Comparative Mangrove Mapping for Mumbai Using GFC, GMW Datasets

Aaryamann Goenka

1. Introduction

Mangroves are specialised trees and shrubs that grow in saline water in intertidal zones. They are characterized by: high carbon dioxide retention capabilities, strong, stilt-like roots that help them survive in muddy and changing water levels, among other features making them one of the most essential coastal ecosystems around the world.

They are extremely effective carbon sinks, which store around 1000 tonnes of carbon per hectare[1], far greater than any terrestrial forests. Moreover, they act as natural coastal defenders against various climate events and calamities. In fact, a 100 meter belt of mangroves can reduce wave height by 13-66% through their dense root network's ability to dissipate wave energy and trap sediments protecting against storm surges and flood risks[2]. Apart from this, they aid in trapping sediments, which stabilize shorelines and reduce erosion.

For densely populated coastal cities such as Mumbai, these features are extremely critical- their functions are approximately valued at ₹1700 crore annually, and the Thane creek mangrove belt alone stores around 238,000 tonnes of carbon[3],[4]. Apart from the ecological aspects, these mangroves also protect fishing communities' livelihoods, by promoting biodiversity and providing nursing grounds for fish and other marine life[5]. Overall, all the aforementioned functions of mangroves make them indispensable for the environment, especially in the case of Mumbai itself.

2. Background and Literature Landscape

2.1 Mangroves and Coastal Protection

Global and Indian studies consistently highlight mangroves as high-value ecological and engineering systems. Research shows that a 100 m mangrove belt can reduce wave heights

[1] United Nations Environment Programme
[2] https://elaw.org/resource/reduction-of-wind-and-swell-waves-by-mangroves
[3] Times of India(Economic valuation of Mumbai's mangrove ecosystem)
[4] Hindustan Times (Carbon in Thane Creek mangrove)
[5] Vision IAS & UNESCO(Role in coastal biodiversity and fisheries)

by 13-66%, significantly decreasing flood risk. Their aerial root systems trap sediments, bind soils, and allow coastlines to keep pace with sea-level rise.

Major findings in the literature review include:

- Mangroves act as buffers against cyclones, storm surges, tsunamis, and tidal currents.
- Mangrove belts significantly reduce wave energy and erosion aiding in coastal protection (Das & Vincent 2009).
- Ecosystem services are economically substantial, as Mumbai's mangroves provide an estimated ₹1700 crore annually in protective functions.

2.2 Mangroves in Mumbai

Mumbai's mangroves occur mainly around Thane Creek, Gorai, Versova, Uran, and Sewri, but rapid urbanization, reclamation, and plastic pollution have caused severe degradation of them. Studies using Landsat (1990–2017) and Sentinel-2 imagery in the Journal of Sea Research (Thane Creek mangrove mapping study which took place from 1990-2017) document major changes in mangrove extent, while IRS-P6 LISS-III-based classification (Pramod et al Journal of the Indian Society of Remote Sensing in 2017) shows thinning, fragmentation, and decline around Mumbai's coastal zones.

- Declines of 15-40% in specific regions due to encroachment.
- Evidence of thinning and fragmentation (density reduction even when total area seems stable/similar).
- Some Localized regrowth in areas of conservation, such as Thane Creek.

2.3 Global Datasets

Two major datasets dominate global forest and mangrove studies: Global Forest Change (GFC), and Global Mangrove Watch (GMW). While both use satellite imagery to map greenery, they differ in terms of how they image mangroves. GFC is a general forest temporal dataset derived mainly from Landsat optical imagery with a 30m resolution, which maps tree cover and annual loss/gain using canopy cover and height thresholds[6]. Since it doesn't explicitly separate mangroves from other first or wetland vegetation, it is more susceptible to the effects of cloud cover, mixed coastal pixels, and flooding, leading to the omission or misclassification of mangroves.

In contrast, GMW is a mangrove-specific spatial dataset that integrates radar data (ALOS PALSAR) with optical imagery and coastal habitat masks, allowing it to more accurately

[6] https://pubmed.ncbi.nlm.nih.gov/24233722/

detect mangroves in waterlogged, intertidal environments[7]. Due to their unique techniques of collecting data, including differences in sensor type (only optical vs radar+optical), classification thresholds, spatial resolution, and ecological constraints, there are often discrepancies between the two.

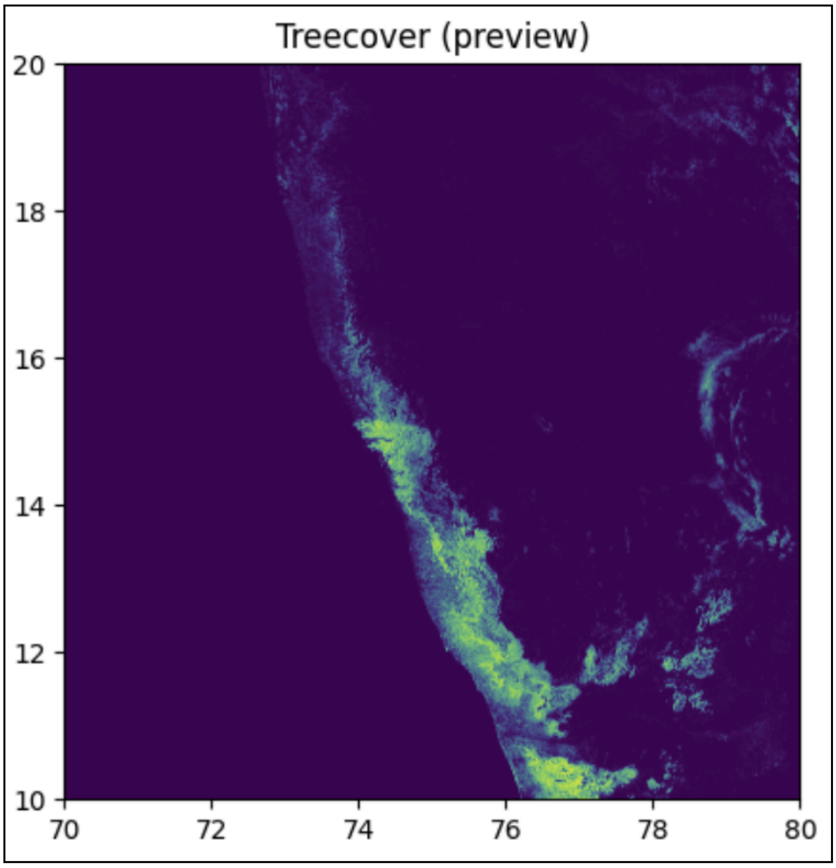
This project addresses a major literature gap: no prior study has directly compared GFW and GMW for Mumbai, despite their widespread use in environmental and engineering studies.

3. Methodology

3.1 Python Geospatial Analysis

- Importing and cleaning geospatial rasters using GeoPandas, Rasterio, NumPy.
- Extracting mangrove polygons for Mumbai's boundary.
- Overlaying GFW annual forest-loss layers with GMW mangrove-extent baselines.
- Generating maps of:
    - Forest loss hotspots.
    - Areas of GFW-detected loss not recognized by GMW.
    - Potential misclassification zones (fragmented or mixed vegetation).

[7] https://www.mdpi.com/2072-4292/10/10/1669



Treecover (preview)
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Figure 0: Global Forest watch dataset geospatial raster for Indian subcontinent

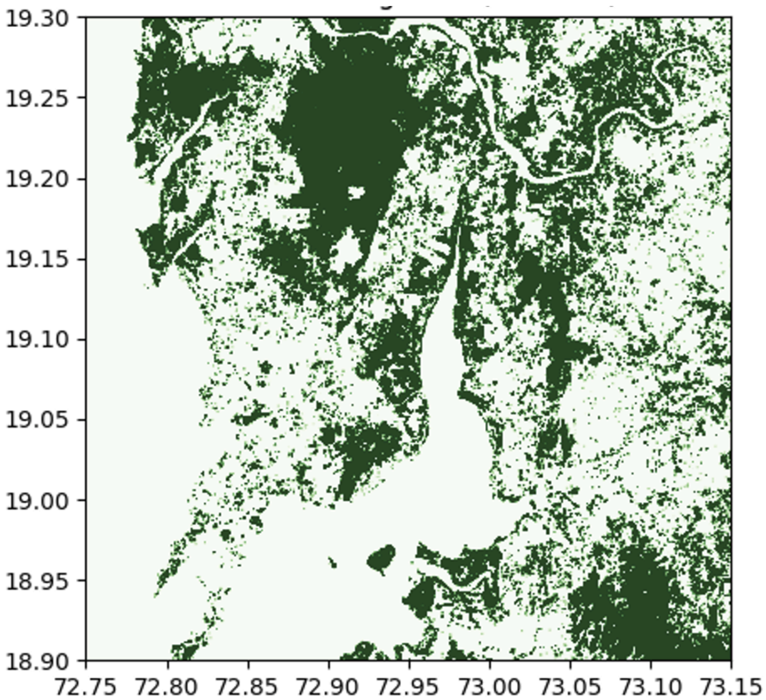


Figure 1:Global Forest Watch Dataset Mumbai region forest cover

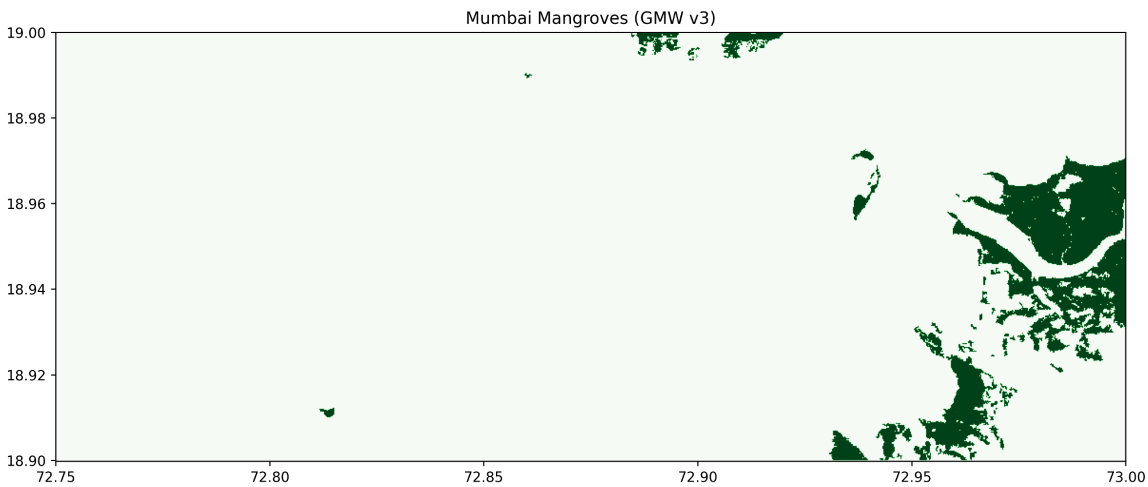


Figure 2: Image depicting Global Mangrove Watch Dataset Mumbai region mangrove cover

3.2 Comparative Dataset Analysis

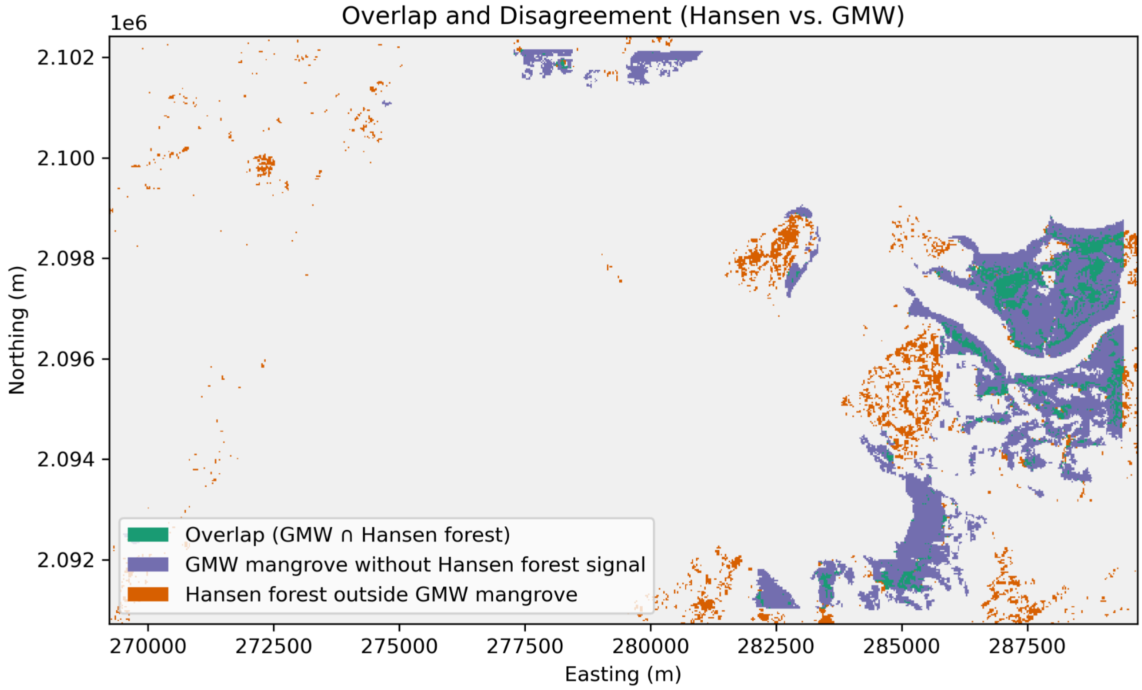
The project evaluates:

1. **Spatial agreement** - (overlap, mismatch area).

2. **Temporal contrast** - (GFW's annual vs. GMW's snapshot years).
3. **Classification sensitivity** - (GFW capturing all tree types vs. GMW capturing only true mangroves)

4. Key Findings (Preliminary)

Figure 3: Overlap and disagreement between Hansen forest and GMW mangroves



These results show that the total GMW mangrove area in the study region is approximately 1508.85 ha, with around 92% of mangrove areas having at least one year of forest detection in Hansen, while about 8% never show a forest signal. Furthermore, the spatial visualizations show clear areas where Hansen detects forest outside GMW mangroves and vice-versa. Put together, these findings suggest that Hansen can generally detect mangroves, but not without flaws in detection potentially caused by sparse canopies, young/degraded mangroves, tidal flooding, and sensor limitation(low resolution).

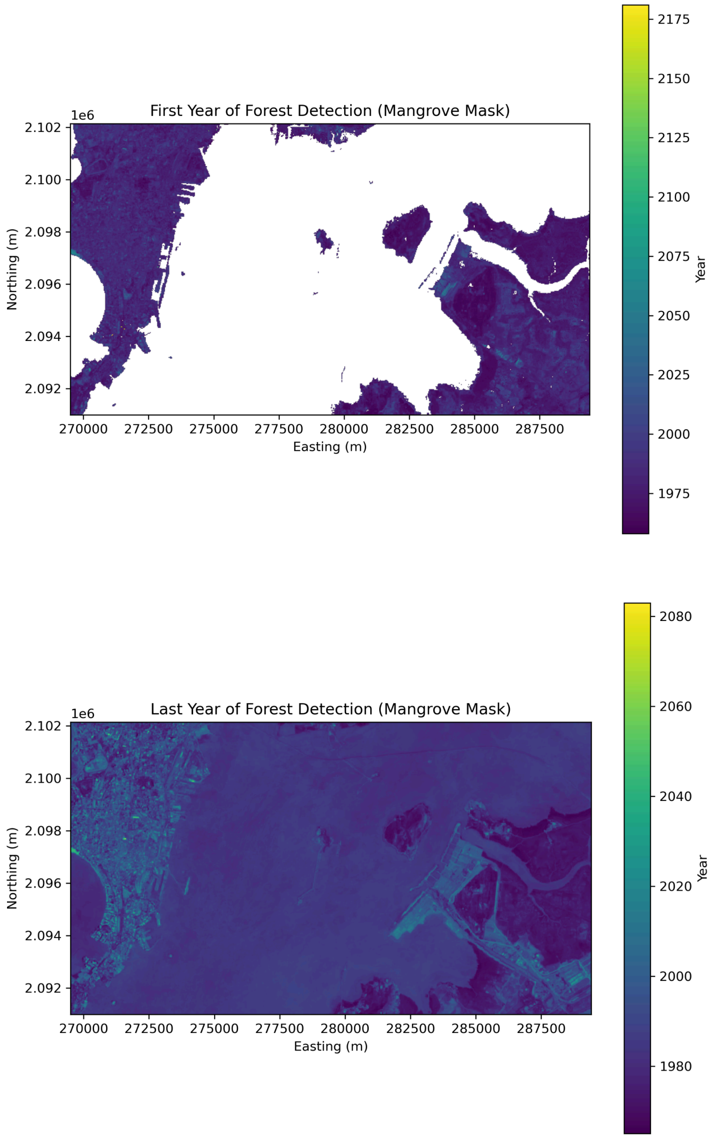


Figure 4: Maps of first year and last year of forest detection within the mangroves

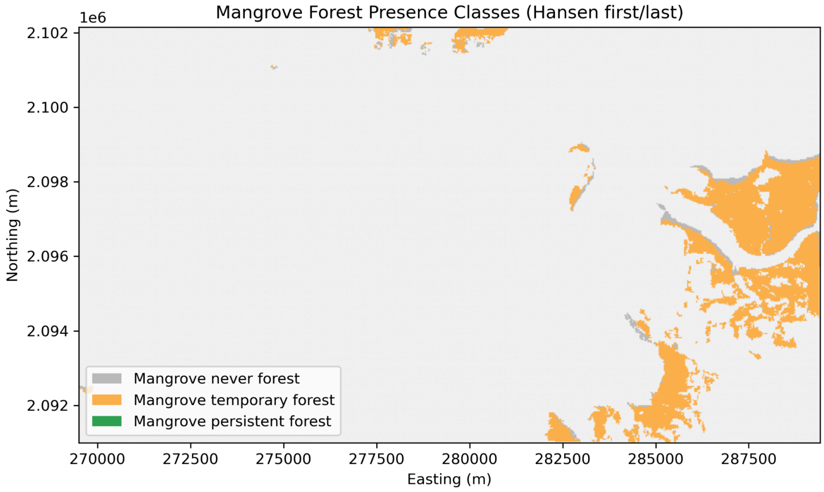
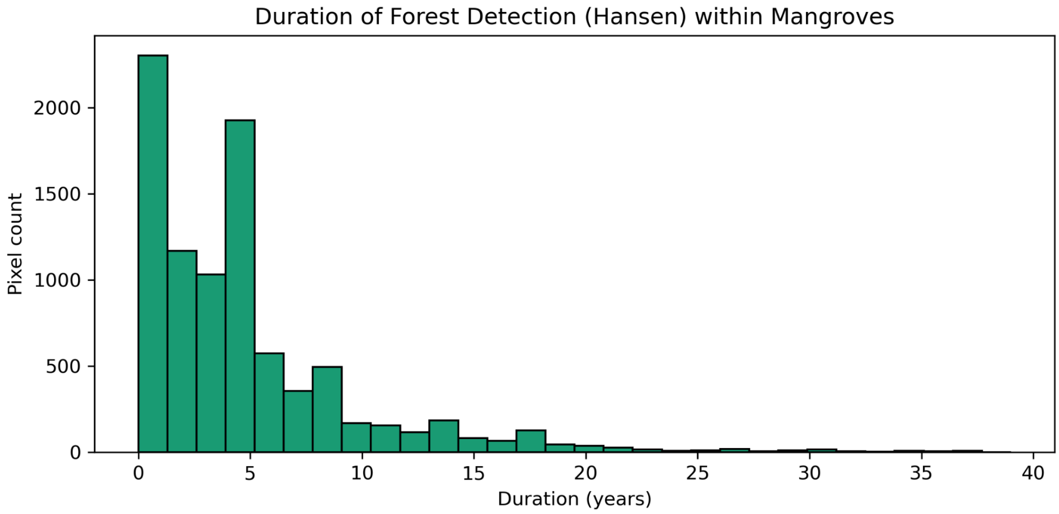


Figure 5: Mangrove forest presence classes (Hansen first/last within GMW mask)

In terms of the classification of mangroves, results show approximately 1393.22 ha (92.34%) of mangroves are classified as "temporary forest" in the Hansen dataset based on the *first > 0* and *last<latest* criterion (Forest signals appear at some point but disappear before the latest year). On the other hand, approximately 115.63 ha (7.66%) are classified as "never forest" (*first == 0*) in the Hansen dataset.

However, persistent forest (*first>0* and *last==latest)* is found to be 0 ha, conveying that all persistent forest pixels are being classified as temporary forest. This outcome is extremely suspicious from a scientific lens considering that mangroves have long lifespans and don't simply remain in a constant cycle of dying out as the data is suggesting.

Due to the suspicious and unstable nature of these results, this data doesn't imply that mangroves are disappearing, but rather suggests that Hansen's forest classification is unstable when applied to Mumbai's mangrove ecosystems.



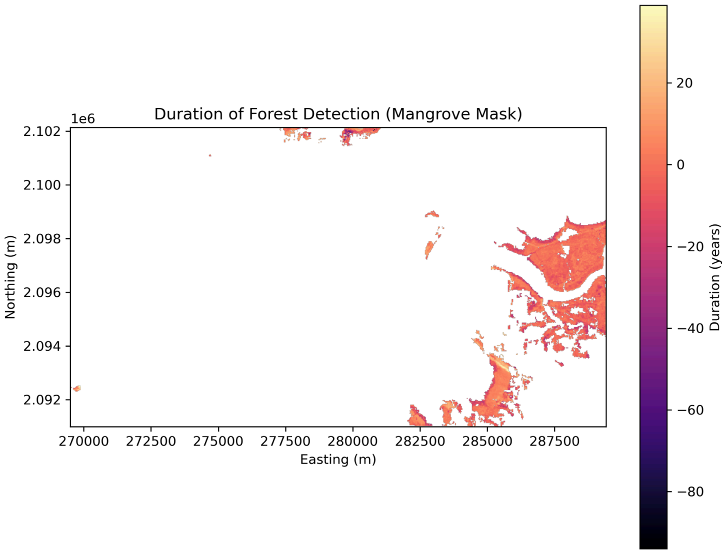


Figure 6: ***Duration of forest detection within mangroves (histogram and spatial map)***

As the histogram shows, the median duration of forest pixel seen in Hansen is near-zero, with very few pixels exceeding a duration of more than 10 years. This suggests that short-lived forest signals dominate duration maps and there is a scarcity of >5 years pixels, again reinforcing the suspicious nature of 0% persistent forest.

The duration spatial map further indicates that mangrove pixels aren't persistent in the Hansen dataset and regularly flicker in and out of its classification of forest. Apart from the reasons stated previously, this can be attributed to tidal effects, phenology, canopy structure, and sensor noise.

Overall, all these results highlight a limitation of applying generic forest metrics to coastal wetlands.

5. Implications for Coastal Engineering and Planning

This research highlights some critical implications:

1. **Dataset choice affects risk assessments**
   - Engineers relying on GFC may overestimate mangrove loss in Mumbai.
   - Policymakers using GMW alone may underestimate short-term degradation.
2. **Combining datasets provides the most reliable picture**
   - GFC - most suitable for annual monitoring
   - GMW - most suitable for accurate mangrove boundaries
3. **Mumbai requires site-specific erosion modelling**
   - Areas like Gorai, Sewri, and Uran need urgent mangrove restoration, not

reclamation.

6. Limitations

This study focuses on a comparison of mangrove detection in Mumbai using two major global datasets: Hansen Global Forest Change (GFC) and Global Mangrove Watch (GMW). The scope is limited to evaluating spatial agreement, temporal detection behavior, and classification stability of mangrove areas within Mumbai's coastal regions. The research does not attempt to quantify actual ecological loss, or model future scenarios, but rather focuses on how dataset choice influences interpretation of mangrove extent and persistence(Categorization of mangroves) in Mumbai.

This study is constrained to Mumbai and its surrounding coastal mangrove ecosystems. While the findings provide meaningful insights into datasets within this coastal context, the results can't be directly generalized to other regions with mangroves globally, which can be attributed to differing canopy structures, sediment characteristics, tidal cycles or climatic conditions.

Additionally, the comparative analysis is only limited to two widely used datasets: Hansen Global Forest Change (GFC) and Global Mangrove Watch (GMW). Although these are among the most commonly referenced datasets for most use cases, other high-resolution or region-specific datasets were not included in this paper. As a result, the conclusions only reflect discrepancies and consistencies between these two datasets, which don't span all available mangrove or forest monitoring datasets.

7. Conclusion

This white paper synthesizes environmental, remote sensing, and engineering perspectives to demonstrate the crucial and irreplaceable role of Mumbai's mangroves in coastal protection. The project's comparative analysis of GFC and GMW datasets fills a major research gap. By employing Python geospatial analysis, this work contributes a novel and practical approach for policymakers, coastal engineers, and conservation planners to work on research related to mangroves.

The ongoing research will in the future refine mismatch quantification, validate results with higher-resolution datasets (Sentinel-2), for multiple future scenarios of mangrove loss and restoration.

8. Sources

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