**Hawai’i Water Resources**

*Monitoring the Impacts of Land-Based Sources of Pollution on Water Quality Along the Coast of West Maui, Hawai’i to Assess Coral Reef Condition*

**Project Team**

***Project Team:***

Arev Markarian (Project Lead)

Emily Deardorff

Arthur Platel

Sophia Skoglund

***Advisors & Mentors:***

Dr. Juan Torres-Pérez (Bay Area Environmental Research Institute, NASA Ames Research Center)

**Project Overview**

***Project Synopsis:*** Coral reef coverage along the coast of West Maui, Hawai’i has decreased between 30 and 75 percent over the last 20 years due to land-based source pollutants (LBSP). The DEVELOP Hawai’i Water Resources team partnered with the West Maui Ridge to Reef Initiative (R2R) and the Hawai’i Department of Land and Natural Resources Division of Aquatic Resources (DLNR-DAR) to identify trends in land use and land cover changes (LULCC) and water quality degradation using Landsat imagery. This 30-year analysis provided partners with maps and a user-friendly tool to inform watershed management and conservation for years to come.

***Abstract:***

West Maui is at risk of losing ecosystem services provided by coral reefs due to land-based sources of pollution (LBSP). In 2011, the US Coral Reef Task Force (USCRTF) identified the West Maui watershed as a priority watershed (along with its sub-watersheds of Wahikuli, Honokōwai, Kahana, Honokahua, and Honolua) after decades of coral decline, giving rise to the multi-agency West Maui Ridge to Reef (R2R) Initiative. The DEVELOP Hawai’i Water Resources team partnered with the R2R Initiative and the Hawai’i Department of Land and Natural Resources Division of Aquatic Resources (DLNR-DAR) to address the need for better watershed management practices. The team provided the partners with a Google Earth Engine tool that displays land use and land cover changes (LULCC) in the five watersheds and detects near-shore turbidity, chlorophyll-a (chl-a), and sea surface temperature using Landsat 4 Thematic Mapper (TM), Landsat 5 TM, Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI), Terra Moderate Resolution Imaging Spectroradiometer (MODIS), and Aqua MODIS. Team members used ancillary data provided by the R2R Initiative and theUSGS Pacific Coastal and Marine Science Center (PCMSC) to validate satellite parameter values.The land cover analysis captured a general trend of increasing impervious cover and decreasing vegetated cover from 1989 to 2019; however, the extent of this change varied between each watershed*.* This analysis, coupled with the tool, can help project partners continually monitor terrestrial and marine patterns associated with coral decline.

***Keywords:***

remote sensing, Landsat, land use and land cover change (LULCC), turbidity, coral reefs, Google Earth Engine

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

***Study Location:*** West Maui, HI

***Study Period:*** January 1989 to October 2019

***Community Concerns:***

* Coral reefs in West Maui are vital to local communities as they support biodiversity, protect coastlines from erosion and storm surge, and contribute significant economic value to the regional recreation, tourism, and fishing industries.
* Decades of coral reef degradation in the region are attributed to poor water quality from LBSP, overfishing, inadequate watershed management, and disruptive weather events.
* Due to their economic and ecological importance, select watersheds of West Maui, HI were designated as priority watersheds in 2011 to be addressed by the US Coral Reef Task Force (USCRTF).
* Understanding sources of LBSP and how they relate to land cover changes and coastal water quality in West Maui can help stakeholders identify locations for conservation and restoration projects.

***Project Objectives:***

* Classify land cover and land use in West Maui over a 30-year time period to assist partners in detecting patterns of development
* Analyze trends in turbidity and chlorophyll-a around West Maui
* Explore the relationship between LULCC and water quality parameters
* Produce a Google Earth Engine tool that allows partners to view annual land cover classification, map land use changes between chosen years, and explore water quality over time

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **US Coral Reef Task Force, West Maui Ridge to Reef Initiative** | Tova Callender, West Maui Watershed Coordinator | End User | Yes |
| **Hawai’i Department of Land and Natural Resources, Division of Aquatic Resources** | Russell Sparks, Lead Biologist | End User | No |
| **USGS Pacific Coastal and Marine Science Center** | Curt Storlazzi, Research Oceanographer | Collaborator | No |

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

The USCRTF leads national efforts to protect coral reefs, and the Hawai’i DLNR-DAR develops tools to reach statewide marine management goals, including herbivore management, subsistence fishing, and direct restoration efforts. The USCRTF meets twice per year to address issues related to coral reefs under US jurisdiction. The Watershed Partnership Initiative is one of the working groups within the USCRTF that specifically addresses water quality and management issues impacting coral reefs at the watershed scale. Representatives from agencies within the Watershed Partnership Initiative establish priority watersheds for focused conservation efforts. The R2R Initiative, instituted after the USCRTF designated West Maui as a priority watershed, implements the Watershed Management Strategic Plan funded by the National Oceanic and Atmospheric Administration and other federal agencies. Citizen science organizations like Hui O Ka Wai Ola have partnered with the R2R Initiative to help communities comply with pollutant limits. While water quality has been actively monitored by citizen science efforts every 2-3 weeks since 2016, long term *in situ* land cover records remain sporadic.

***Project Benefit to End Users:***

This project will build the geospatial monitoring capabilities of the R2R Initiative and the DLNR-DAR by providing them with a Google Earth Engine tool that can be used to analyze long-term trends in land cover change and water quality. The team will also provide the partners with 30-year time series analyses of annual land cover, vegetation, and water quality assessments. These products will give the end users a better understanding of the historical relationship between changes in land cover and water quality, which will allow them to better understand the present coral conditions and implement watershed management best practices.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 4 TM** | Chlorophyll-a (chl-a), turbidity, remote sensing reflectance (Rrs), Normalized Difference Vegetation Index (NDVI) | Chl-a and turbidity were used as a proxy for analyzing water quality trends in the waters surrounding West Maui, Hawai’i in 1989. NDVI was measured to further evaluate vegetation changes and agricultural activities in comparison to subsequent water quality values. |
| **Landsat 5 TM** | Chl-a, turbidity, Rrs, NDVI | Chl-a and turbidity were used as a proxy for analyzing water quality trends in the waters surrounding West Maui, Hawai’i from 1990 to 1992. NDVI was measured to further evaluate vegetation changes and agricultural activities in comparison to subsequent water quality values. |
| **Landsat 7 ETM+** | Chl-a, turbidity, Rrs, NDVI | Chl-a and turbidity were used as a proxy for analyzing water quality trends in the waters surrounding West Maui, Hawai’i from 1993 to 2003. NDVI was measured to further evaluate vegetation changes and agricultural activities in comparison to subsequent water quality values. |
| **Landsat 8 OLI** | Chl-a, turbidity, Rrs, NDVI | Chl-a and turbidity were used as a proxy for analyzing water quality trends in the waters surrounding West Maui, Hawai’i from 2013 to 2019. NDVI was measured to further evaluate vegetation changes and agricultural activities in comparison to subsequent water quality values. |
| **Terra MODIS** | Sea Surface Temperature (SST) | The SST product served as an additional water quality parameter in West Maui, Hawai’i from 2000 to 2019. |
| **Aqua MODIS** | SST | The SST product served as an additional water quality parameter in West Maui, Hawai’i from 2000 to 2019. |

***Ancillary Datasets:***

* Hawai’i Statewide GIS Program Hydrology, Watershed Boundary Shapefiles, and Digital Elevation Model Raster – delineation of watershed boundaries for study location, streams for effluent location, and elevation for runoff direction
* Pacific Islands Ocean Observing System Hui O Ka Wai Ola Water Quality Data – in situ water quality data for validation of remote sensing analyses
* NASA Oak Ridge National Laboratory Daymet V3: Daily Surface Weather and Climatological Summaries – daily total precipitation featured in a time series chart
* NOAA Global Historical Climatology Network Daily Precipitation – analyzed trends in rainfall to understand potential changes in water quality after storms
* USGS Pacific Seafloor Mapping Project Bathymetry Map – integrated bathymetry layer into preliminary maps to consider changes when establishing buffers
* University of Puerto Rico (Dr. William J Hernández-López) Maui Water Quality Samples – validated model-derived water quality with *in situ* points

***Software & Scripting:***

* Esri ArcGIS Pro 2.0.0 – raster manipulation and map product generation
* Esri ArcMap 10.6 – manipulate raster datasets, produce and manage shapefiles, and generate map products
* Google Earth Engine Application Programming Interface (API) – process Landsat data to generate land classification and water quality parameters and construct geospatial tool to automate processing
* RStudio 3.5 – filter large datasets and execute statistical analyses

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Land Cover and Vegetation Maps** | Landsat 4 TM  Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | The product assists the partners in detecting patterns of urban and agricultural land development in West Maui over time. | I |
| **Water Quality Maps** | Landsat 4 TM  Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | This product allows the partners to visualize turbidity and chlorophyll-a, important indicators of water quality along the coast of West Maui, Hawai’i. | I |
| **Land Cover and Water Quality Time Series Charts** | Landsat 4 TM  Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | These charts will highlight the long-term changes in land cover and water quality in West Maui, allowing partners to examine landscape level environmental variations over the last 30 years. | I |
| **Terrestrial Impacts on Marine Environments (TIME) Tool** | Landsat 4 TM  Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI  Terra MODIS  Aqua MODIS | This cloud-based tool hosts a time series analysis of West Maui land cover and water quality. Partners can explore the relationship between land use and land cover changes and water quality degradation. A better understanding of that relationship can inform watershed management with the goal of conserving coral reef ecosystems. | IV |
| **TIME Tool Tutorial** | N/A | This video tutorial informs our partners on how to use the Google Earth Engine Tool. | N/A |

**Project Handoff Package**

***Transition Plan:*** A formal handoff took place at the end of the project term in the form of a video conference via Google Hangouts. Project end products and deliverables were sent to partners via NASA Large File Transfer (LFT) shortly after the conference. The end users will receive access to the TIME Tool, including access to datasets and code, after the NASA Software Release Process is complete.

***Software Release Plan:*** The partners were informed of the NASA Software Release Process and the subsequent delayed delivery of the TIME Tool. Upon completion of Software Release, the partners will be notified that the code for the TIME Tool is available on GitHub and will be sent a video tutorial.

***Team POC:*** Arev Markarian, amarkarian@csumb.edu

***Software Release POC:*** Sophia Skoglund, sophiakskoglund@gmail.com

***Partner POC:*** Tova Callender, tovacallender@gmail.com; Russel Sparks, russell.t.sparks@hawaii.gov; Curt Storlazzi, cstorlazzi@usgs.gov

***Handoff Package:***

* Land Cover and Vegetation Maps
* Water Quality Maps
* Land Cover and Water Quality Time Series Charts
* Technical Paper
* Presentation
* Poster

**References**

Falinsky, K. (2019). Quality assured sampling by engaged citizen scientists supports state agency coastal water

quality monitoring programs. *PeerJ Preprints 7:e27548v1*

https://doi.org/10.7287/peerj.preprints.27548v1

PIFSC (2017). Baseline assessments for coral reef community structure and demographics on west Maui.

Data Report. *NOAA Fisheries Pacific Science Center, PIFSC Special Publication*, SP-17-001, 44p.

http://doi.org/10.7289/V5/SP-PIFSC-17-001

State of Hawaii Department of Land and Natural Resources (2019). Coral Reef Mitigation [webpage].

Retrieved from https://dlnr.hawaii.gov/coralreefs/mitigation-bank/

United States Coral Reef Task Force [website]. (2018). Retrieved from https://www.coralreef.gov/

West Maui Ridge to Reef Initiative [website]. (n.d.). Retrieved from https://www.westmauir2r.com/