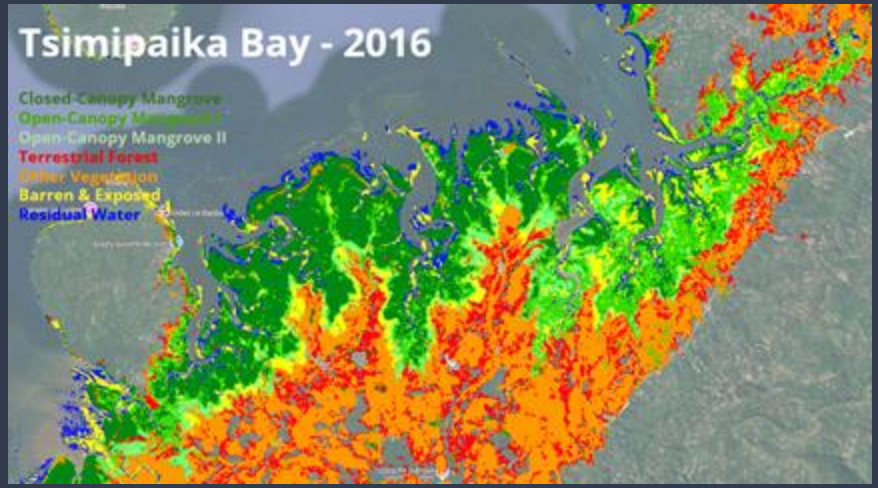
- upwards of 50% to c. 2010
- some success stories since but loss hotspots remain

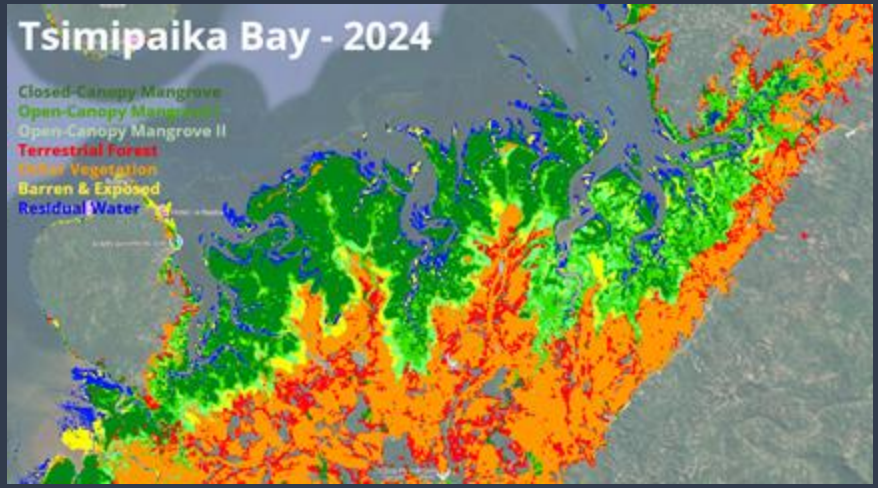
- GHG emissions
- functionally valueless…
- mainly anthropogenic



# The need for multi-date mangrove maps

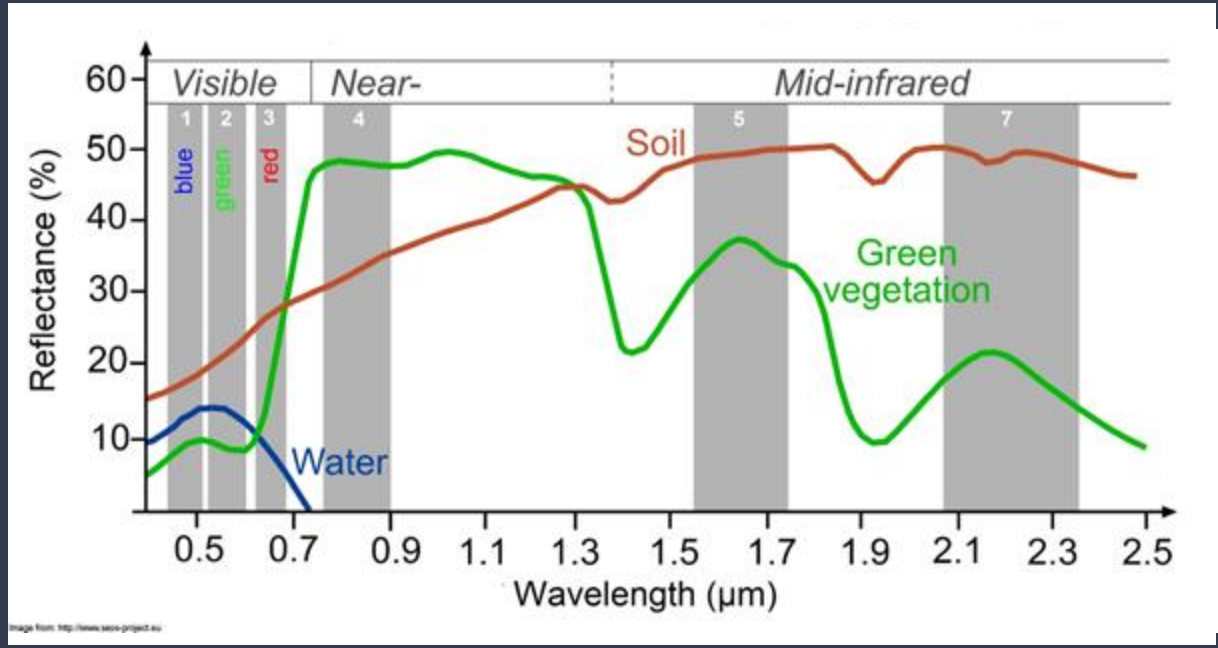
- Management needed for provisioning, regulating, cultural services, biodiversity
- Maps help us manage mangroves
  - A single mangrove map tells us mangrove extent
  - Multi-date maps give us dynamics (change over time)



# Remote sensing

- Acquiring information about an object or phenomenon without making contact with the observation target
- The electromagnetic spectrum - wavelengths of light from the sun
- Typical wavelengths used for vegetation:
- Bands measure regions of wavelengths within the electromagnetic spectrum
  - Visible (BGR)
  - Near-infrared
  - Short-wave infrared



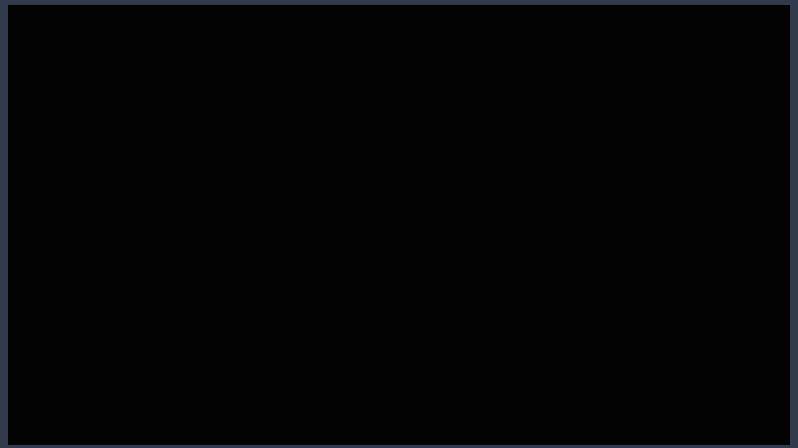
# Satellite sensors available in GEM

**Landsat (NASA)**

- 9 satellites since the 1970s
- Landsat 8 and 9 currently operational
- 30 m spatial resolution

**Sentinel-2 (ESA)**

- Launched in 2015
- Constellation of 2 satellites
- 10 m spatial resolution



*GIF from NASA*

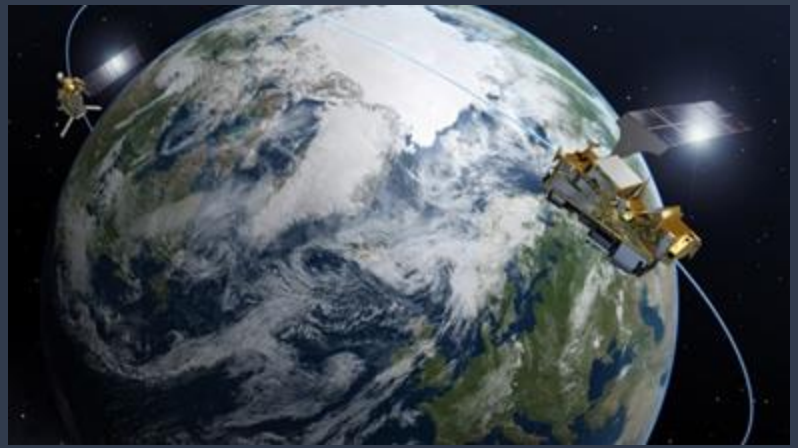
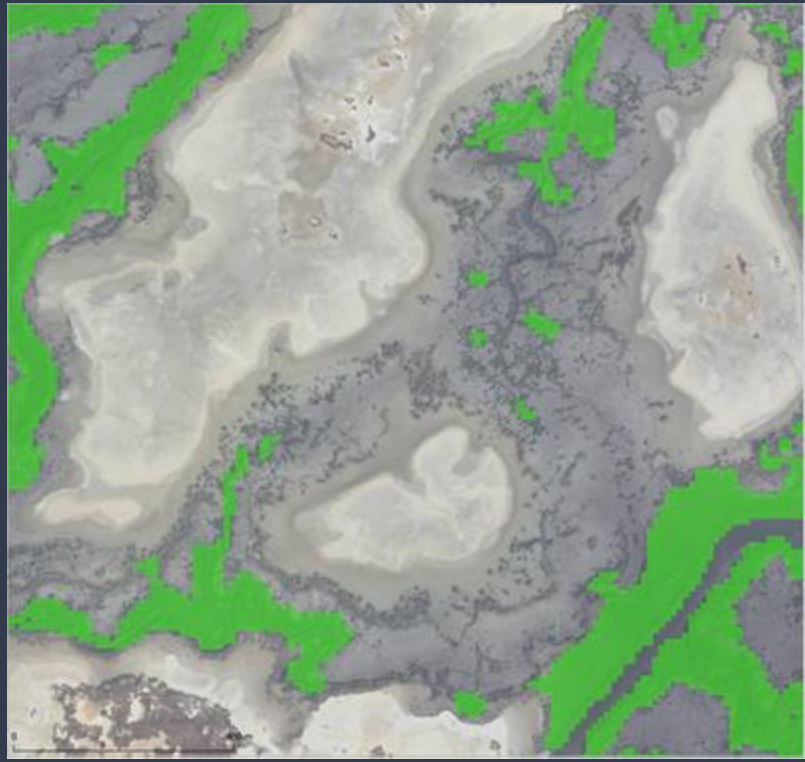


*Image from GIM International*

The southern edge of Somone Lagoon

# Limitations with existing datasets

- National and regional maps at limited time intervals
- Global products (e.g., GMW) have unprecedented detail, time steps, coverage
- But: limited use when applied to local scale
- Typically only one mangrove class
- No nuance re: ecological variability (sub-types)
- No distinction between mangrove forest and wider ecosystem (including non-forest)
- Definition? What constitutes mangroves?
- Often underrepresents true mangrove extent
- Typically ignore tidal conditions



*Map from Global Mangrove Watch v4*

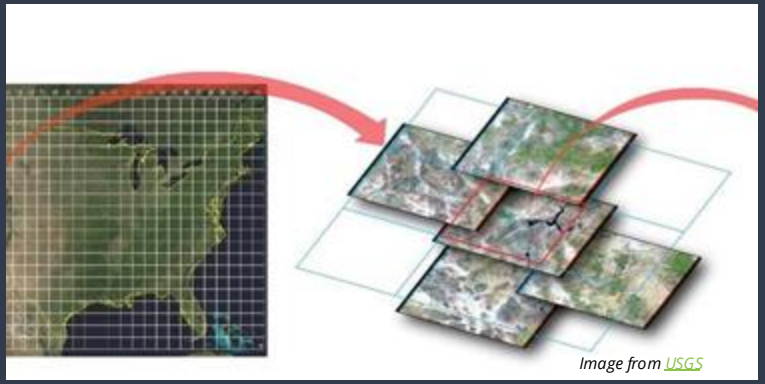
# The need for local mapping

- Overcome limitations in global products
- Make high quality local-level maps

- Overcome traditional barriers:
  - Technical capacity
  - Data access/storage
  - Data processing

There are many satellites...


taking many images...



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1. Mangrove mapping
1. **GEM**
1. CRAs
1. Next steps


Click to play video

# GEM: An Introduction

What is it?

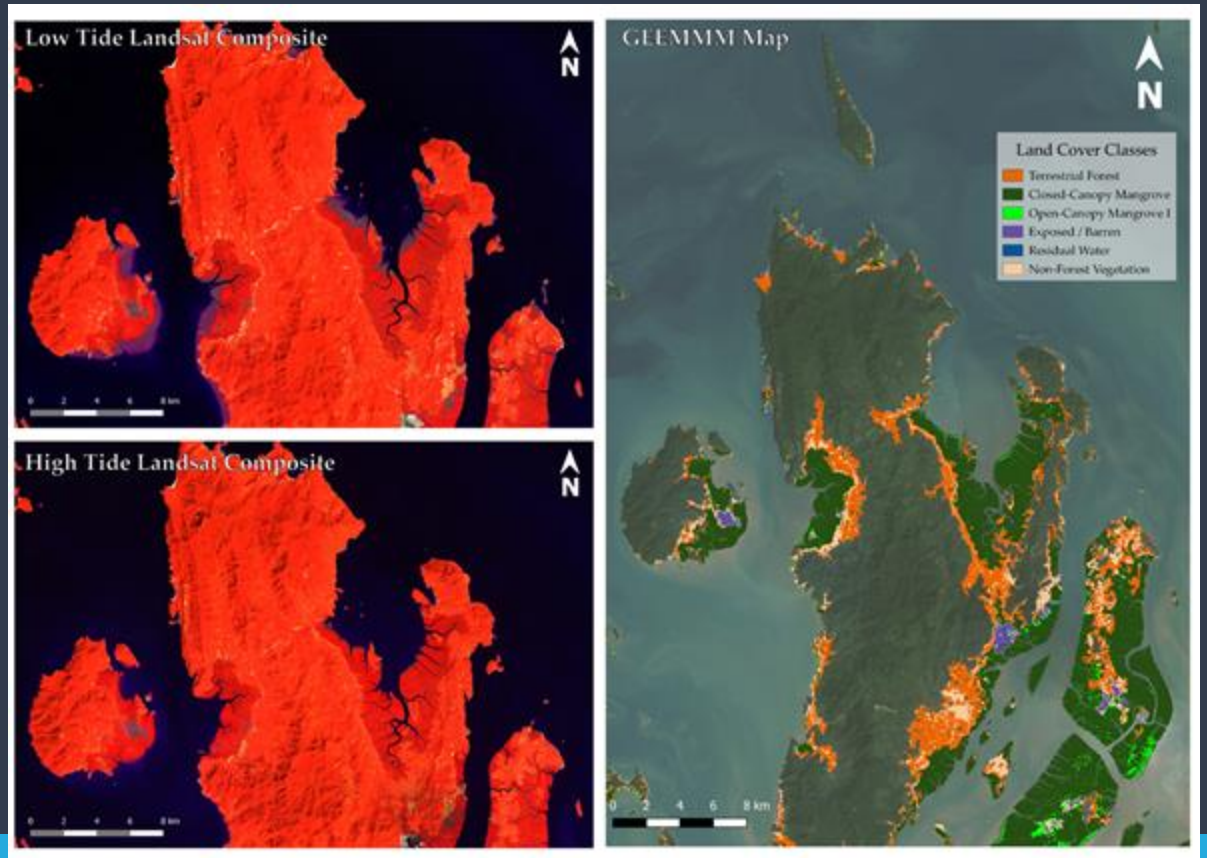
- Conceived in 2016
- Google Earth Engine Mangrove Mapping Methodology (GEM)
- New tool: produce maps of + assess change in mangroves

Why it's needed:

- Fill gaps in data availability for smaller areas
- Open-access, free-to-use, accessible, semi-automated
- Uses cloud-based storage and processing
- Overcomes: data access, processing, and software barriers
- Outputs: accurate, reliable, timely, and locally relevant

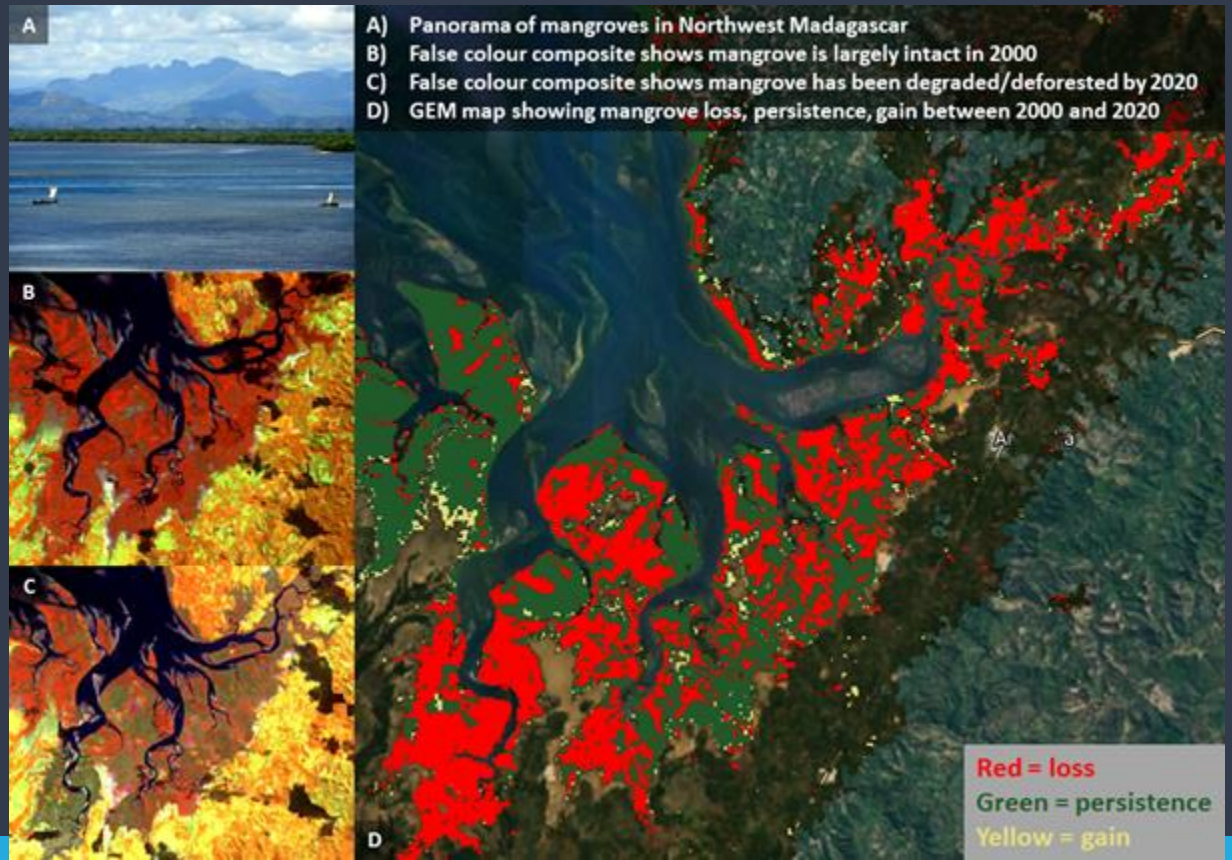
# GEM makes maps

Using a novel methodology ensuring images are captured at high and low tide



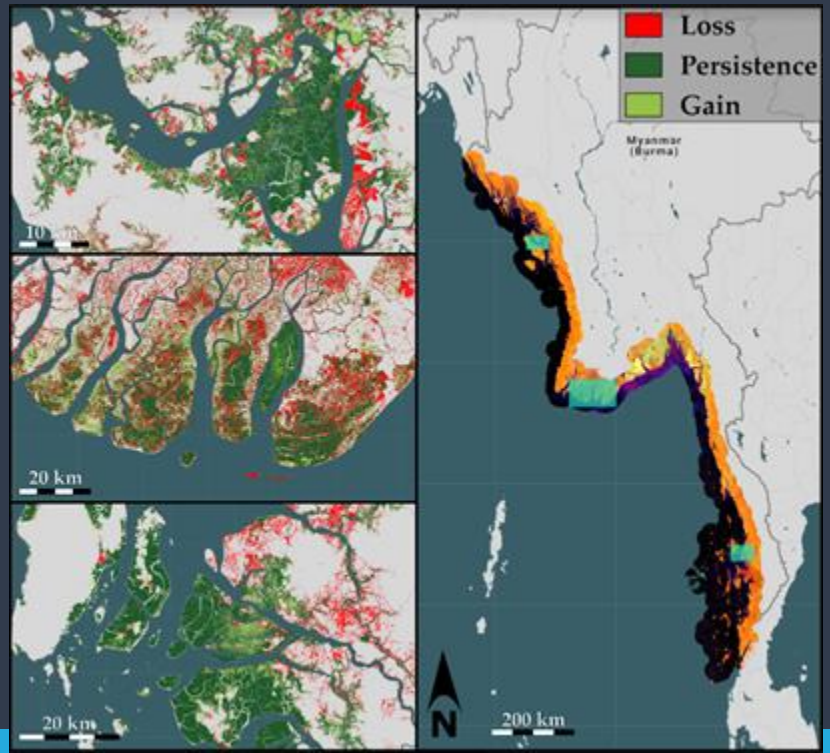
# GEM assesses dynamics

Using maps based on comparable tidal inputs

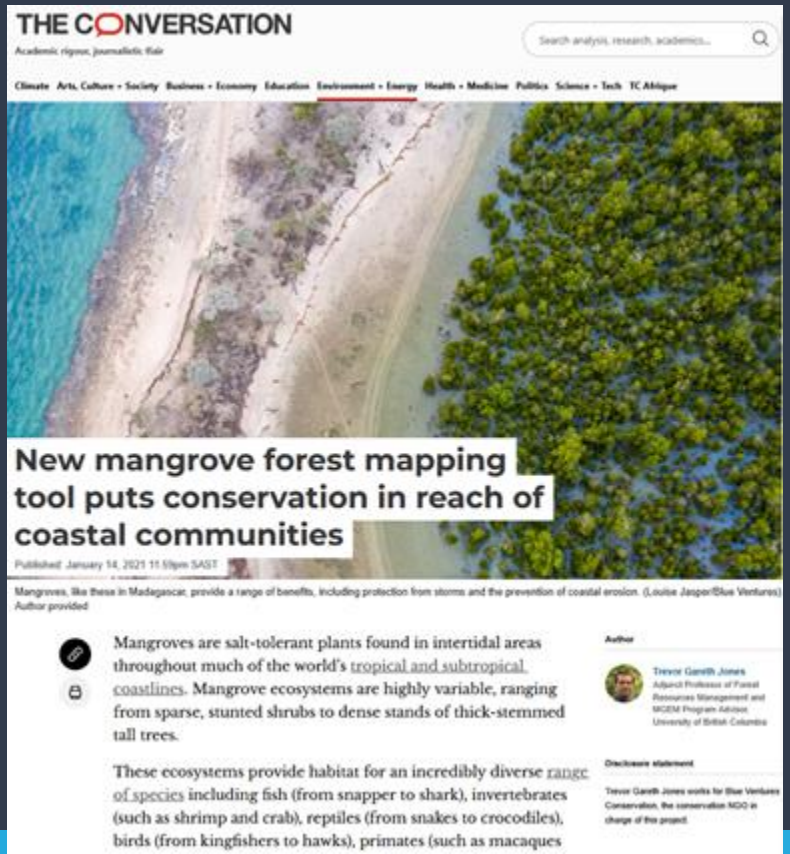


# 2020 Publication: Myanmar

The Google Earth Engine Mangrove Mapping Methodology (GEM), Yancho et al, 2020, Remote Sensing Journal




# 2021: *The Conversation* Article


THE CONVERSATION

Academic rigour, journalistic flair

Search analysis, research, academics...

Climate Arts, Culture + Society Business + Economy Education Environment + Energy Health + Medicine Politics Science + Tech TC Afrique

**New mangrove forest mapping tool puts conservation in reach of coastal communities**

Published: January 14, 2021 11.59pm SAST

Mangroves, like these in Madagascar, provide a range of benefits, including protection from storms and the prevention of coastal erosion. (Louise Jasper/Blue Ventures) Author provided

Mangroves are salt-tolerant plants found in intertidal areas throughout much of the world's tropical and subtropical coastlines. Mangrove ecosystems are highly variable, ranging from sparse, stunted shrubs to dense stands of thick-stemmed tall trees.

These ecosystems provide habitat for an incredibly diverse range of species including fish (from snapper to shark), invertebrates (such as shrimp and crab), reptiles (from snakes to crocodiles), birds (from kingfishers to hawks), primates (such as macaques

Author

Trevor Gareth Jones
Adjunct Professor of Forest Resources Management and MGEM Program Advisor, University of British Columbia

Disclosure statement

Trevor Gareth Jones works for Blue Ventures Conservation, the conservation NGO in charge of this project.

# 2022 Trialing GEM at the local level (Madagascar)

## GEM Trials Internal Summary

Samir Gandhi, Max Yancho, Trevor Jones

March 2022

*The GEM tool was created in 2020 and piloted for all of Myanmar's coastline. In 2021, we carried out a series of trials to hone in on the optimal settings for applications to smaller areas of interest in Madagascar. This summary is intended for anyone on the BV team, and overviews the details of the trials and optimal GEM settings. These lessons can be applied around the world to any sub-national areas of interest containing mangrove ecosystems.*

### The GEM: what it is, why it's needed and who it's for

The GEM (Google Earth Engine Mangrove Mapping Methodology) tool was first published in 2020 by the Blue Forests team. The tool's primary utility is producing current and historical maps of mangrove extent and calculating change over time. Compared to conventional mapping methods: it's relatively accessible and intuitive.

The GEM reduces the significant hurdles resource managers face when producing reliable mangrove maps at the local level. Accurate mapping requires extensive and typically costly expertise in satellite imagery analysis, data processing, and coding. Existing mangrove maps, such as those offered by Global Mangrove Watch, provide critical data but are not intended for smaller areas of interest (AOIs). In contrast to "force-fitting" global datasets to local applications, the GEM can be used to generate maps for specific AOIs following a step-by-step workflow. The tool taps into an online cloud-based analysis platform called Google Earth Engine (GEE), which removes most of the conventional data processing burdens.

### The Myanmar pilot:

The GEM was initially assessed (in 2020) at the national-level for all of Myanmar for contemporary (2014-2018) and historical (2004-2008) time periods. The results were compared with 11 previously published studies that had mapped mangrove distribution in Myanmar over similar periods. Although direct comparisons between datasets are challenging for various reasons (ex: different mapping methodologies, misaligned time periods, different definitions of "mangrove"), the GEM results broadly agreed with overall trends observed across other studies (see **Figure 1**), identifying a 35% overall loss in mangroves.

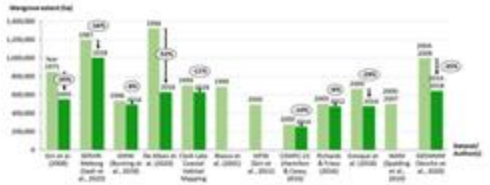
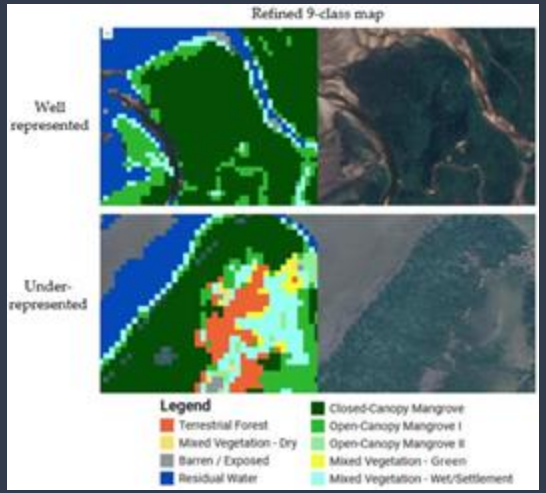


**Figure 1:** Results of mangrove extent and change from published studies and the GEM pilot.

# 2024 GEM Desktop v2 released

- GEM v1 used 30 m pixels
  - Landsat-based
  - Best available option at the time for assessing dynamics
- GEM v2 adds 10 m pixels
  - Sentinel-2 launched in 2015
  - 10 year archive of imagery
  - GEM reconfigured to use smaller pixels
- Increase in spatial resolution (30 to 10 m)
- Better data inputs
- Improved dynamics
- Less bugs

# 2025 GEM App launched

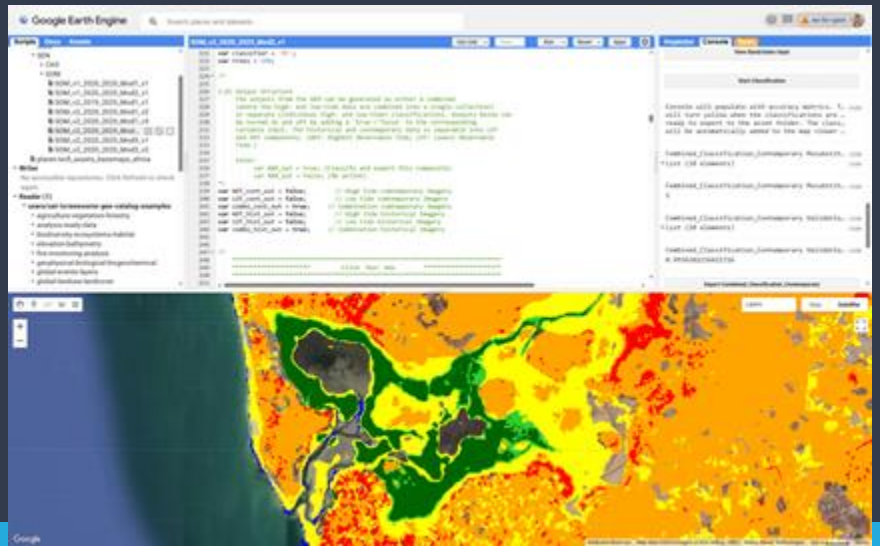
© Blue Ventures

# Accessing GEM

# GEM is available in two formats

## GEM Desktop

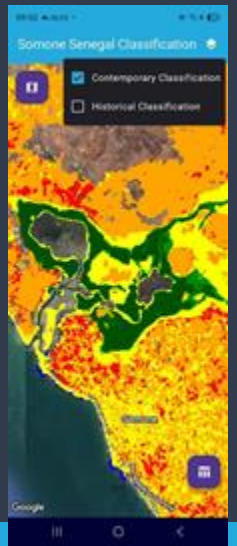
- The easiest format to develop, GEM Desktop came first in 2020
- Best for expert geospatial users
- Has advanced features
- Can be tailored for their own purposes
- Where the GEM Team build new GEM versions

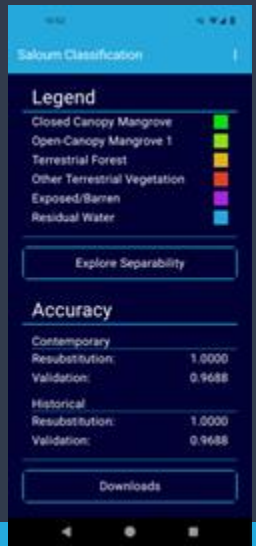



## GEM App

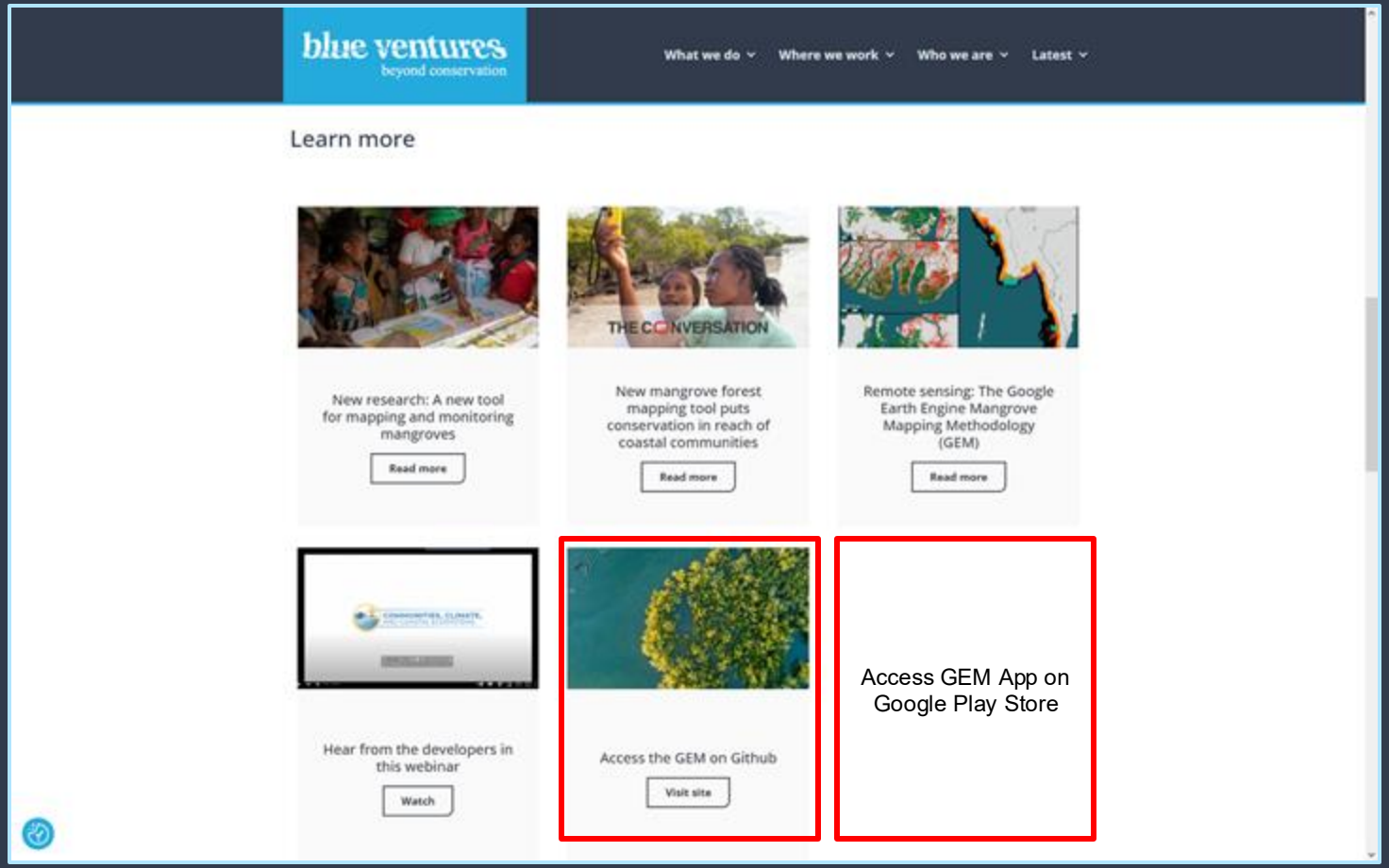
- Launched in 2024 for Android devices
- Designed for less technical users
- More accessible, user-friendly and intuitive
- Automates many of Desktop's decision points
- Available in 10 languages

  English, French, Malagasy, Swahili, Portuguese, Spanish, Cebuano, Indonesian, Tetun, Tagalog

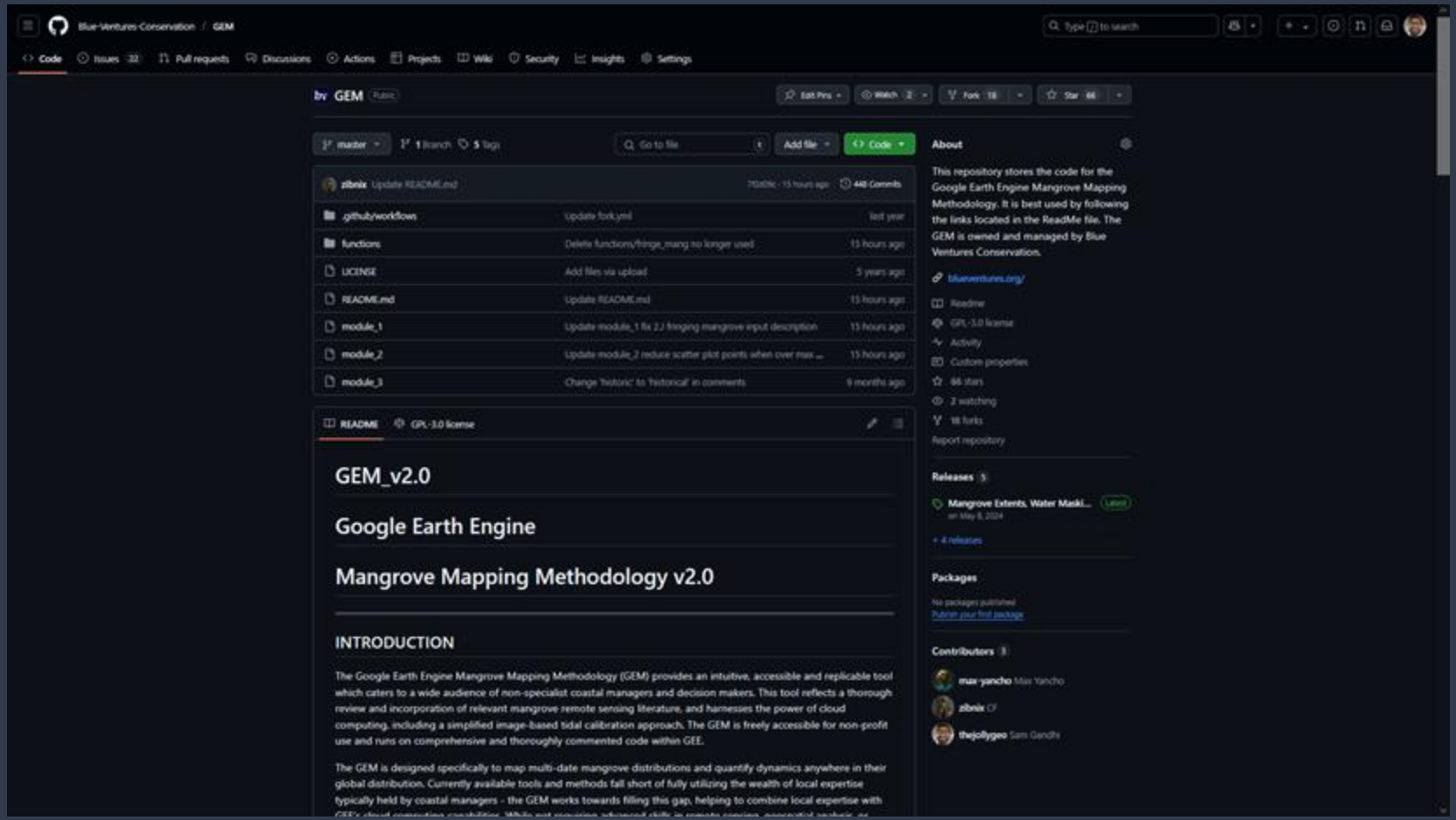



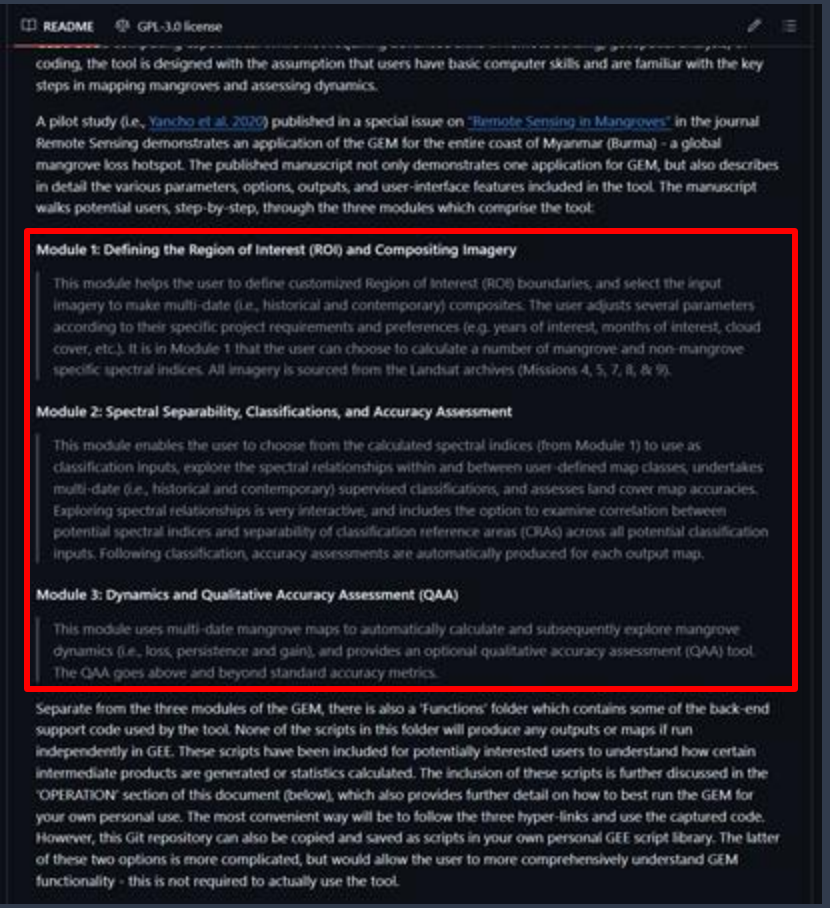
# Access both from the BV website



# GEM Desktop is on GitHub



# Where the 3 modules of GEM Desktop are found



README GPL-3.0 license

coding, the tool is designed with the assumption that users have basic computer skills and are familiar with the key steps in mapping mangroves and assessing dynamics.

A pilot study (i.e., Yancho et al. 2020) published in a special issue on "Remote Sensing in Mangroves" in the journal Remote Sensing demonstrates an application of the GEM for the entire coast of Myanmar (Burma) - a global mangrove loss hotspot. The published manuscript not only demonstrates one application for GEM, but also describes in detail the various parameters, options, outputs, and user-interface features included in the tool. The manuscript walks potential users, step-by-step, through the three modules which comprise the tool:

**Module 1: Defining the Region of Interest (ROI) and Compositing Imagery**

> This module helps the user to define customized Region of Interest (ROI) boundaries, and select the input imagery to make multi-date (i.e., historical and contemporary) composites. The user adjusts several parameters according to their specific project requirements and preferences (e.g. years of interest, months of interest, cloud cover, etc.). It is in Module 1 that the user can choose to calculate a number of mangrove and non-mangrove specific spectral indices. All imagery is sourced from the Landsat archives (Missions 4, 5, 7, 8, & 9).

**Module 2: Spectral Separability, Classifications, and Accuracy Assessment**

> This module enables the user to choose from the calculated spectral indices (from Module 1) to use as classification inputs, explore the spectral relationships within and between user-defined map classes, undertakes multi-date (i.e., historical and contemporary) supervised classifications, and assesses land cover map accuracies. Exploring spectral relationships is very interactive, and includes the option to examine correlation between potential spectral indices and separability of classification reference areas (CRAs) across all potential classification inputs. Following classification, accuracy assessments are automatically produced for each output map.

**Module 3: Dynamics and Qualitative Accuracy Assessment (QAA)**

> This module uses multi-date mangrove maps to automatically calculate and subsequently explore mangrove dynamics (i.e., loss, persistence and gain), and provides an optional qualitative accuracy assessment (QAA) tool. The QAA goes above and beyond standard accuracy metrics.

Separate from the three modules of the GEM, there is also a 'Functions' folder which contains some of the back-end support code used by the tool. None of the scripts in this folder will produce any outputs or maps if run independently in GEE. These scripts have been included for potentially interested users to understand how certain intermediate products are generated or statistics calculated. The inclusion of these scripts is further discussed in the 'OPERATION' section of this document (below), which also provides further detail on how to best run the GEM for your own personal use. The most convenient way will be to follow the three hyper-links and use the captured code. However, this Git repository can also be copied and saved as scripts in your own personal GEE script library. The latter of these two options is more complicated, but would allow the user to more comprehensively understand GEM functionality - this is not required to actually use the tool.

Module 1

- Defines the Area of Focus (AOF)
- Generates satellite image composites

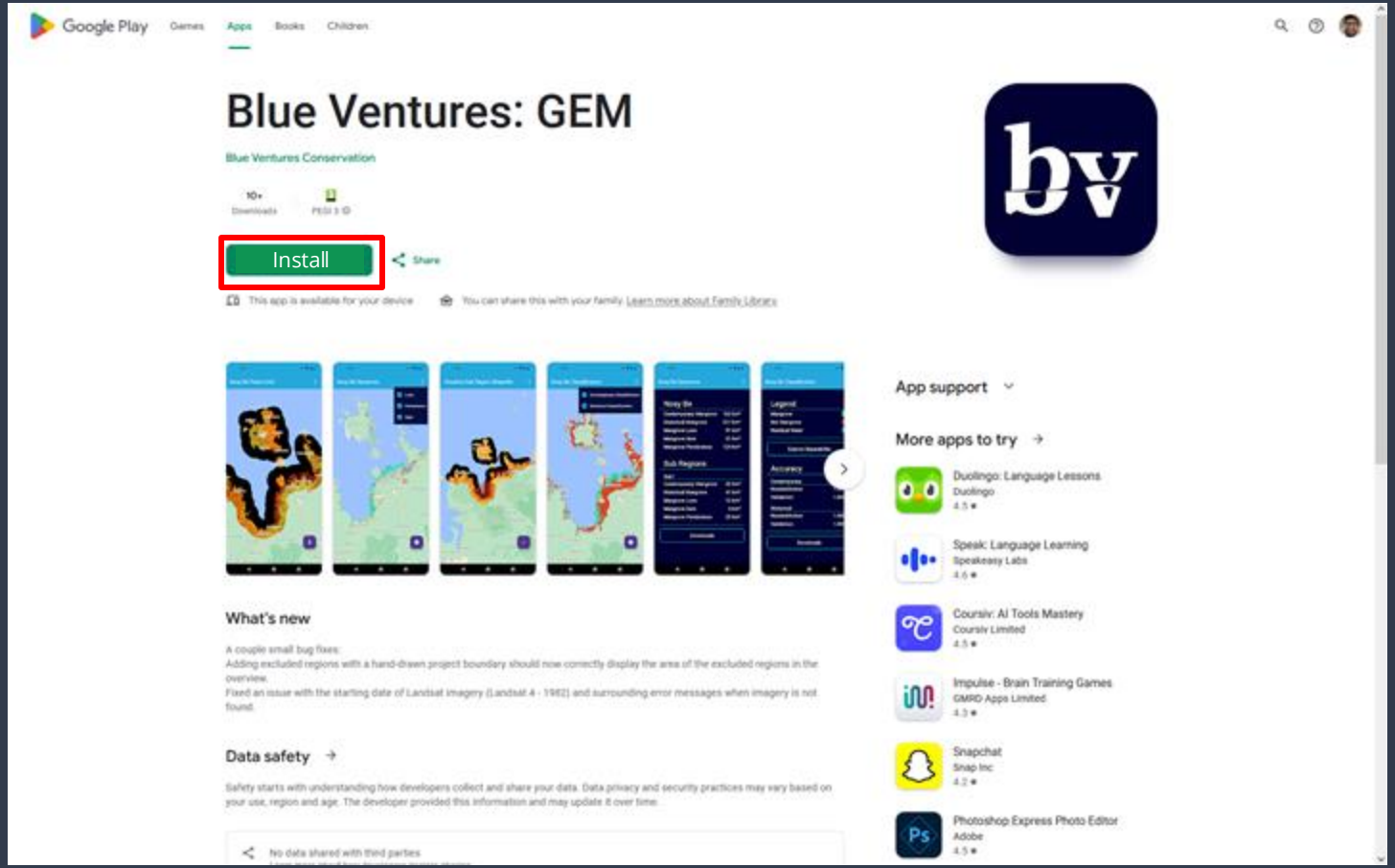
Module 2

- Assesses spectral separability
- Produces map classifications
- Calculates accuracy assessments

Module 3

- Dynamics (table and maps)

# GEM App is on the Google Play Store

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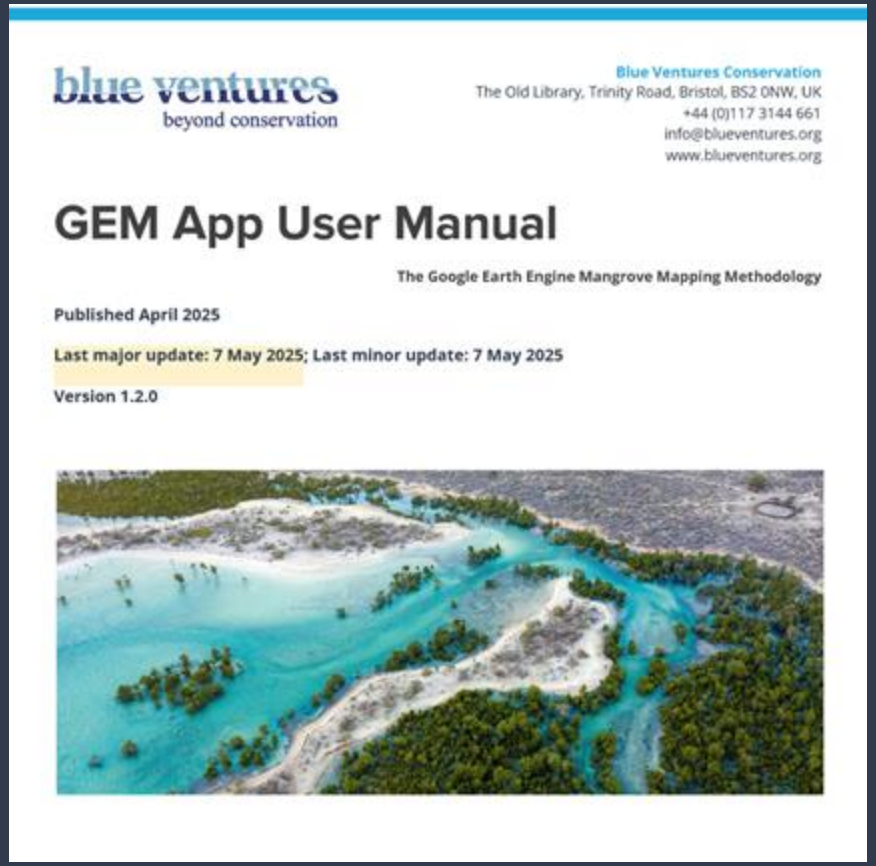
# Using GEM App

# Refer to the GEM App User Manual



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beyond conservation

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## GEM App User Manual

The Google Earth Engine Mangrove Mapping Methodology

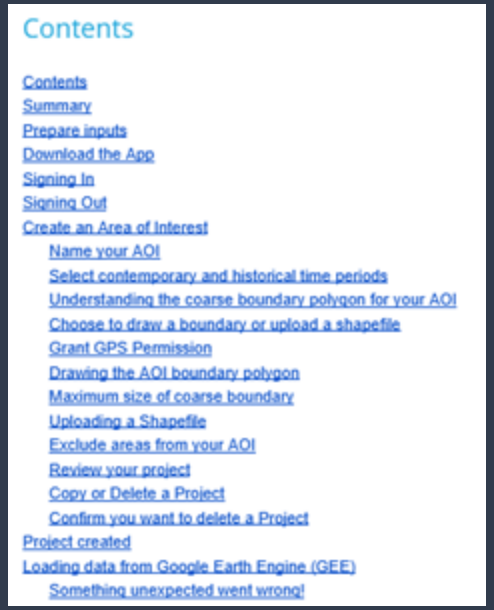
Published April 2025

Last major update: 7 May 2025; Last minor update: 7 May 2025

Version 1.2.0



- Link here
- Updated regularly
- Lengthy document - no need to read all!
- Refer to sections you require guidance



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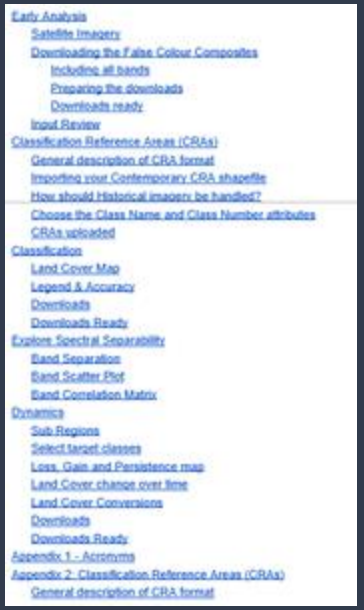


# Using GEM App to map mangroves in Somone


- 130 ha mangrove in the Marine Protected Area of Somone
- Some degradation
  - Sedimentation
  - Rising sea-levels
  - Climate change
- Key impact is increased salinity

# The GMW map under-represents mangrove

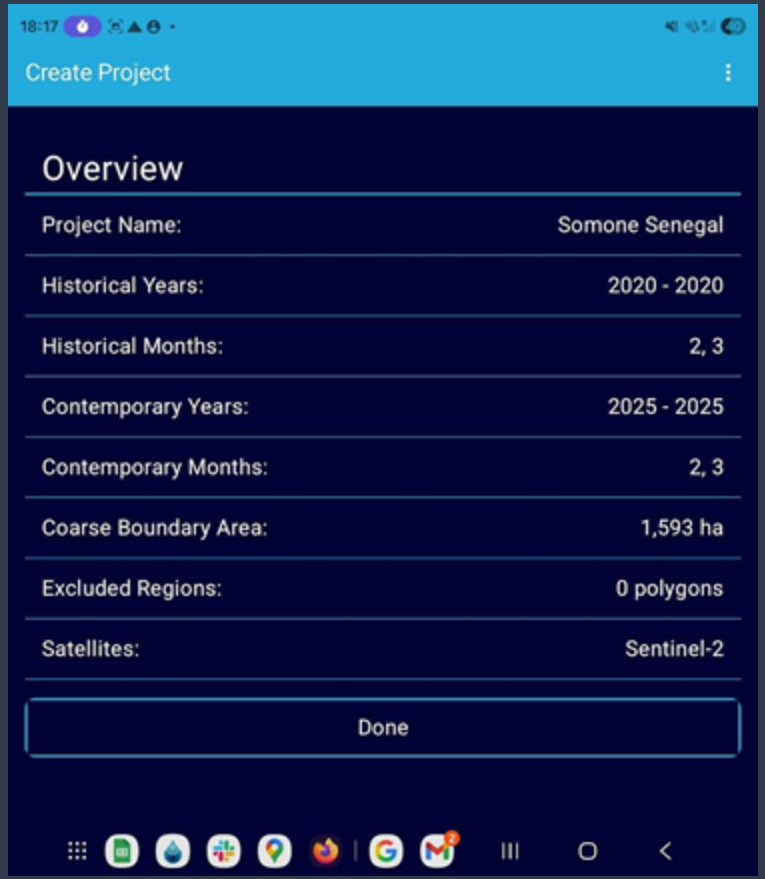
- GMW v4 = 125 ha of mangrove in the MPA of Somone
- GEM: 130 ha of mangrove forest
  - 108 ha of CCM
  - 22 ha of OCM

- GMW under-represents mangroves
- Extend 4 km further upstream
- Only uses one broad class
- No insight regarding the surrounding classes immediate to the mangroves

# GMW under-represents open mangrove

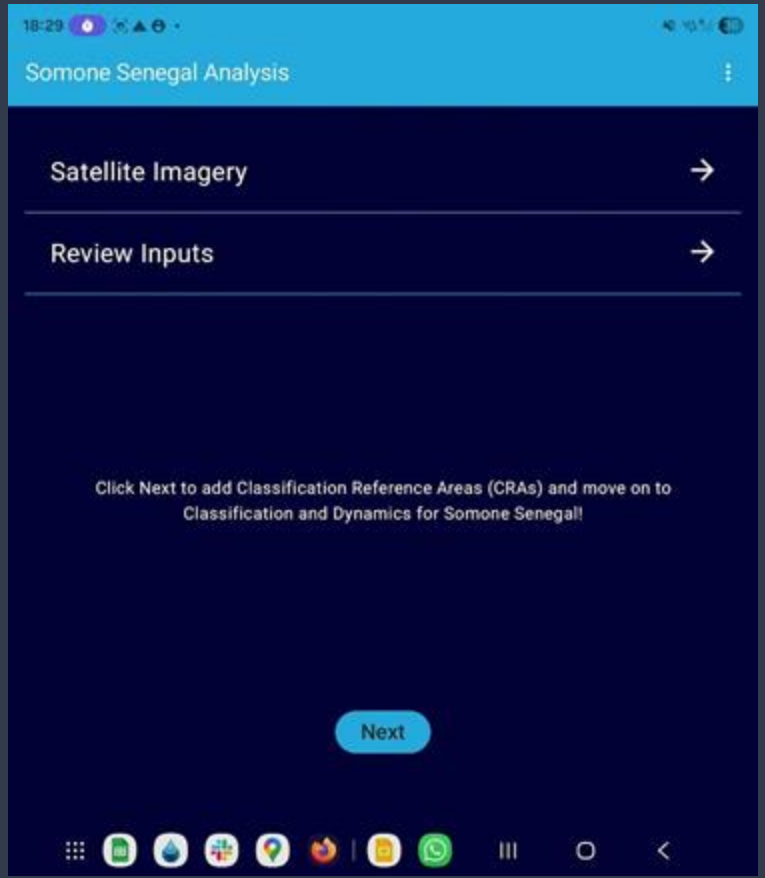
# Setting up a project

- Naming your project
- Select your timesteps
- Draw or upload your AOI
- Add excluded areas
- Choose satellite sensor



# Review satellite image composites

- Contemporary high tide
- Contemporary low tide
- Historical high tide
- Historical low tide
- Are they fit-for-purpose?
  - Low tide: exposed tidal flats
  - High tide: Water inundating mangroves + mudflats
- Onto CRAs...



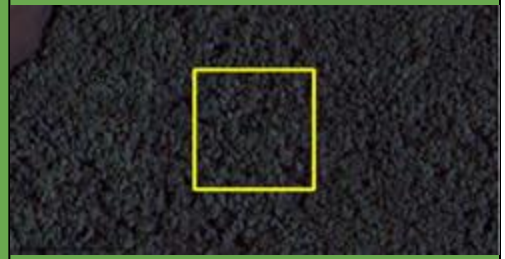


1. Mangrove mapping
1. GEM
1. **CRAs**
1. Next steps

# What is a CRA?

- **C**lassification **R**eference **A**rea
- Train the classifier and validate maps
  - 70% used for training
  - 30% used for validation
- CRAs required for each class
- Each class should be ecologically and spectrally distinct
- CRAs for each class should represent full spectral and ecological variability across AOI

# Classification structure - Somone

| Class | Example |
| --- | --- |
| **1. Closed-Canopy Mangrove** |  |
| **2. Open-Canopy Mangrove** |  |
| **3. Terrestrial Forest** |  |

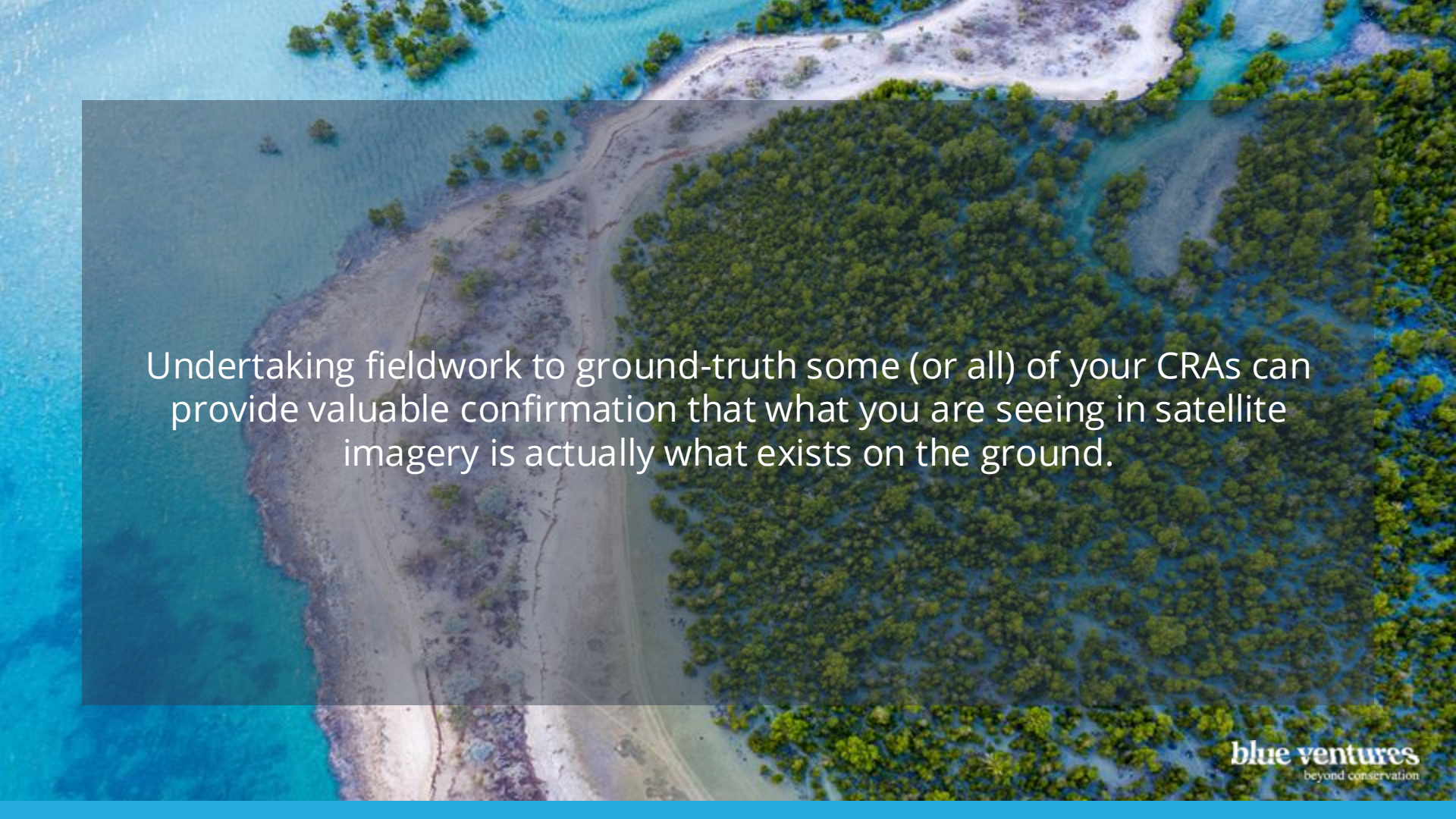
| Class | Example |
| --- | --- |
| **4. Other Vegetation** E.g. grassland, shrubland, cropland |  |
| **5. Barren Exposed** E.g. soil, mud |  |
| **6. Residual Water** |  |

# Why are CRAs important?

- CRAs define the spectral (EMS) values which represent your map classes
- GEM assigns class membership to each pixel
- Map accuracy tested using 30% of the CRAs "held back"
- The maps made by the GEM are only as good as the examples you provide!
- True for mangrove classes AND surrounding non-mangrove classes



# GEM Fieldwork


Undertaking fieldwork to ground-truth some (or all) of your CRAs can provide valuable confirmation that what you are seeing in satellite imagery is actually what exists on the ground.
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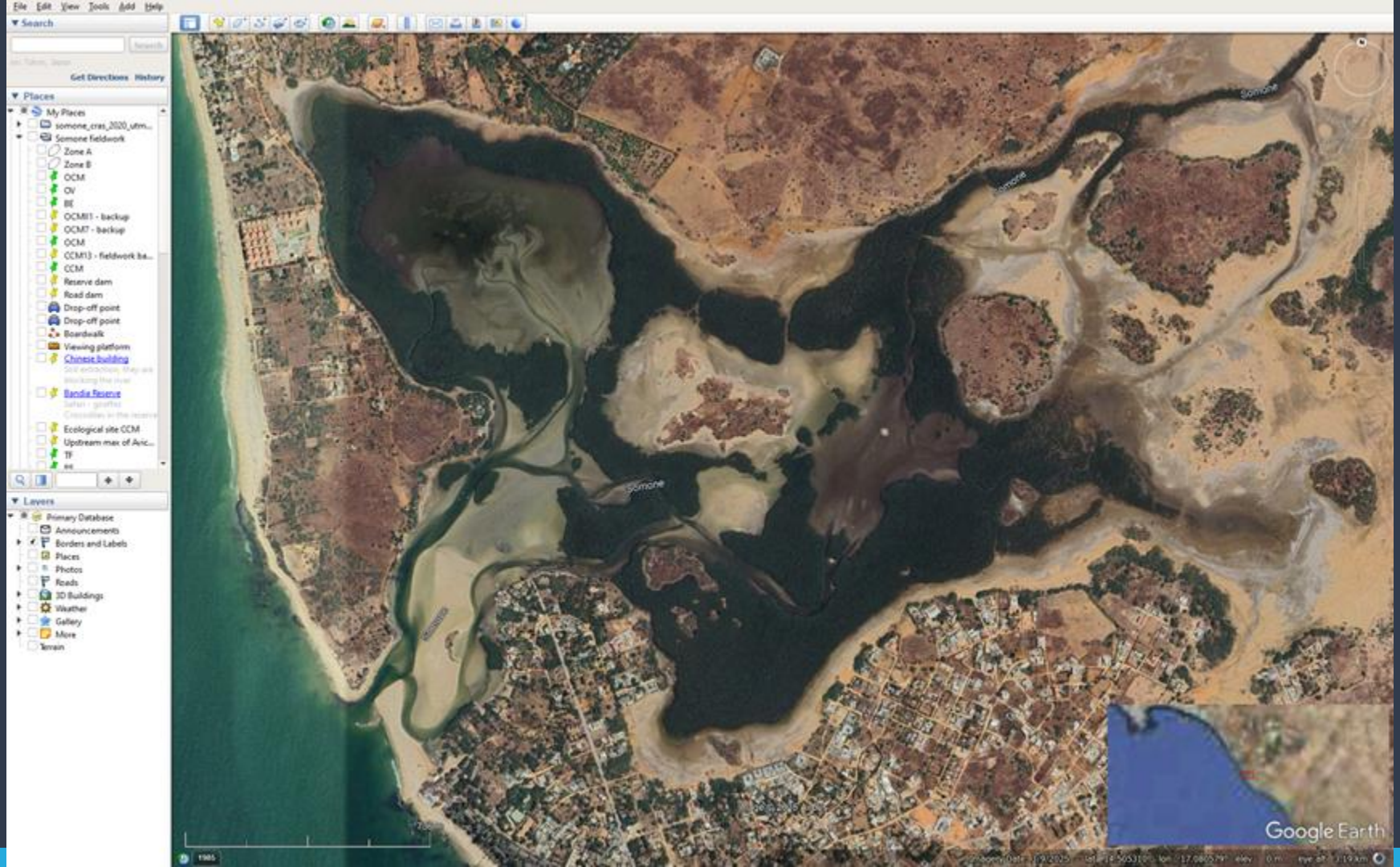
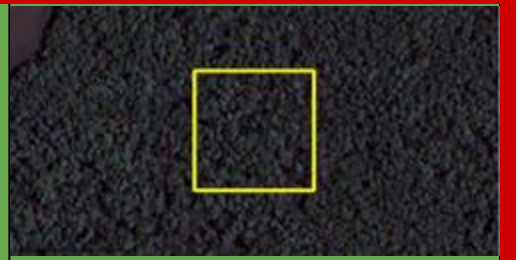
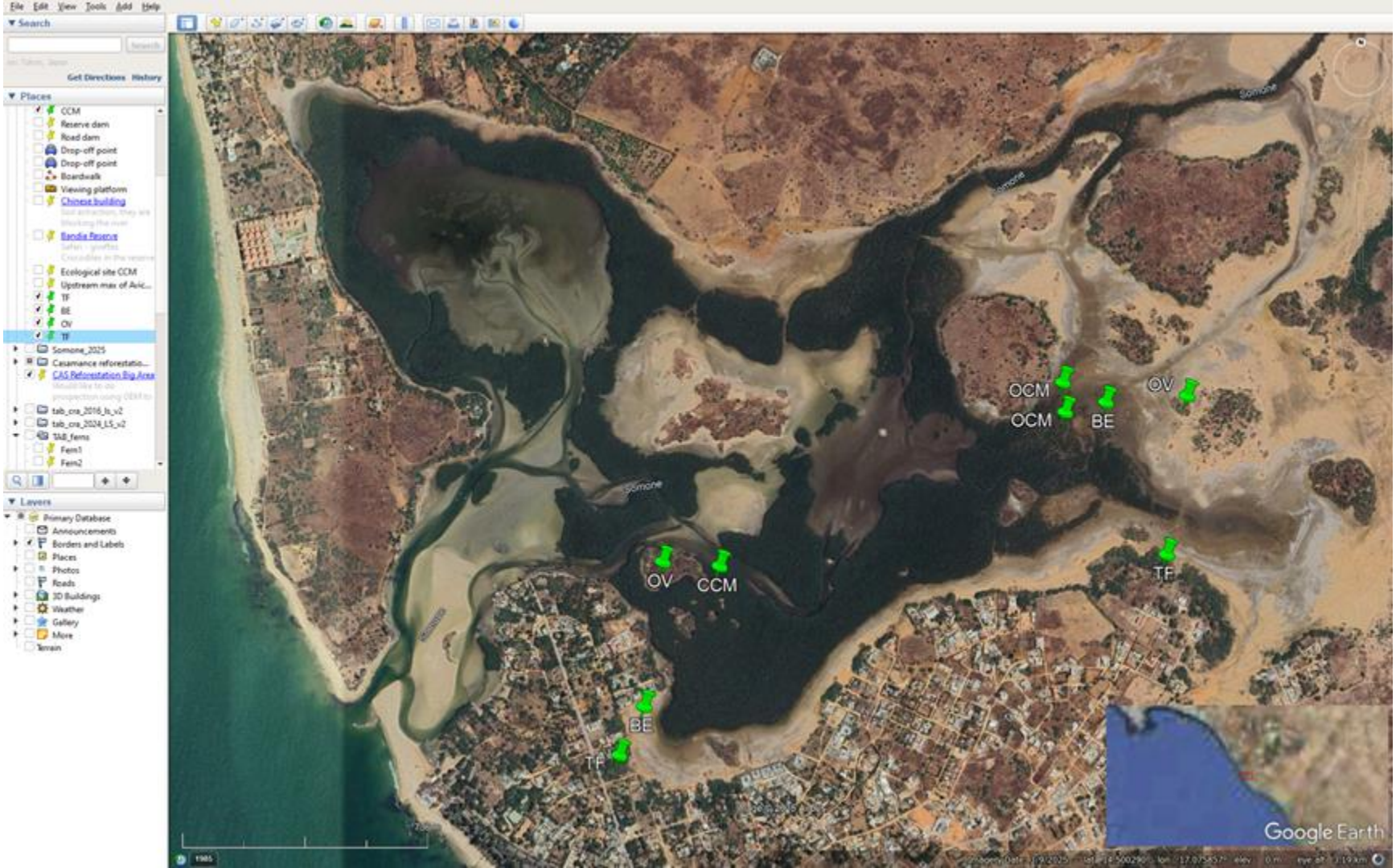

File Edit View Tools Add Help
Search
Get Directions History
Places
My Places
somone_cras_2020_utm...
Somone fieldwork
Zone A
Zone B
OCM
OV
BE
OCM11 - backup
OCM7 - backup
OCM
CCM13 - fieldwork ba...
CCM
Reserve dam
Road dam
Drop-off point
Drop-off point
Boardwalk
Viewing platform
Chinese building
Bandia Reserve
Ecological site CCM
Upstream max of Aric...
Layers
Primary Database
Announcements
Borders and Labels
Places
Photos
Roads
3D Buildings
Weather
Gallery
More
Terrain
Somone
Somone
Somone
Google Earth

# Targeting 5 plots representing 5 classes

| Class | Example | Class | Example |
|---|---|---|---|
| **1. Closed-Canopy Mangrove** |  | **4. Other Vegetation** E.g. grassland, shrubland, cropland |  |
| **2. Open-Canopy Mangrove** |  | | |
| **3. Terrestrial Forest** |  | **5. Barren Exposed** E.g. soil, mud |  |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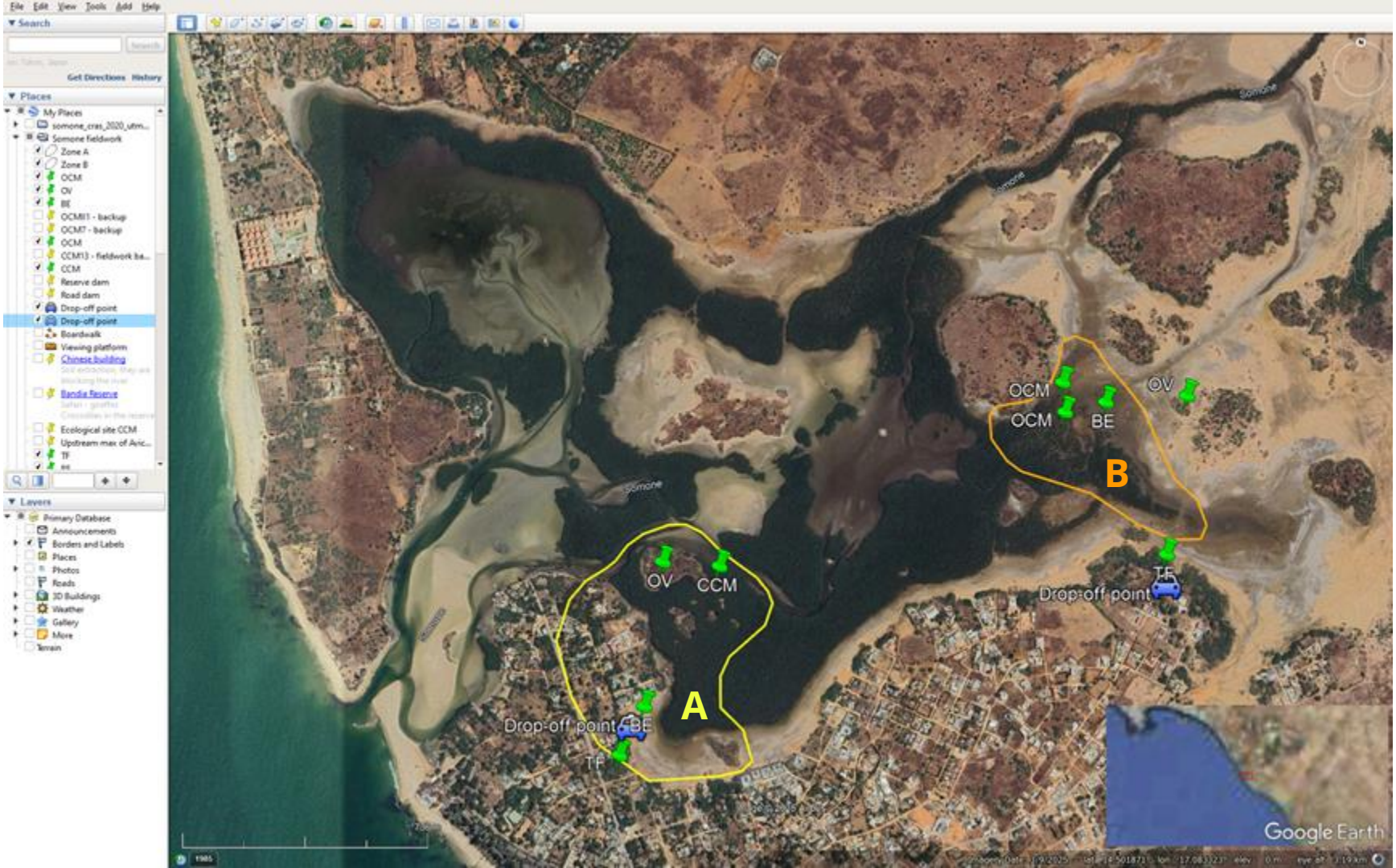
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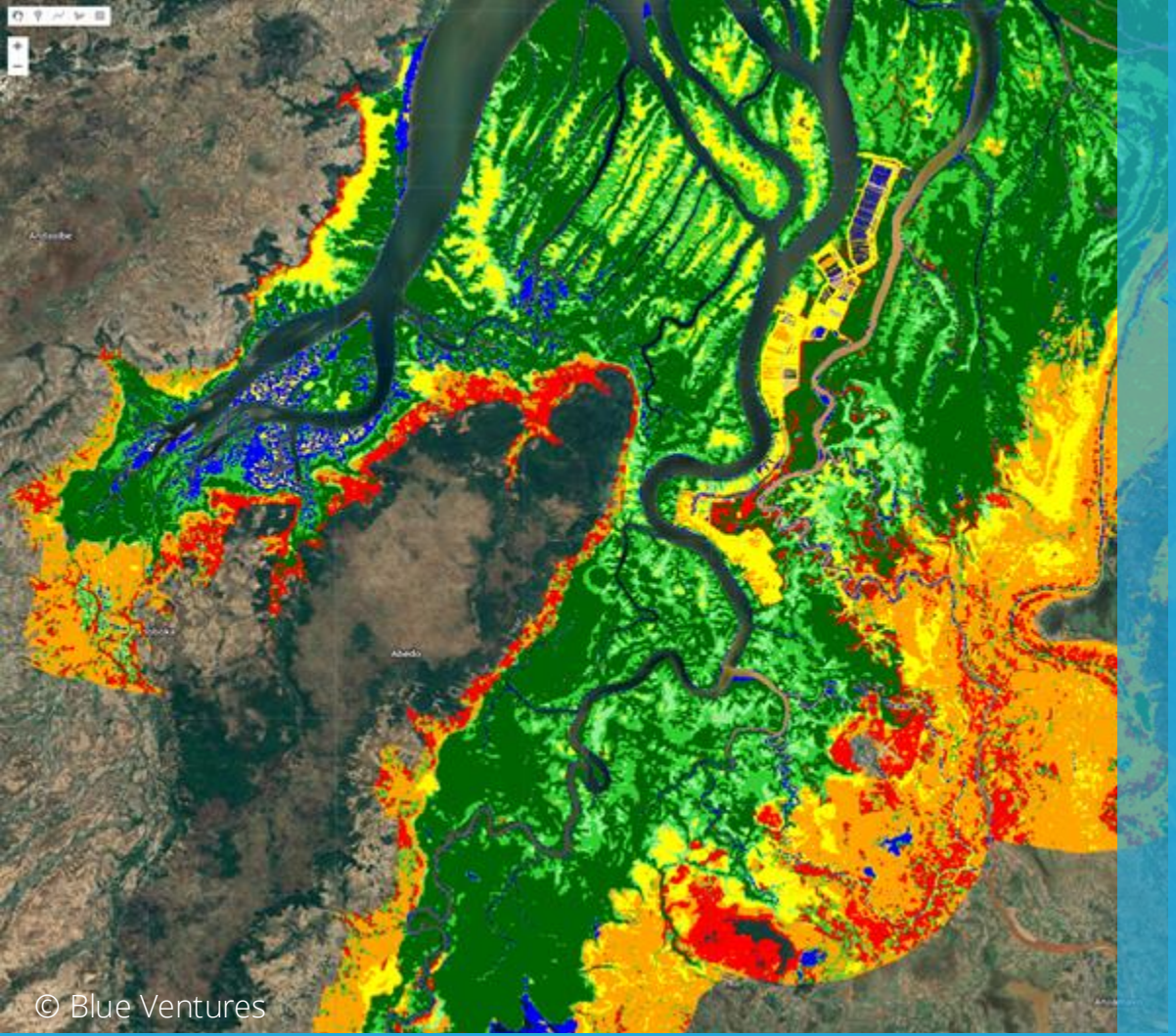
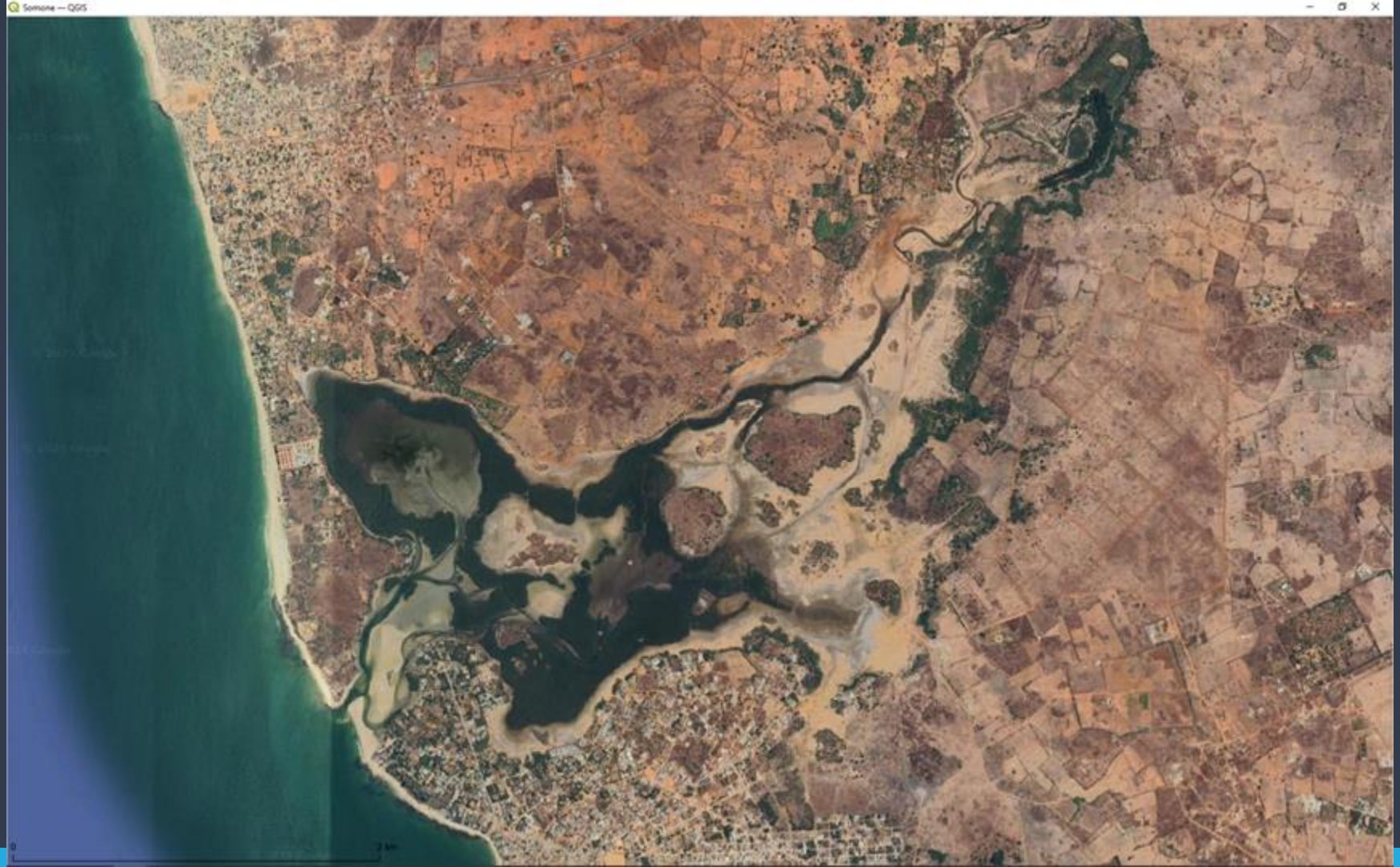
# Field safety - please read!

**http://bit.ly/40nvqFK**




# GEM Maps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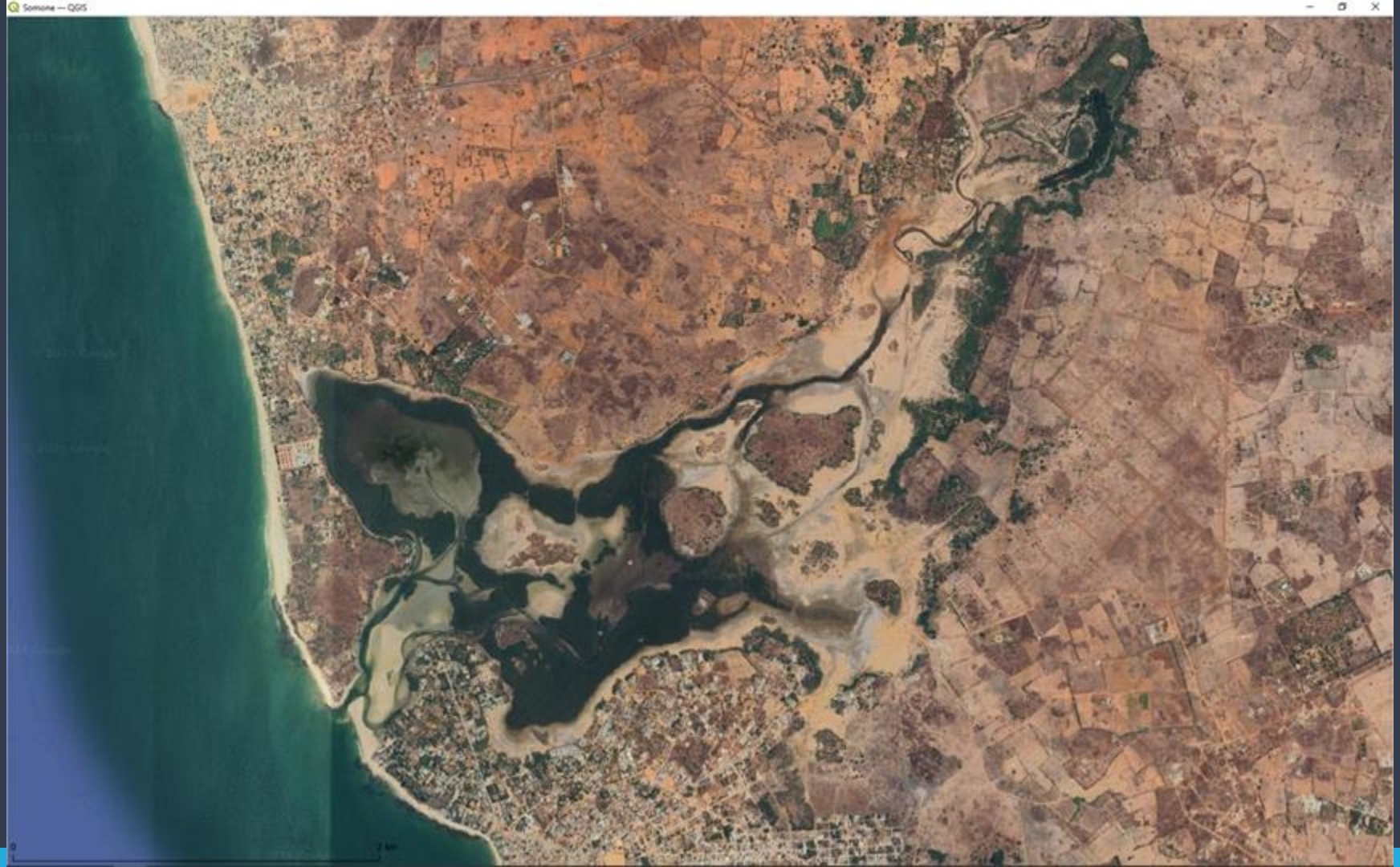
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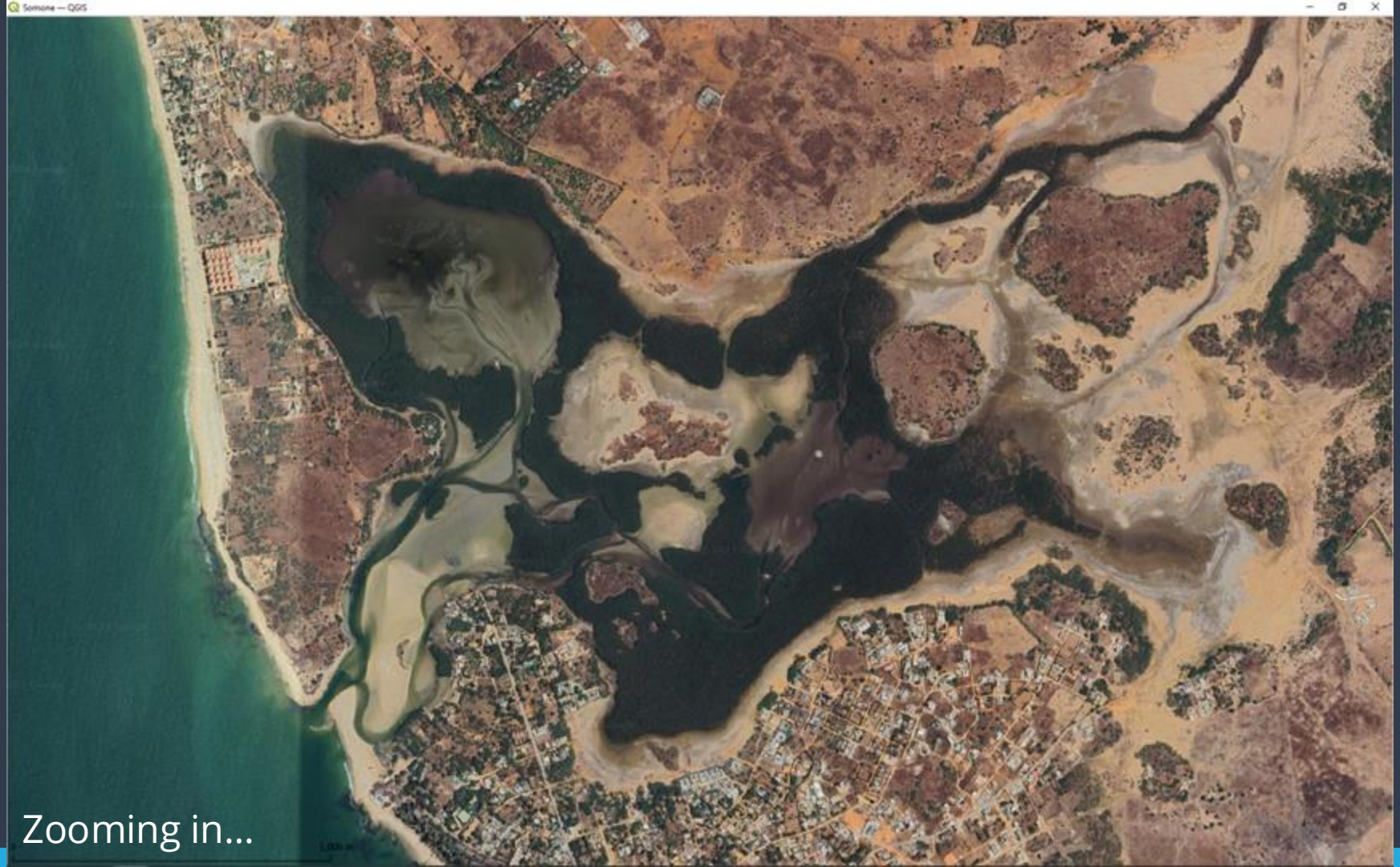
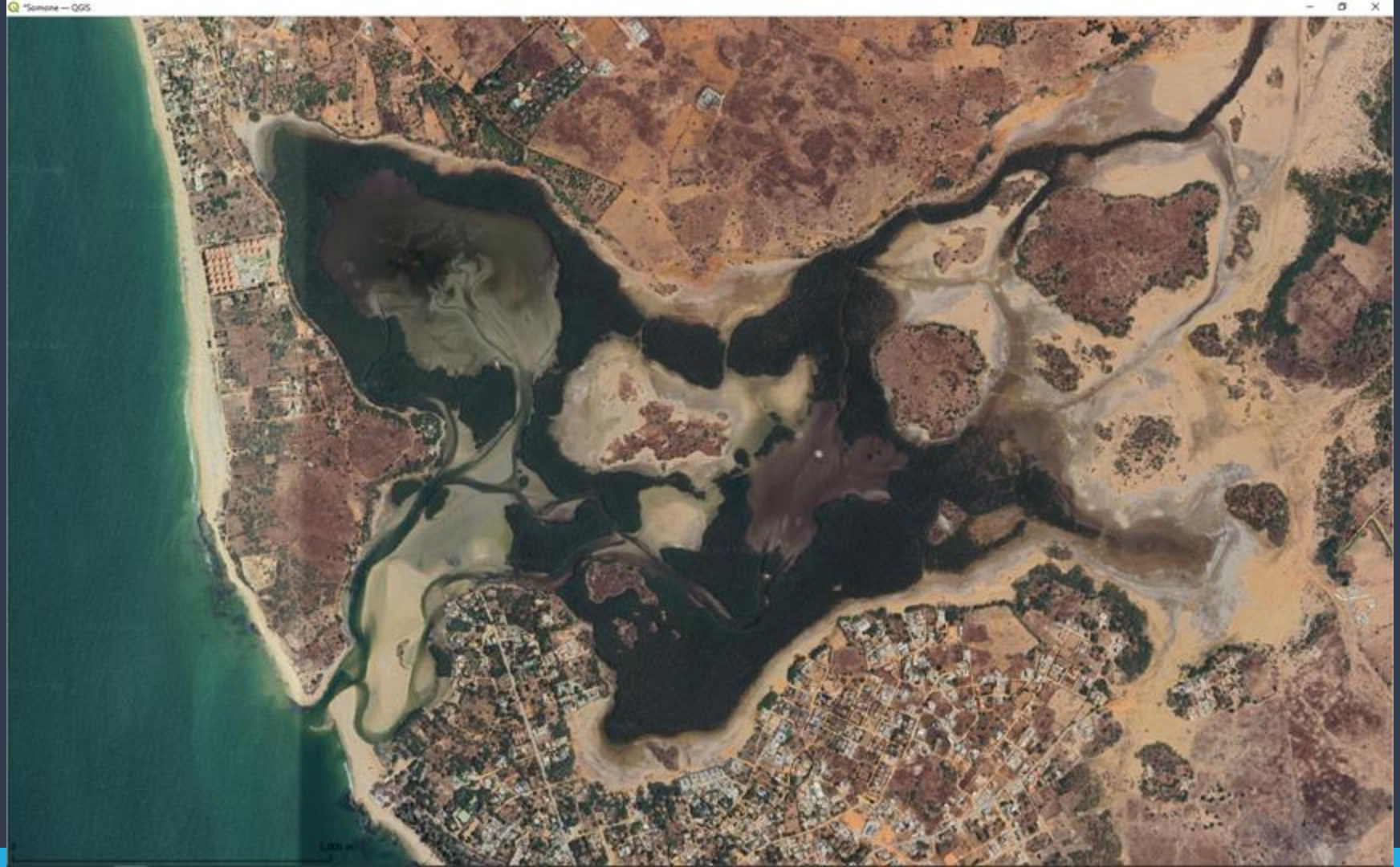



Zooming in...

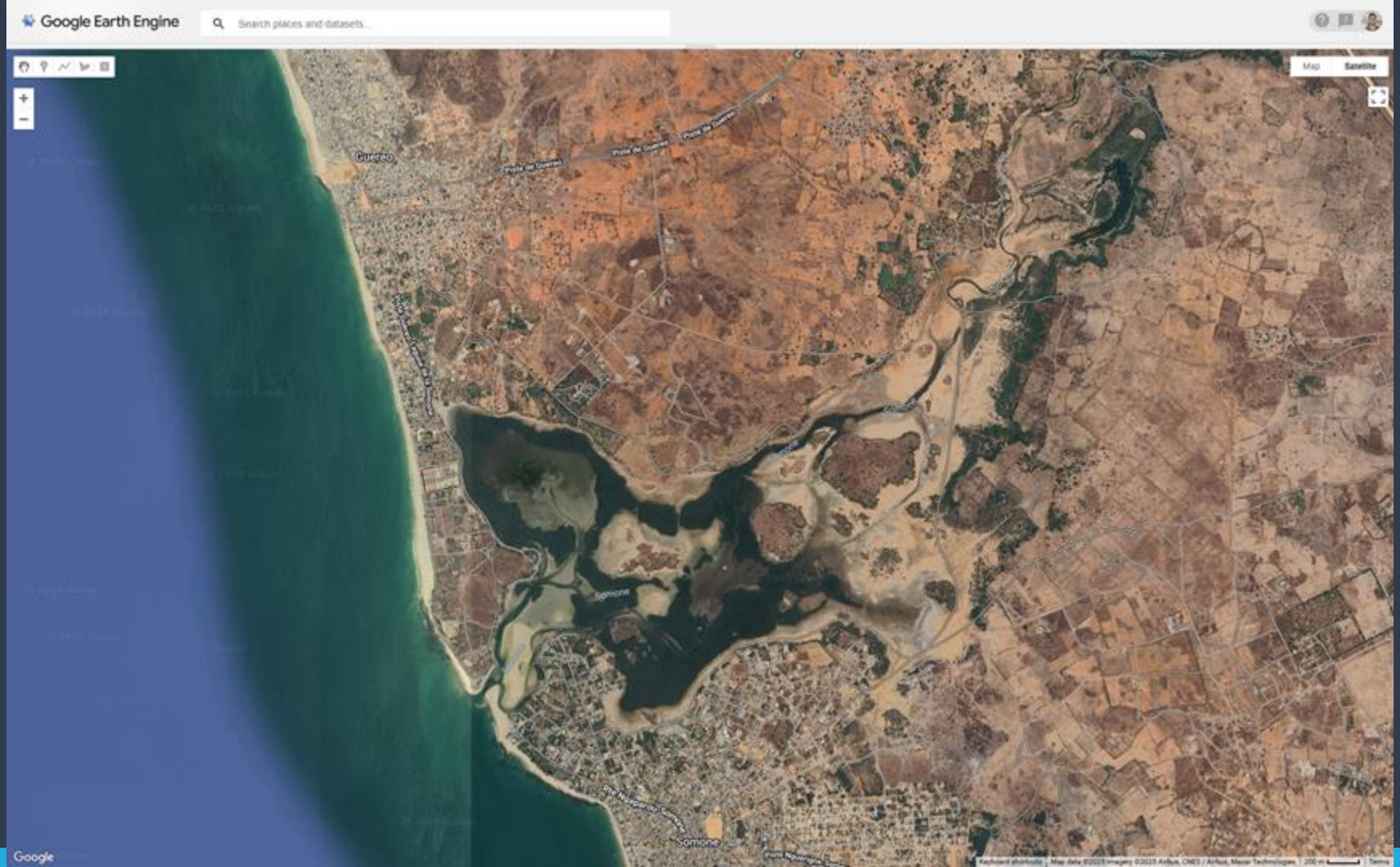

*Somone — QGIS

# Dynamics in Somone

| Class | Historical | Contemporary | PercentChange | Loss | PercentLoss | Persistence | PercentPersistence | Gain | PercentGain |
|---|---|---|---|---|---|---|---|---|---|
| Mangroves (CCM+OCM) | 129.7 | 130.5 | 0.6% | 4.2 | 3.2% | 125.5 | 96.8% | 4.9 | 3.8% |
| Closed-Canopy Mangrove | 107.4 | 108.6 | 1.1% | 3.3 | 3.1% | 104.1 | 96.9% | 4.5 | 4.2% |
| Open-Canopy Mangrove | 22.3 | 21.8 | -2.0% | 6.0 | 26.9% | 16.3 | 73.2% | 5.5 | 24.9% |
| Terrestrial Forest | 221.6 | 140.8 | -36.5% | 122.4 | 55.2% | 99.2 | 44.8% | 41.5 | 18.7% |
| Other Vegetation | 1,972.0 | 1,976.8 | 0.2% | 450.5 | 22.8% | 1,521.5 | 77.2% | 455.3 | 23.1% |
| Barren Exposed | 709.0 | 702.2 | -1.0% | 290.6 | 41.0% | 418.4 | 59.0% | 283.8 | 40.0% |
| Residual Water | 18.5 | 18.8 | 1.7% | 2.5 | 13.7% | 15.9 | 86.3% | 2.9 | 15.5% |

- Minimal change in mangrove extent
- 1.1% gain in CCM
- 2% fall in OCM

- Significant fall in Terrestrial Forest extent (34 ha converted to Other Vegetation)
- 170 ha of Exposed Barren converted to Other Vegetation (new suburbs in work)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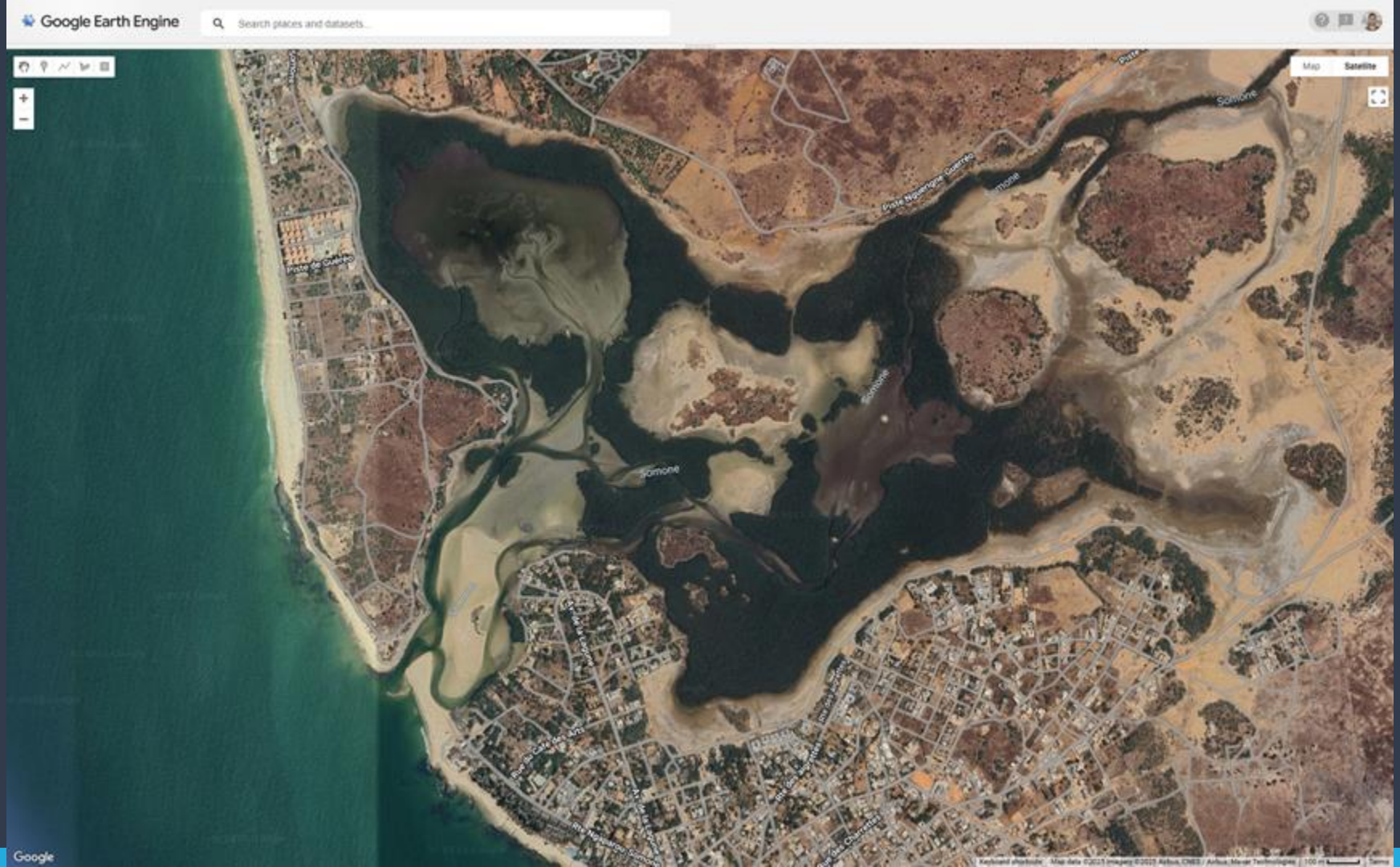
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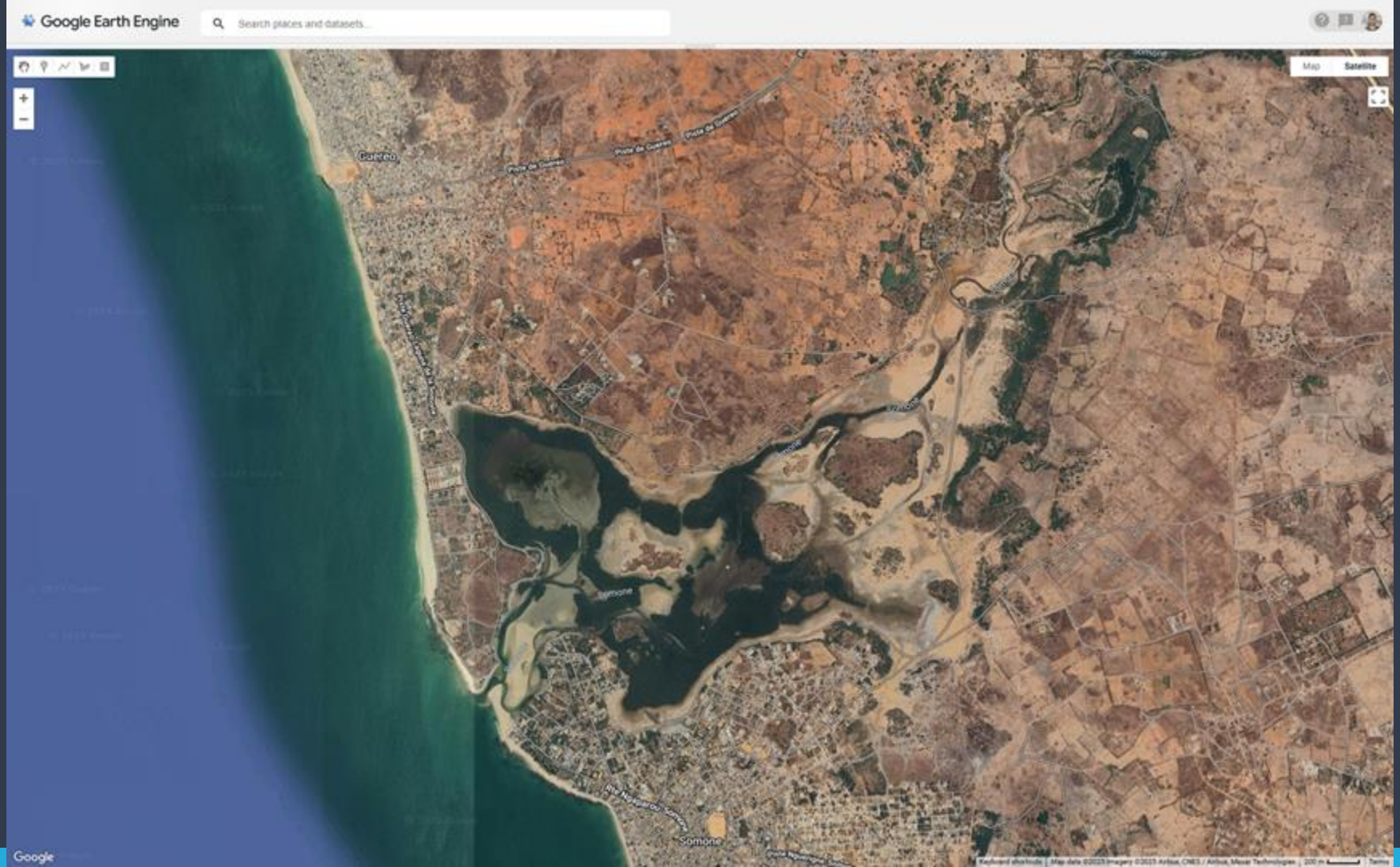
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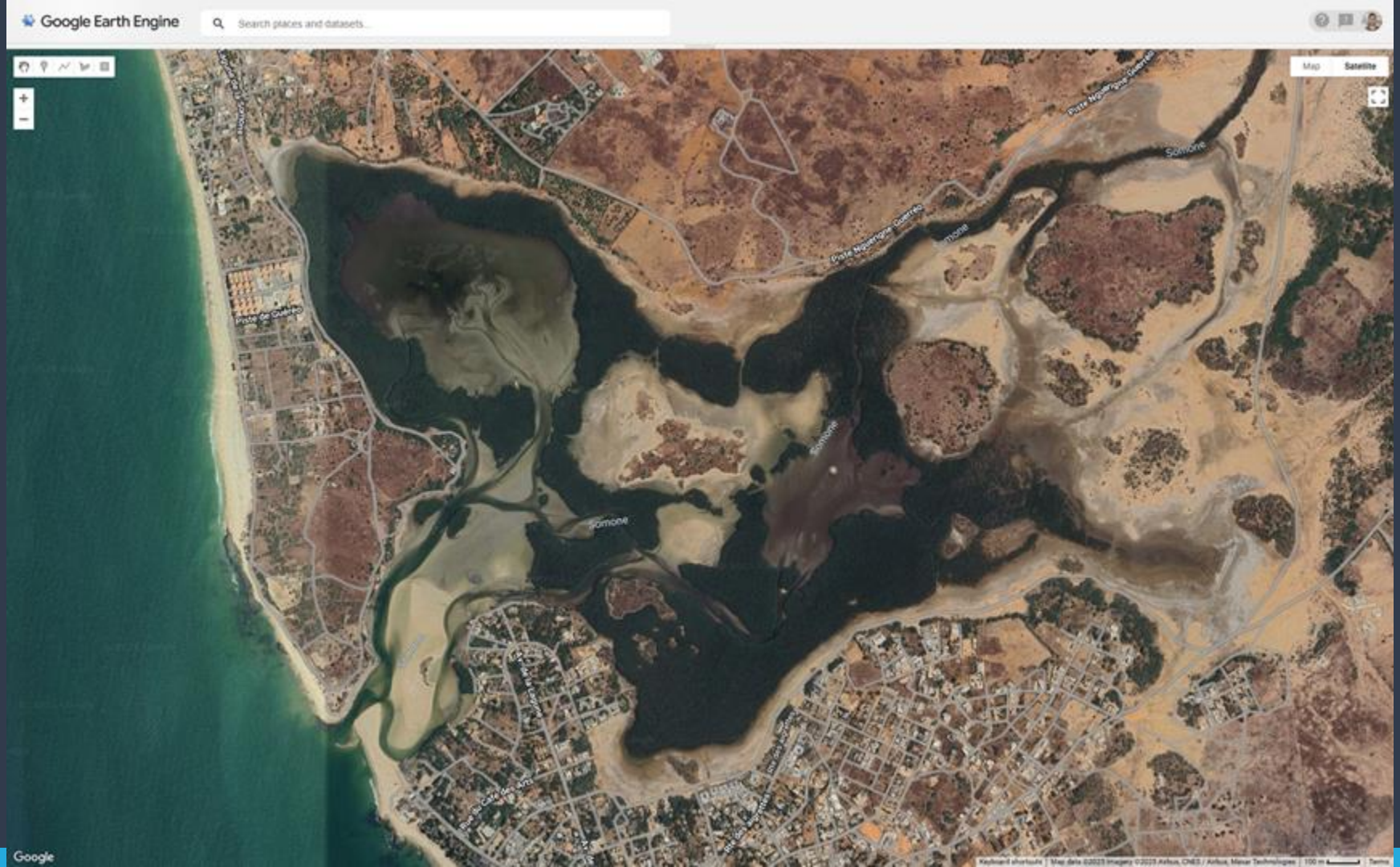
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1. Mangrove mapping
1. GEM
1. CRAs
1. **Next steps**

# How GEM outputs can be used

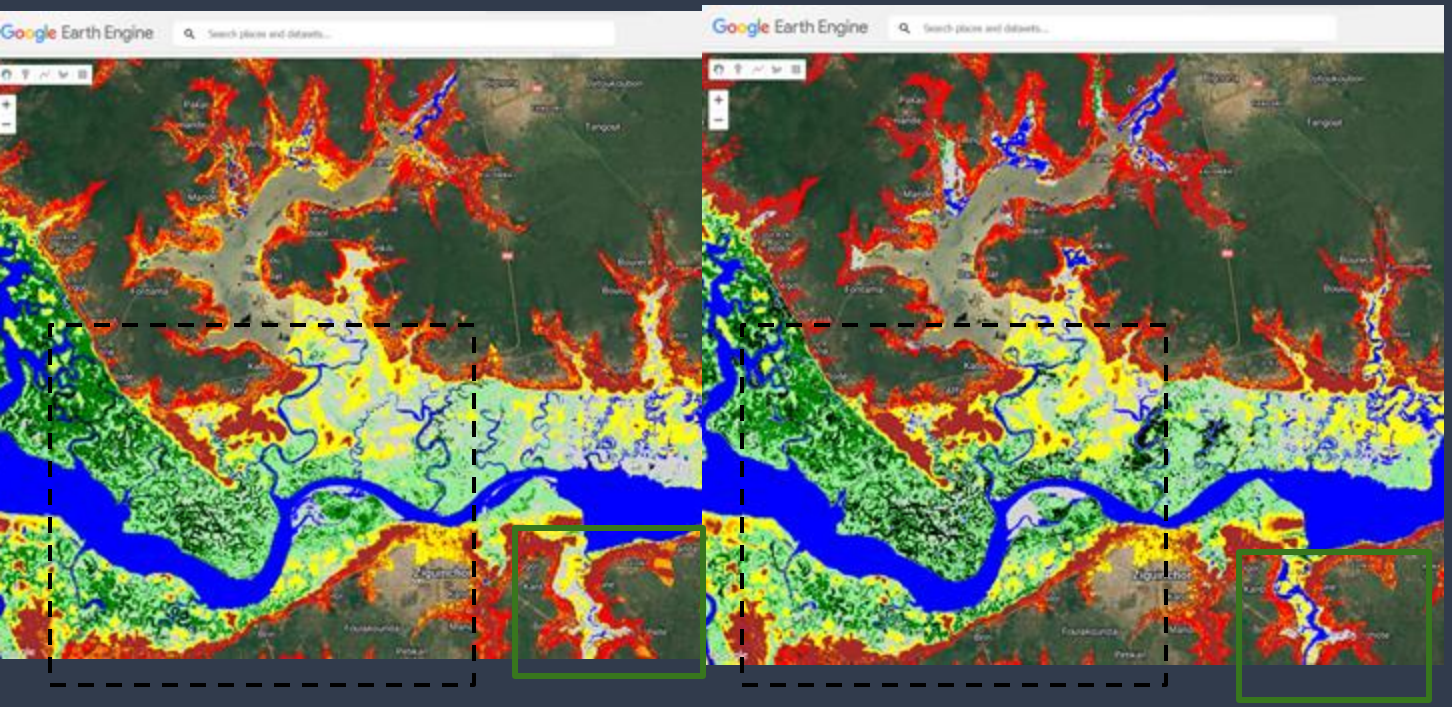
- Monitor extent and dynamics
- Help identify factors behind loss and gain
- Monitor existing / inform further management measures
- Visualising impact of management/reforestation measures
- Inform and monitor reforestation projects
- Support community engagement

# Example of Kawawana Area of considerable gain in Eastern region

Closed-Canopy Mangrove 1
Closed-Canopy Mangrove 2
Open-Canopy Mangrove 1
Open-Canopy Mangrove 2
Terrestrial Forest
Dry Vegetation
Wet Vegetation
Exposed & Barren
Residual Water

2013

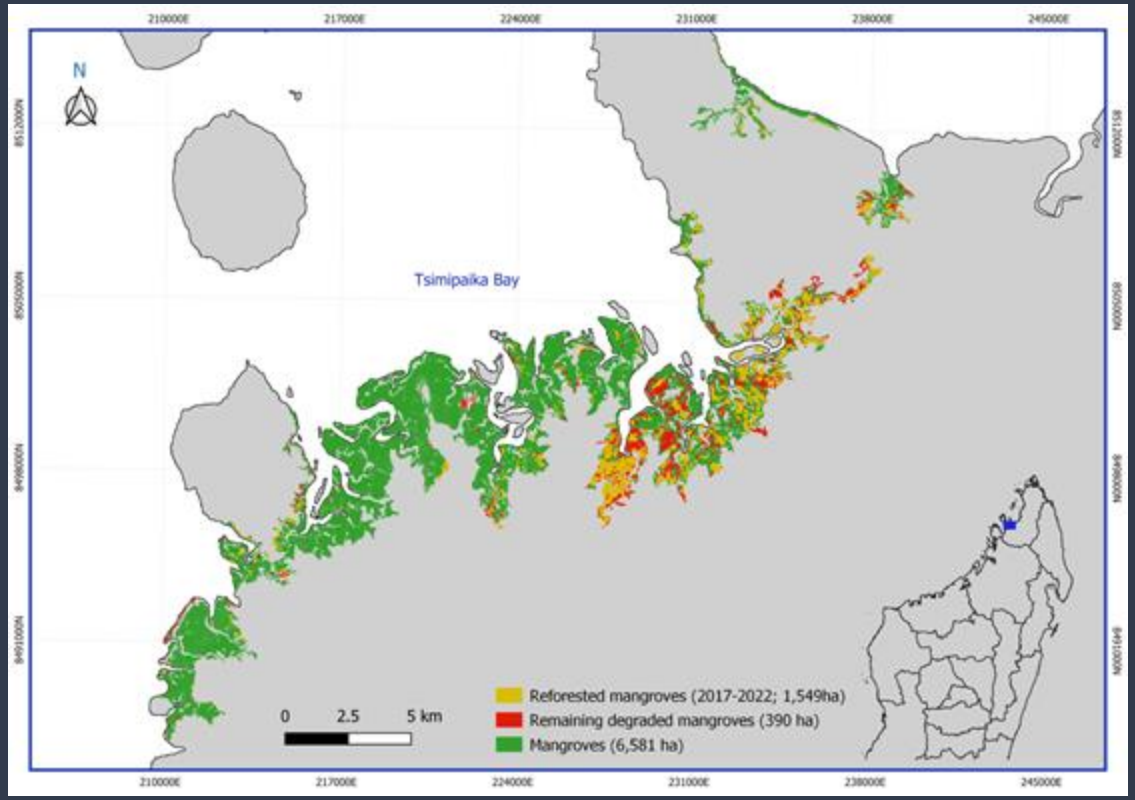
2023




Mangrove forest area 2013 : 11152.30 ha
Mangrove forest area 2023 : 11701 ha
Mangrove forest loss : 260.08 ha
See next slide
Mangrove forest gain : 818.87 ha

# Reforestation example (Tsimipaika)

- Tsimipaika Bay located in Northwest Madagascar
- Using GEM maps to inform community-led mangrove restoration projects
- 1500ha reforested by local communities



# What’s coming in GEM v3?

- Carbon data
- Link-up to partner systems (databases, dashboards, web maps)
- Drone CRA fieldwork protocol
- Please send feedback + ideas to gem@blueventures.org

# Merci beaucoup

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Jaona Ravelonjatovo (jaona@blueventures.org)