**Osa Peninsula Water Resources III**

*Evaluating Potential Sites for Coral Reef Restoration in the Golfo Dulce, Costa Rica Based on Turbidity and Sea Surface Temperature*

**VPS Title:** Canopy to Coral: Monitoring conditions for coral and watershed health in Golfo Dulce, Costa Rica

**Project Team**

***Project Team*:**

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**Project Overview**

***Project Synopsis*:** NASA DEVELOP collaborated with Osa Conservation to assess suitable locations for coral reef restoration in the Golfo Dulce of the Osa Peninsula, Costa Rica. Understanding the connection between river water quality and aquatic conditions in the gulf is critical to the success of reef restoration efforts. Previous terms assessed land use change in the region’s watersheds and the impacts on water quality in its rivers. This third iteration of the project used NASA Earth observations to examine these rivers’ effects on water quality in the gulf.

***Abstract*:**

The Osa Peninsula, located in the southern region of Costa Rica’s Pacific coast, is one of the most biologically diverse places on Earth. NASA DEVELOP partnered with Osa Conservation to analyze the impact of human activity on vital water resources, with a focus on determining suitable locations for coral reef restoration in the Golfo Dulce. Coral reefs play a crucial role as a habitat provider, an ecosystem stabilizer, and as food security for marine and terrestrial communities; however, they are highly sensitive to changes in aquatic conditions, which can lead to bleaching and slowed reef accretion. This project used Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI), and Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) satellite imagery to investigate turbidity and sea surface temperature (SST). These data were compiled into time series maps to assess variability within a season and over the years. The variability data were used to evaluate sites for coral restoration and provide insight into the connections between land use, river health, and fluctuations in water quality within the gulf.

**Keywords:**

Landsat, Google Earth Engine, turbidity, coral, MODIS, sea surface temperature

***National Application Area Addressed:*** Water Resources

***Study Location:*** Area of Conservation Osa: Osa Peninsula and Golfo Dulce, Costa Rica

***Study Period:***  February 1986 – May 2018

***Community Concern:***

* Costa Rica had one of the highest deforestation rates in the world during the 1980s, with forest cover decreasing from over 50% during the 1940s to 29% by 1986. In response, the Costa Rican government introduced Forest Law 7575 of 1996, which aims to support reforestation by protecting riparian zones and compensating landowners for conservation.
* Agricultural byproducts and deforestation in watersheds on the Osa Peninsula have decreased river water quality. This ultimately has a negative impact on the many endemic and endangered species in the region.
* The rivers on the peninsula pick up sediment, pollutants, and nutrients from their watersheds that can destabilize ecosystem health in the Golfo Dulce.
* Coral reefs provide vital ecosystem services such as shoreline protection and food security, but their sensitivity to fluctuations in turbidity and temperature has led to slowed reef accretion, bleaching, increased bioerosion and dissolution rates, and ultimately destabilization of the reefs.
* Ecotourism is an important development and conservation tool on the Osa Peninsula that provides a reliable source of employment for local residents as well as important funding for conservation. Land use change and agricultural practices have led to a decrease in terrestrial and aquatic biodiversity in the region, and the ecotourism economy may be negatively impacted if the trend continues.

***Project Objectives:***

* Produce 30 m spatial resolution time series maps for median annual turbidity for 1986 – 2016
* Produce 30 m spatial resolution maps of seasonal differences in median turbidity for 2015 – 2017 (February – May and August – November)
* Produce 500 m spatial resolution maps of seasonal differences in median SST for 2015 – 2017 (February – May and August – November)
* Produce 30 m spatial resolution, zoomed-in time series maps of seasonal differences in median turbidity at key river deltas for 2015 – 2017 (February – May and August – November)
* Produce a bivariate change in SST and turbidity map to identify areas in the Golfo Dulce most suited for coral restoration
* Create a correlation chart for the relationship between turbidity and SST
* Produce an interactive SST map tool for 2002 – 2018

***Previous Term:*** 2018 Spring (GA) – Osa Peninsula Water Resources, 2018 Summer (GA) – Osa Peninsula Water Resources II

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Osa Conservation** | Hilary Brumberg, Watershed  Conservation (Ríos Saludables)  Program Coordinator;  Dr. Noelia Hernandez, Osa Conservation Science Director;  Mónica Espinoza Miralles, Marine Conservation Scientist | End User | Yes |

***Decision Making Practices & Policies***:

Osa Conservation works to protect and conserve critical river-coastal-marine ecosystems through their

Watershed Conservation, Mangrove Conservation and Marine Conservation Programs and by partnering with

Costa Rican universities and international researchers. Their biologists use extensive field monitoring and lab analysis to observe and study the needs of species within the surrounding aquatic areas. As part of these efforts, they are looking for areas to implement coral rehabilitation where reefs have been damaged by natural or man-made causes. Osa Conservation is developing a plan to create a marine reserve to protect at-risk marine ecosystems and resident and migratory species. Osa Conservation facilitates social engagement mechanisms to promote conservation and sustainable use of river and marine species and ecosystems at local, national and international scales. The organization has used limited Landsat imagery and Google

Earth Engine (GEE) for prior projects but has not done extensive analyses. In addition, they have collected randomized, observational data by exploring potential coral restoration sites around the Golfo Dulce.

***Project Benefit to End User***:

Osa Conservation will be able to use the end product maps and analyses created from NASA Earth observation data to determine areas in the Golfo Dulce with stable water conditions for coral viability. Because fluctuations in turbidity and SST are some of the main stressors for coral destabilization, time scale analyses of these characteristics will inform the organization of sites that are least susceptible to these changes. Furthermore, detailed turbidity analyses of major river deltas will aid in localizing and finding the root causes of fluctuations to inform methods of protecting the area’s coastal marine environment. The partner will use and distribute results of this project to the National System of Conservation Areas (SINAC), Ministry of Environment and Energy (MINAE), and local communities to inform land management decisions, policy enforcement, education and outreach initiatives, and watershed restoration and monitoring efforts.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Aqua MODIS** | SST | Aqua MODIS data were used to determine changes in SST since 2002. |
| **Landsat 5 TM** | Turbidity | Landsat imagery from 1986 to 2012 was used to evaluate changes in turbidity over the past few decades. |
| **Landsat 7 ETM+** | Turbidity | Turbidity, derived from reflectance, was used to fill the temporal gap between Landsat 5 and 8 data availability. |
| **Landsat 8 OLI** | Turbidity | Data from the OLI sensor were used to compare turbidity from 2015 to 2018 with values from past decades. |

***Software & Scripting:***

Google Earth Engine API – Image composites and mosaics

Esri ArcGIS 10.5 – Image classification and analysis, map creation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Median Normalized Difference Turbidity Index (NDTI) Time Series Across 26 Years in Five Year Intervals** | Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | The partner will use the analysis of how gulf conditions have changed over the past three decades from 1986 to 2016 to assess which areas of the gulf have been most stable over time. | III |
| **Seasonal Fluctuations  in NDTI and SST Time Series** | Landsat 8 OLI  Aqua MODIS | The partner will use these seasonal maps from 2015 to 2017 to determine gulf areas least impacted by seasonal changes. | III |
| **NDTI at River Intersect High Resolution Time Series by Season** | Landsat 8 OLI | The partner will use this end product to analyze recent seasonal trends in runoff pollution from key rivers with deltas flowing into the Golfo Dulce from 2015 to 2017. | III |
| **Coral Reef Restoration Area Suitability Map** | Landsat 8 OLI  Aqua MODIS | The final suitability map will allow Osa Conservation to determine potential coral reef rehabilitation zones based on SST and NDTI fluctuations. | III |
| **Correlation Chart for NDTI and SST** | Landsat 7 ETM+  Landsat 8 OLI  Aqua MODIS | This chart will help the partner understand how their chosen parameters, NDTI and SST, interact over time from 2002 to 2017. | III |
| **Interactive SST Tool** | Aqua MODIS | This interactive tool will allow Osa Conservation to create and export time series charts of SST from 2002 to 2018 for any point in the gulf. | III |

**Project Handoff Package**

**Transition Plan:**

The Osa Peninsula Water Resources III team held a virtual handoff session via Skype with the partner at Osa Conservation to present and discuss the final analyses and deliverables produced during the term. Since this is the final term of the project, the team also held a virtual training webinar to discuss the technical methodologies used by the team to produce this research while also providing all final documents, maps, data analyses, and promotional materials from the term through Google Drive.

*Software Release Plan*: The Osa Peninsula Water Resources III team used Google Earth Engine (GEE) to explore changes in turbidity and SST in the Golfo Dulce. Osa Conservation was aware of possible delays in receiving code from GEE. Access to the materials were given to the partner through the Center Lead. A heavily commented coding guide will be uploaded to the Google Drive once it has been cleared through the software release process. The code will be alterable for potential future use by Osa Conservation following the completion of the project.

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**Software Release POC:** Samuel Furey, stfurey1@gmail.com

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**Handoff Package:**

* Final deliverables
* Median NDTI Time Series
* Seasonal Fluctuations in NDTI and SST Time Series
* NDTI at River Intersect High Resolution Time Series by Season
* Coral Reef Restoration Area Suitability Map
* Correlation Chart for NDTI and SST
* Interactive SST Tool
* Recording of training webinar

**References:**

About the Osa. (2018). Retrieved from http://osaconservation.org/about-the-osa-peninsula/

Chen, Z., Hu, C., & Muller-Karger, F. (2007). Monitoring turbidity in Tampa Bay using MODIS/Aqua 250-m

imagery. *Remote Sensing of Environment, 109*(2), 207-220. https://doi.org/10.1016/j.rse.2006.12.019

Driscoll, L., Hunt, C., Honey, M. & Durham, W. (2011). The importance of ecotourism as a development

and conservation tool in the Osa Peninsula. *Costa Rica Report for the Centre of Responsible*

*Tourism (CREST)*.

Hansen, M. C., & Loveland, T. R. (2012). A review of large area monitoring of land cover change using

Landsat data. *Remote Sensing of Environment*, *122*, 66-74. https://doi.org/10.1016/j.rse.2011.08.024

Neil, D. T., Orpin, A. R., Ridd, P. V., & Yu, B. (2002). Sediment yield and impacts from river catchments to

the Great Barrier Reef lagoon. *Marine Freshwater Research,* *53*, 733-752. https://doi.org/10.1071/MF00151

Palmer, S. C., Kutser, T., & Hunter, P. D. (2015). Remote sensing of inland waters: Challenges, progress and

future directions. *Remote Sensing of Environment, 157*, 1-8. https://doi.org/10.1016/j.rse.2014.09.021

Protecting Osa’s Marine and Coastal Ecosystems. (2018). Retrieved from

http://osaconservation.org/projects/habitat/marine-ecosystems/

Rodricks, S. (2010). Enabling the legal framework for PES, Costa Rica. Retrieved from

http://www.TEEBweb.org/

Silbiger, N. J., Nelson, C. E., Remple, K., Sevilla, J. K., Quinlan, Z. A., Putnam, H. M., . . . Donahue, M. J.

(2018). Nutrient pollution disrupts key ecosystem functions on coral reefs. *Proceedings of the Royal Society B: Biological Sciences,* *285*(1880), 20172718. https://doi.org/10.1098/rspb.2017.2718

Wang, M., Nim, C. J., Son, S., & Shi, W. (2012). Characterization of turbidity in Florida's Lake Okeechobee

and Caloosahatchee and St. Lucie Estuaries using MODIS-Aqua measurements. *Water Research, 46*(16), 5410-5422. https://doi.org/10.1016/j.watres.2012.07.024