PGRSC – Pacific GIS and Remote Sensing Council

PGRSC Conference – 25-29 November 2024

Sustainable Management for Coastal Areas through Remote Sensing & GIS

Automated Shoreline Monitoring in French Polynesia's Atolls:

A Case Study on Tetiaroa

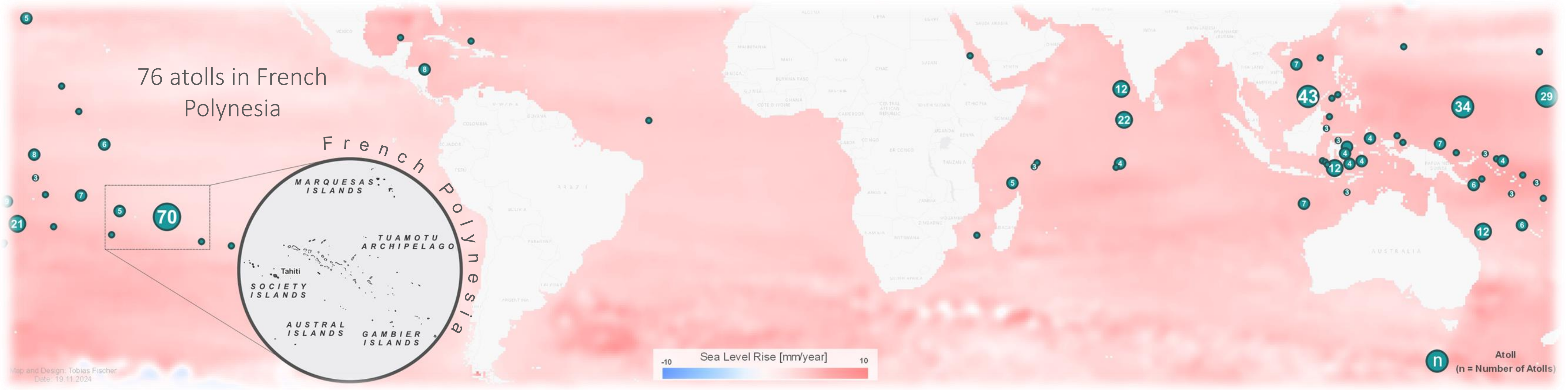
Tobias Fischer
PhD Student, University of French Polynesia
tobias.fischer@doctorant.upf.pf

Benoît Stoll
Associate Professor, University of French Polynesia

RÉPUBLIQUE FRANÇAISE – Liberté Égalité Fraternité · UPF Université de la Polynésie Française · UMR 241 SECOPOL · GePaSud · Tetiaroa Society · D·A·F Direction Affaires Foncières · DAG Direction de l'Agriculture – Pū fa'aterera'a nō te 'ohipa fa'a'apu · Oxford Seascape Ecology Lab

Introduction

Understanding Vulnerabilities of Pacific Atolls through Systematic Monitoring



Problem:

Pacific atolls are **vulnerable** to sea level rise, with a lack of systematic monitoring

Objective:

Develop an automated, high-precision **shoreline monitoring** method

Significance:

Provide Insights for **climate adaptation** and coastal management

Tetiaroa Atoll

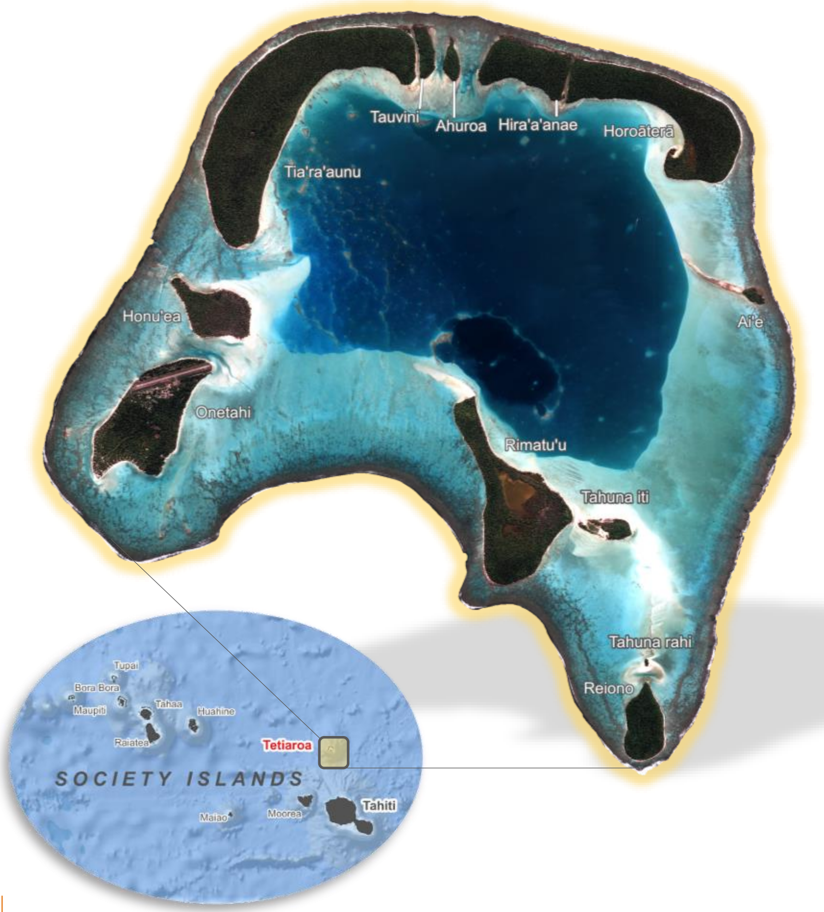
A Case Study of Reef Island Vulnerability

Native Avian Species

Vegetation Loss

Terrestrial Biodiversity

Coastal Erosion



Geographic Context:

Low-lying **reef islets** with exceptional **biodiversity**.
Cultural Significance as preserved atoll.

Environmental Challenges:

Dynamic sediment changes affecting certain motus.
Localized increases in **erosion** and **vegetation loss**.

Study Focus:

Analyzing changes over time to identify **vulnerable areas**.

Defining the Shoreline

The Interface between Land and Water

A shoreline represents the interface between land and water, which can vary depending on environmental factors and classification methods.

Instantaneous Line

Vegetation Line

Stability Line

Combined Shoreline

Final integrated shoreline for comprehensive monitoring

*Combined shoreline approach adapts to **short- and medium-term monitoring**.*

Methodology

Comparing Shoreline Extraction Methods

Pléiades Imagery:
Spatial Resolution: 50 cm
Spectral Resolution: RGB + NIR
Accessibility: Commercial

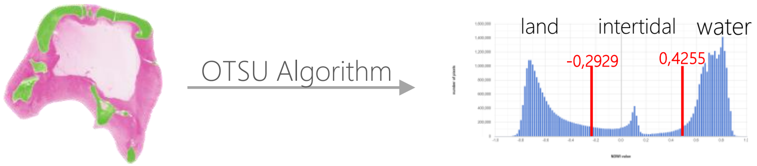
Temporal series of Pléiades satellite imagery (2016-2023) supports multi-year shoreline extraction.

Index-based Approach

NDWI Thresholding

Almeida et al., 2021

*Separates land and water using **Multi-Otsu Algorithm***

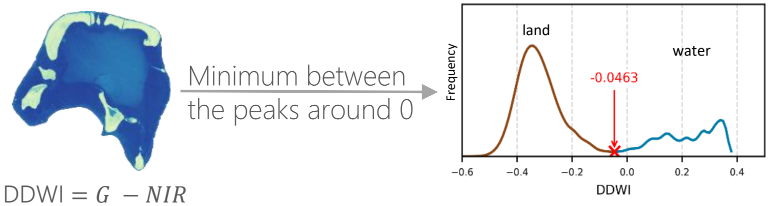


$NDWI = \frac{(G - NIR)}{(G + NIR)}$

DDWI Thresholding

Abdelhady et al., 2022

*Separates land and water using the **smoothed histogram***

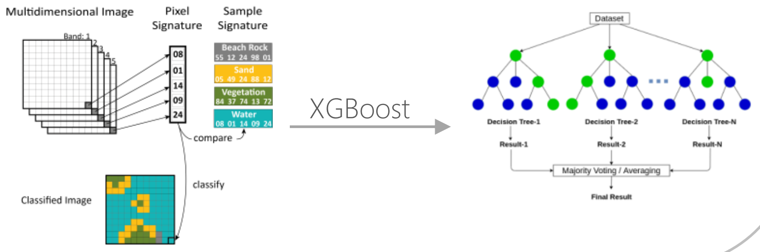


$DDWI = G - NIR$

Machine Learning Approach

XGBoost Classification

Supervised classification *integrating spectral, color space and texture features*

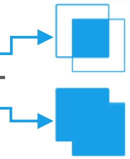


*Methods evaluated for **accuracy, adaptability** and **transferability** across years.*

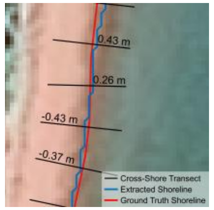
Results

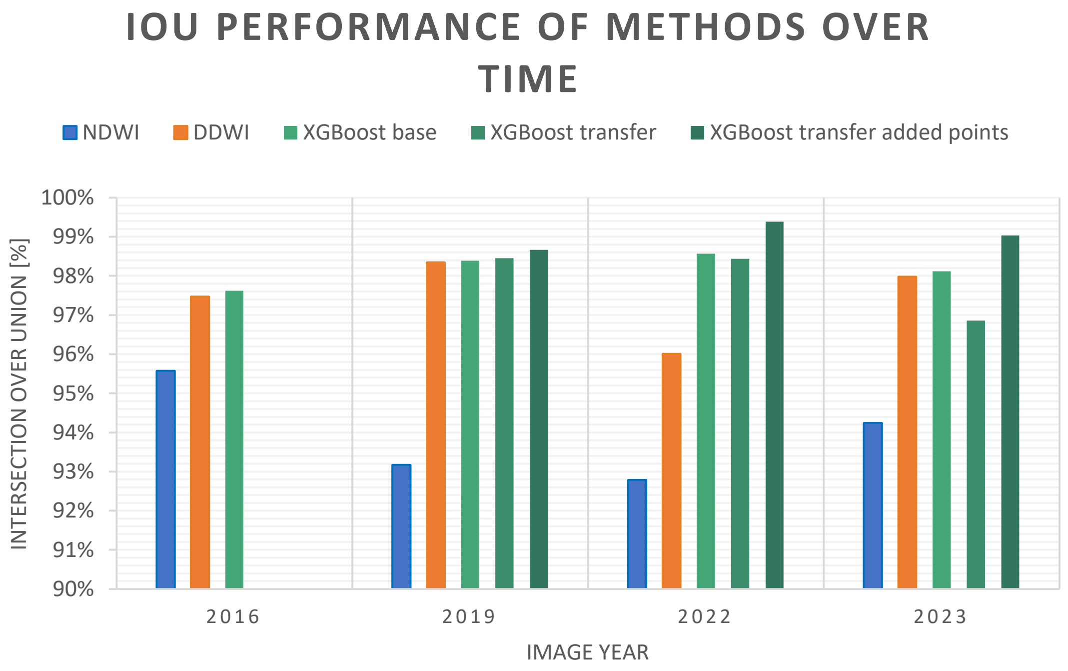
Performance of Shoreline Extraction Methods

$$Intersection\ over\ Union(IoU) = \frac{Area\ of\ Overlap}{Area\ of\ Union}$$



$$Mean\ Positional\ Error\ (MPE) = \frac{1}{n}\sum_{i=1}^{n}|d_i|$$





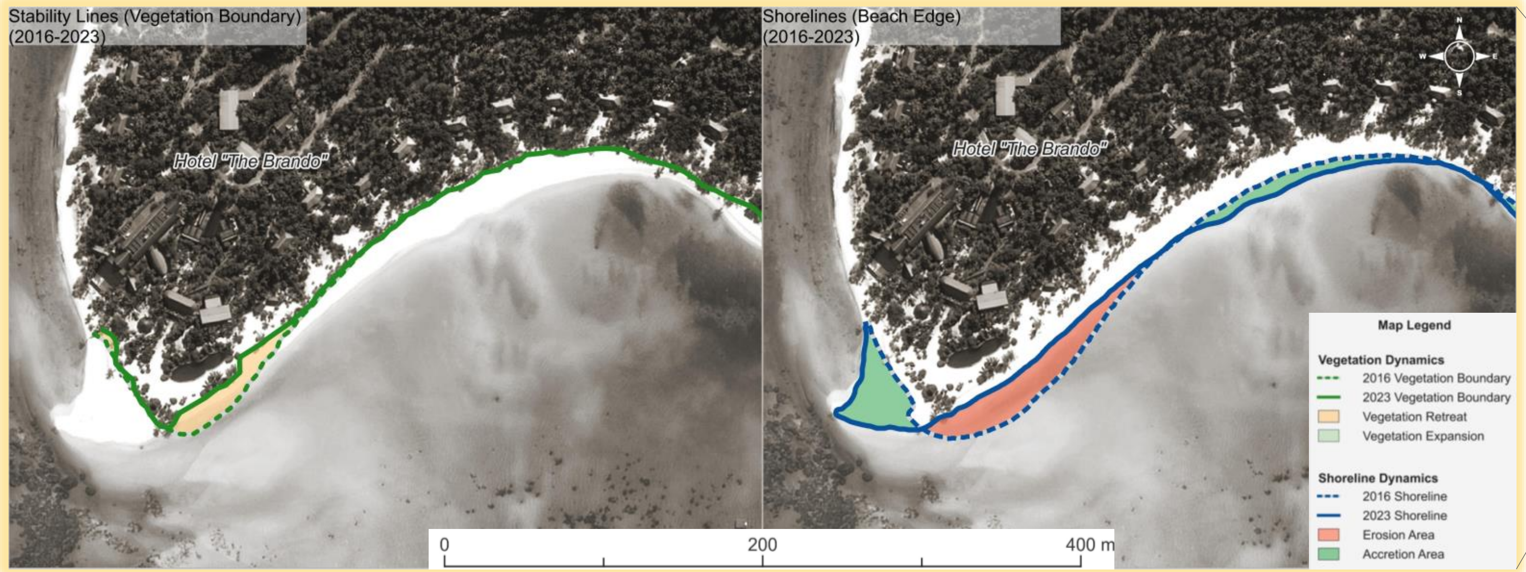
Model	IoU [%]	MPE [m]	Std Dev [m]
NDWI	0,93	5,20	8,20
DDWI	0,97	1,65	3,77
XGBoost Transfer added Points	**0,99**	**1,09**	**1,57**

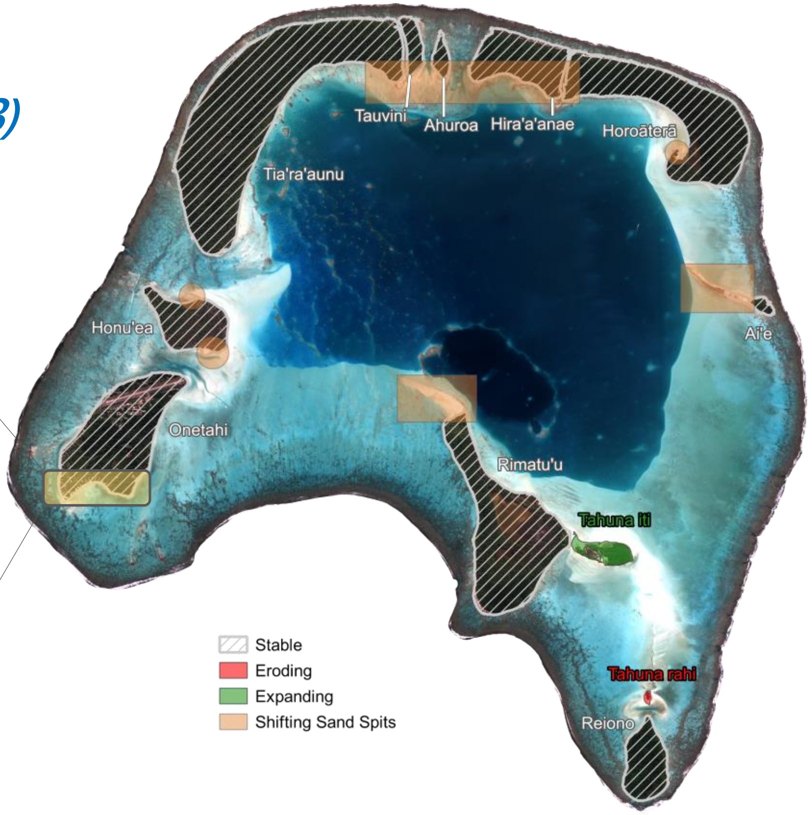
XGBoost *delivers* ***superior adaptability*** *and* ***precision.***

Results

Key Insights in Motu Dynamics (2016-2023)

Indicators of Coastal Changes on Onetahi, Tetiaroa





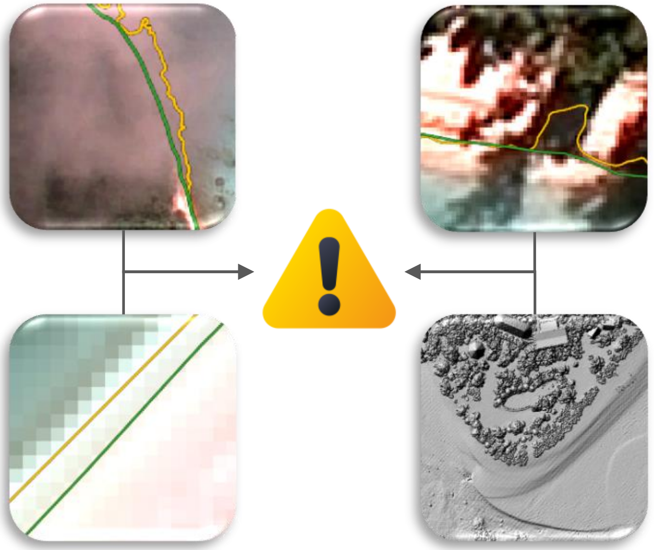
Category	Dynamics
Stable Motu	Minimal change; shifting sand spits (e.g., Honu’ea, Ai’e)
Dynamic Motu	Tahuna Rahi: -0.31 ha shoreline, -0.20 ha vegetation Tahuna iti: +0.67 ha shoreline, -0.09 ha vegetation
Onetahi Beach	-0.26 ha erosion, +0.27 ha accretion, sand shift impacts hotel amenities

Stability lines ***overlook*** *significant* ***sediment dynamics****, highlighting the need for* ***combined indicators***

Discussion

Advancing Shoreline Extraction Methods for Dynamic Atoll Monitoring

Limitations of Shoreline Extraction



Broader Implications and Future Directions

1. Complementary Indicators
   - Shorelines capture short-term sediment dynamics
   - Stability lines reflect long-term stability and resilience
   - Combining both offers a comprehensive view of coastal change.
2. Machine Learning Impact
   - XGBoost shows spatial and temporal transferability.
   - Struggles with cloud and tree shadows.
3. Future Directions
   - Expand training data for better generalization across atolls.
   - Use LiDAR or drone data for 3D profiling to enhance precision in shoreline delineation.

Key Takeaway

Challenges *in* ***shoreline extraction*** *require* ***innovative solutions*** *like* ***combined indicators*** *and* ***adaptable machine learning models****.*

Conclusion

Advancing automated Shoreline Monitoring

Key Summary

Performance

- **XGBoost** excels in shoreline detection with **high precision** and **adaptability**.
- Effectively monitors changes over **short**, **medium**, and **long time scales**.

Challenges

- **Shadows**, **clouds**, and **shallow water zones** require complementary approaches.
- Lack of **tidal correction** data limits temporal comparisons.

Significance

- **Reduces manual effort** and improves efficiency.
- Enables **large-scale monitoring** across atolls, strengthens regional resilience.

Shorelines extracted from Pléiades images using XGBoost

Tetiaroa Shoreline 2022

Puka Puka Shoreline 2023

Collaborate to improve shoreline monitoring and protect vulnerable coastal regions!

PGRSC Conference – 25-29 November 2024

Sustainable Management for Coastal Areas through Remote Sensing & GIS

ACKNOWLEDGEMENTS

UMR Espace Dev : Marc Despinoy
Tetiaroa Society Management : Frank Murphy, Vairupe Huiouto Pater
Tetiaroa Society Rangers : Temakehu Murphy, Tuterai Apuarii, Juju Wazalpha
Tetiaroa Society Guides : Tihoni Maire, Teva Salmon, Herehia Sanford
Tetiaroa Society Botaniste : Jean-Yves Meyer
DAF Topo : Mathieu Villard, Yoann Roncin

VINAKA VAKA LEVU!
QUESTIONS?

SCAN ME

Let's stay in touch