Fall 2022 Project Summary

Maldives Climate

Monitoring Shoreline Changes and Island Loss in Response to Climate Change

Project Team

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Project Overview

Project Synopsis:
The Republic of Maldives has been heavily affected by the impacts of climate change for decades due to rising sea level and shoreline erosion. With the majority of the country's islands being impacted, monitoring and understanding these changes is essential for decision making and mitigation. The team utilized NASA, ESA, and Planet satellites to create maps that highlight areas most affected by shoreline erosion and demonstrate changes in water quality throughout the country. These maps, along with a methodology tutorial, will allow partners to expand on the team's work and enhance current climate change adaptation and mitigation plans.

Abstract:
Global sea level rise as a result of climate change continues to pose a critical threat to coastal ecosystems and populations. The archipelagic country of the Maldives is of critical concern due to being one of the lowest lying areas in the world. The development of reclaimed land in the Maldives by sand dredging has been a frequent response to both increasing sea levels and population increase. Such disturbance can lead to increased sedimentation off the coast and negatively impact coastal environments. Remote sensing tools such as satellite imagery have proved to be an effective tool in observing coastal changes in response to climate change and development. We, the NASA DEVELOP team, created a methodology to analyze both water quality and shoreline erosion in the Maldives utilizing satellite imagery. Our methods relied on open-source software such as QGIS and Google Earth Engine (GEE) and Satellite Imagery from PlanetScope, Landsat 8 Operational Land Imager (OLI), Sentinel-2 Multi Spectral Instrument (MSI), and Aqua & Terra Moderate Resolution Imaging Radiospectrometer (MODIS) to analyze the changes in shorelines and assess water quality of select atolls within the Maldives. We found that there is less shoreline change in developed parts of the island and more shoreline change in natural parts of the island. Additionally, water quality varies throughout the year and our data did not indicate seasonal trends. Our methodology will be replicated to

continue to monitor island erosion and water quality with the Maldives and will be applicable to other island and coastal systems.

Key Terms:
remote sensing, Google Earth Engine, QGIS, shoreline change, sea level rise, NDWI, Chlorophyll-a, turbidity

National Application Area Addressed: Climate
Study Location: Maldives
Study Period: March 2016 – September 2022

Community Concerns:

- Climate change has caused land loss along the coastline due to sea level rise, leading to less habitable areas.
- Changes in water conditions may affect reef ecosystems and general community health.
- Sea level rise threatens fresh water sources due to saltwater intrusion.

Project Objectives:

- Measure and map water quality using turbidity (water clarity indices), chlorophyll-a, and sea surface temperature (SST) values
- Quantify and map coastal erosion using Normalized Difference Water Indices (NDWI) derived from Earth observations
- Create a tutorial tailored to technical staff in the Maldives Ministry of Environment, Climate Change and Technology detailing how to replicate the methodology of this project

Partner Overview

Partner Organizations:

Organization	Contact (Name, Position/Title)	Partner Type
Maldives Ministry of Environment, Climate Change, and Technology	Khadeeja Naseem, Minister of State; Abdulla Naseer, Minister of State; Aishath Aileen Niyaz, Director; Thibyan Ibrahim, Assistant Director; Aishath Reesha Suhail, International Relations Officer; Ahmed Raidh, Coastal Analyst	End User
U.S. Department of State, Bureau of South and Central Asian Affairs, Office of Bangladesh, Nepal, Sri Lanka, Maldives, and Bhutan	Alan Brinker, U.S Mission Maldives A/DCM; Ellen Connorton, Senior Science Advisor; Charlotte Volpe, Economic Officer; Abigail Bard, Foreign Affairs Officer; Aishath Rifga, U.S Mission Maldives Economic Specialist; Amelia VanderLaan, SCA Climate	End User
USAID, Maldives Office	Hillery Midkiff, Program Coordinator; Nihani Riza, Environmental Program Specialist	End User

Decision-Making Practices & Policies:

The Ministry of Environment, Climate Change and Technology currently oversees several programs and services in the Maldives that encourage mitigative and adaptive procedures and policies aimed towards climate change. The country is composed of over 1,100 islands which are home to an abundance of species under monitoring and protection efforts by the Ministry of Environment, Climate Change and Technology. The Ministry is currently overseeing effects of land reclamation, the process of dredging up from the sea floor and using it to create more available land for development. Currently, our partners aim to build capacity to utilize and incorporate Earth observations into their decision-making processes.

Earth Observations & End Products Overview

Earth Observations:

Platform & Sensor	Parameters	Use
Landsat 8 OLI	Turbidity	These data were used from 2016-2022 to calculate water quality indices, create maps, and develop time series analyses.
Sentinel-2	Chlorophyll-a, turbidity	These data were used from 2016-2022 to monitor changes in water quality, create maps, and develop time series analyses.
Aqua MODIS	Chlorophyll-a, SST	These data were used from 2016-2022 to monitor changes in water quality, create maps, and develop time series analyses.
PlanetScope	True color (R, G, B), NDWI	These data were used from 2017-2022 to monitor changes in shoreline, create maps, and develop time series analyses.

Software & Scripting:

- Google Earth Engine Application Programming Interface (API) – Acquire remotely sensed data, and calculate NDWI, MNDWI, NDTI, and true color composites
- QGIS 3.26 – Visualize satellite imagery, conduct shoreline erosion analyses
- Optical Reef and Coastal Area Assessment (ORCAA) Tool – Map and create time series of water quality parameters retrieved from satellite imagery in Google Earth Engine

End Products:

End Product	Earth Observations Used	Partner Benefit & Use	Software Release Category
Shoreline Change Maps	PlanetScope	Partners will have access to imagery detailing the change in shoreline from 2017 to 2022. Imagery will show area change from each year.	N/A
Water Quality Maps	Sentinel-2, Aqua MODIS, and Landsat 8	Partners can observe any changes in chlorophyll concentration and turbidity from March 2016 to September 2022.	N/A
Timeseries Plots of Change in Shoreline	Sentinel-2, Landsat 8	Partners will be able to observe specific changes or events that	N/A

and Water Quality parameters		may have occurred over time from maps, graphs, and imagery provided for them.	
Maldives Climate ORCAA Water Quality Analysis and QGIS Shoreline Change Tutorials	N/A	Tutorials provide the partners the ability to recreate shoreline and water quality analysis for continued shoreline and water quality monitoring.	N/A

Product Benefit to End User:

Shoreline change maps will provide insight into future management and development decisions as well as assessing potential risks that may be associated with changes in sea level and erosion. Island area plots derived from shoreline processing can help partners to observe changes in overall area for specific islands due to both erosion and reclamation of land. The tutorial the team produced will provide partners with an introduction to QGIS and how to recreate the shoreline analysis process so that future monitoring can be done. Water quality maps and time-series plots will allow our partners to assess whether there have been extreme changes in turbidity and chlorophyll-a concentrations, where they may be occurring, and at the date on which it occurred. Tutorial of the ORCAA will help our partners to operate the tool and perform future monitoring of water quality parameters.

Project Continuation Plan:

In the project's second term, efforts will be made to better understand the impacts of human development and infrastructure on climate change impacts such as shoreline erosion and water quality. Additionally, results and methodology from the first term will guide and enable teams to effectively gather results in future terms.

References

García-Rubio, G., Huntley, D., & Russell, P. (2015). Evaluating shoreline identification using optical satellite images. *Marine Geology* 359, 96–105. https://doi.org/10.1016/j.margeo.2014.11.002

Pippin, H, Olarte, A, Pilot, R, & Valenti, V. (2019) Developing a Google Earth Engine Dashboard for Assessing Coastal Water Quality in the Belize and Honduras Barrier Reefs to Identify Adequate Waste Control and Inform Coastal Resource Monitoring and Management. https://github.com/NASA-DEVELOP/ORCAA

Rasheed, S., Warder, S. C., Plancherel, Y., & Piggott, M. D. (2021). An improved gridded bathymetric data set and tidal model for the Maldives archipelago. *Earth and Space Science, 8*. https://doi.org/10.1029/2020EA001207