Remote Sensing Analysis of Mangrove Resilience and Cover Change in the Grand-Pierre Bay, Artibonite, Haiti

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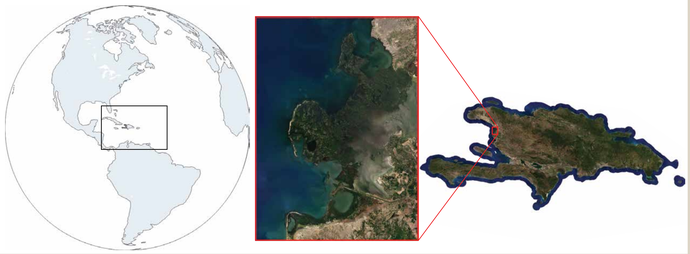
Background and Motivation

Mangroves as Natural Coastal Defense in the Caribbean

- Island Nations in the Caribbean, such as Haïti, are severely threatened by sea-level rise and coastal flooding due to hurricanes' increased frequency and strength.
- Mangroves have the potential to be part of a natural infrastructure strategy for these islands to protect their coastal communities.
- Mangrove forests are, unfortunately, under both climate and anthropogenic pressures.
- One such forest is the Grand-Pierre Bay Mangrove Forest in Haiti, the most extensive mangrove cover in the country.



Data Sources

Satellite Imagery from PlanetLabs is used to conduct this study. We looked at imagery between January 2010 and January 2020 taken by PlanetLabs[1]' RapidEye satellite.

- These images feature high spatial resolution (5 meters) and near-daily temporal resolution, letting us find frequent cloud-free observations to classify and analyze.
- RapidEye (5m) features only five bands **(Red, Green, Blue, Red Edge, and Near Infrared)**; however, this is adequate for the indices used and to accurately classify land covers.

The indices used are **NDVI, NDWI, and UVVR**, as defined below. A Histogram-Based Gradient Boosting Classifier by scikit-learn is used for land classification.

[1]Planet Team (2017). Planet Application Program Interface: In Space for Life on Earth. San Francisco, CA. https://api.planet.com.

Indices and Models

- **Normalized Difference Vegetation Index (NDVI)**

$$NDVI = \frac{NIR - Red}{NIR + Red}$$

Quantifies the density and health of vegetation, providing insights in vegetation health changes.

- **Normalized Difference Water Index (NDWI)**

$$NDWI = \frac{Green - NIR}{Green + NIR}$$

Assesses the presence and extent of surface water bodies.

- **Unvegetated to Vegetated Ratio (UVVR)**

Helps establish vegetation cover status and tracking changes in wetlands.

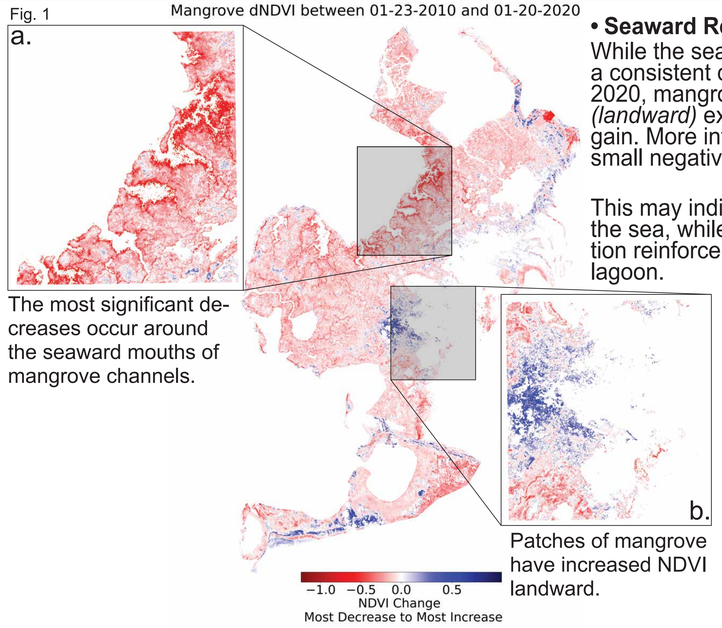
- **Histogram-based Gradient Boosting (HGB) Classifier[2]**

Ensemble algorithm combining the boosting technique with histogram-based binning. It achieves high-performance and efficient classification. We use it for land classification.

[2]Scikit-learn: Machine Learning in Python, Pedregosa et al., JMLR 12, pp. 2825-2830, 2011.

How has the GP Mangrove Forest responded to external pressure?

Fig. 1



The most significant decreases occur around the seaward mouths of mangrove channels.

Patches of mangrove have increased NDVI landward.

- **Seaward Retreat, Landward Advance**

While the sea-facing region *(seaward)* denotes a consistent drop in NDVI between 2010 and 2020, mangroves in the lagoon-facing region *(landward)* exhibit disperse pockets of NDVI gain. More interior regions show no change to small negative change.

This may indicate mangrove diebacks towards the sea, while new establishment or vegetation reinforcement is occuring towards the lagoon.

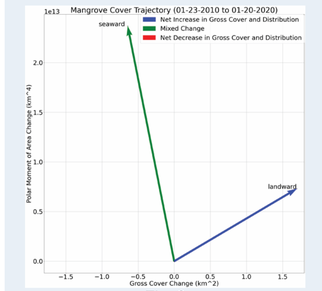
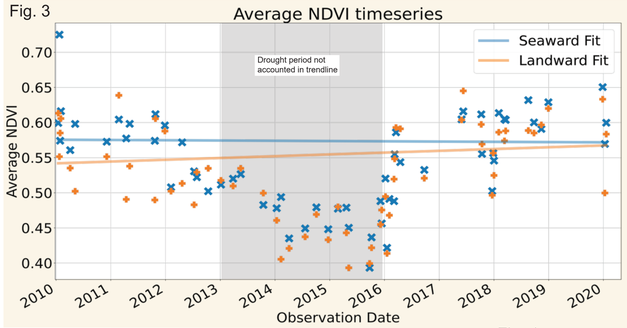


Fig. 2

Fig. 3



- **What is driving this decline?**

Looking at the timeseries of NDVI and UVVR for both seaward and landward regions shows a period of decreased vegetation health and an increase in the unvegetated ratio between 2013 and 2016.

This matches with an extended drought period experienced in Haiti during the same period. However, the landward region is recovering better from this drought than the seaward one.

Mangrove Cover Change between 01-23-2010 and 01-20-2020

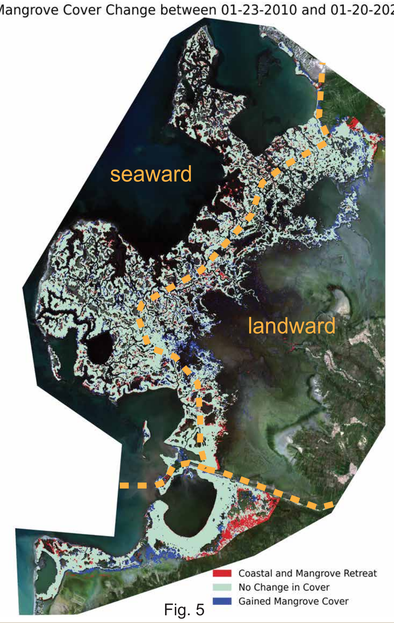
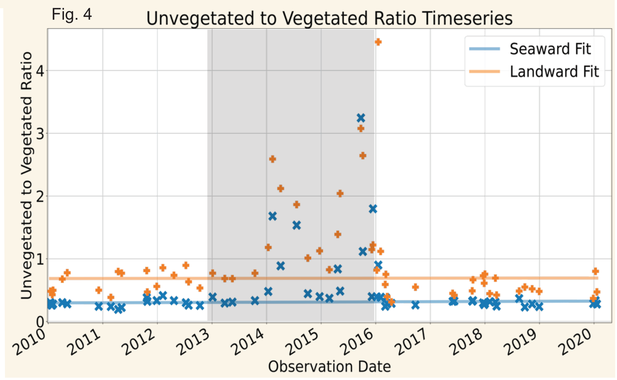


Fig. 5

Fig. 4

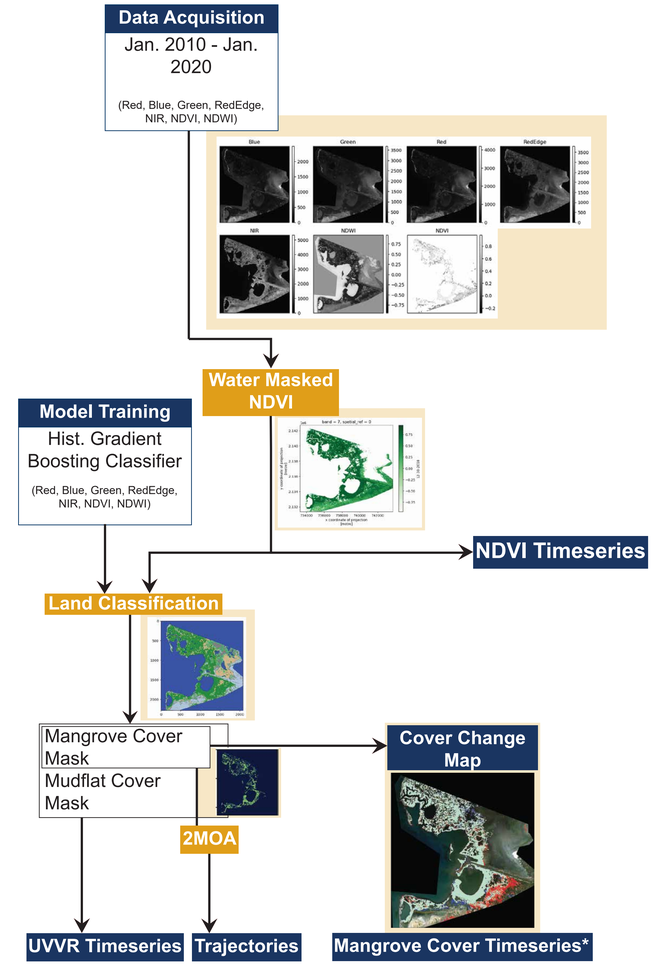


- **The forest is migrating landward, but not fast enough**

As seen in Fig. 2, the landward section shows increased mangrove cover and distribution, indicating forest expansion, while the seaward section experiences reduced cover but higher distribution, suggesting decreased forest density.

With the landward section being smaller than the seaward, the landward migration is insufficient to offset the seaward

Methods and Workflow



Future Work

- Future work on remote sensing analysis will involve validating our classifying model using ground truth data from Trinidad, expanding the analysis to other important mangrove sites in the Caribbean, and conducting a comparative study of dynamics between different Caribbean sites.
- In addition to remote sensing, using mangrove cover maps and changes in coupled hydrodynamic and dynamic vegetation models will enable the study of mangrove response to sea-level rise and provide insights into the processes driving seaward retreat.

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