**Moloka’i Water Resources**

*Employing NASA Earth Observations to Map the Impacts of the 'Ohi'a Rust on Forest Health and Coastal Turbidity on Moloka’i, Hawaii*

**VPS Title:** The Rusted Get Busted: Exploring the Impacts of the 'Ohi'a Rust Outbreak on Moloka’i, Hawaii, from Space

**Project Team**

***Project Team:***

Nicole Pepper (Project Lead)

David Fluharty

Sophia Leiker

Caroline Odell

***Advisors & Mentors:***

Dr. Paul Evangelista (Colorado State University, Natural Resource Ecology Laboratory)

Dr. Catherine Jarnevich (United States Geological Survey, Fort Collins Science Center)

Nicholas Young (Colorado State University, Natural Resource Ecology Laboratory)

Tony Vorster (Colorado State University, Natural Resource Ecology Laboratory)

**Project Overview**

***Project Synopsis:*** In 2017, a fungal pathogen outbreak of *Puccinia psidii* on the island of Moloka’i, Hawaii, greatly impacted the island’s dominant overstory tree species, the 'ohi'a (*Metrosideros polymorpha)*. This project assessed the feasibility of using Landsat 8 Operational Land Imager (OLI) and Sentinel-2 Multispectral Instrument (MSI) to model the pathogen’s impact on forest health and resulting changes in watershed dynamics across the eastern side of Moloka’i. These high-resolution impact maps will be used as a tool to improve the decision-making of our partners at the United States Geological Survey and The Nature Conservancy in their efforts to conserve this vital tree.

***Abstract:***

The threat of invasive species has impacted fragile forests across the globe; such impacts can be particularly damaging on island ecosystems where a loss in vegetation can lead to increased runoff. In 2017, a fungal pathogen outbreak of *Puccinia psidii* impacted 'ohi'a (*Metrosideros polymorpha*) on Moloka’i, Hawaii, caused widespread defoliation and tree mortality. The impacts of this disease have been intensified by invasive ungulates which stress the trees and increase their vulnerability to disease. Our team partnered with The Nature Conservancy and the United States Geological Survey to better understand the impacts of rust outbreak on forest health and resulting changes in watershed dynamics on Moloka’i. The Nature Conservancy constructed exclosures around the island to protect vital sections of the forest from ungulates, which can overgraze forest understory, damage trees, and increase their susceptibility to pathogen outbreaks. This project assessed the feasibility of using Landsat 8 Operational Land Imager and Sentinel-2 MultiSpectral Instrument to map the impact of 'ohi'a forest health, evaluate the effectiveness of fenced exclosures, and assess the feasibility of detecting turbid events from 2013 - 2019. Our results demonstrated a general decline in spectral vegetation indices within impacted areas of the forest while within the exclosures vegetation indices improved over time. Additionally, we found that we were unable to significantly distinguish between turbid and non-turbid events. With an increased understanding of the rust outbreak impacts, our partners can make better informed management decisions to conserve the 'ohi'a and maintain its crucial ecosystem services, such as providing habitat, storing water, and maintaining the island’s hydrologic cycle.

***Keywords:***

remote sensing, Landsat 8, Sentinel-2, turbidity, forest health, invasive species, 'ohi'a, *Puccinia psidii*

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

***Study Location:*** Moloka’i, HI

***Study Period:*** January 2015 to May 2019

***Community Concerns:***

* In 2017, an outbreak of the rust disease *Puccinia psidii* impacted 'ohi'a trees across Moloka’i, causing widespread defoliation and tree mortality. The impacts of this disease have been further compounded by ungulates that can physically transfer the fungus and burrow into the root systems of an 'ohi'a, increasing the tree’s vulnerability to the pathogen.
* The 'ohi'a is endemic to Hawaii and an important part of the ecosystem. The 'ohi'a maintains the hydrologic cycle, provides habitat and nectar for native species and represents great cultural significance. Local community members are concerned with protecting these ecosystems as they have observed an overall decline in 'ohi'a health.
* Invasive pathogens and ungulates are especially damaging to fragile island ecosystems. The decline of forest health can cause a loss in vegetation and increased runoff into coastal waters that ultimately affect coral reef health.

***Project Objectives:***

* Create impact maps of 'ohi'a forest health from January 2015 to May 2019
* Map changes in coastal turbidity
* Assess the effectiveness of animal exclosures on 'ohi'a forest health

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **USGS, Fort Collins Science****Center** | Dr. Helen Soafer, Ecologist | End User  | Yes |
| **The Nature Conservancy**  | Stephanie Dunbar, Project Manager | End User | No |
| **Pu’u O Hoku Ranch** | Rudi Hunke, Pu’u O Hoku Ranch Manager | Collaborator | No |

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

Our project partners are dedicated to preserving biodiversity and managing damages related to invasive species across public lands. For this reason, outbreaks like the rust disease occurring on Moloka’i are of particular concern to these agencies. The Nature Conservancy of Moloka’i is addressing this outbreak by analyzing defoliation and mortality of the 'ohi'a tree and implementing efforts to mitigate associated impacts. Mitigation efforts include introducing exclosures intended to keep invasive ungulates, such as deer, feral pigs, and goats, out of vital sections of the forest. Anecdotally, The Nature Conservancy has noticed that forests within the exclosures are experiencing a smaller impact from the rust disease and, in some cases, are improving in health. The USGS is focused on managing invasive species on a national level, so better understanding of non-native ungulate impacts and the effectiveness of mitigation efforts on Moloka’i are of particular concern to this organization. Both of these organizations have limited remote sensing capabilities to address this issue and would benefit from increases in spatial resolution and accuracy of their data. Detailed maps will help partners obtain a more comprehensive understanding of 'ohi'a mortality patterns, changing water dynamics, and the success of attempted mitigation strategies.

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

Our products will support the efforts of The Nature Conservancy, USGS, and Pu’u O Hoku Ranch by providing regional-scale (30-meter and 10-meter resolution) impact maps of 'ohi'a vegetation health indices. Improved maps will provide our partners with a better understanding of 'ohi'a forest areas that are most at risk to allow for more direct, targeted approaches to disease mitigation and prevention. The maps will also provide quantitative evidence of animal exclosure effectiveness, which will influence the continued use of this conservation practice. Overall, we expect our maps to help partners better understand the connection between 'ohi'a forest health and water quality, thus informing better decision-making on land use policy. As a result, these various remote sensing products will lead to more effective management strategies and influence future conservation policies.

**Earth Observations & End Products Overview**

***Earth Observations:***

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| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Surface reflectance,Normalized DifferenceVegetation Index (NDVI),Normalized DifferenceMoisture Index (NDMI),Normalized DifferenceTurbidity Index (NDTI), tasseled cap brightness,greenness, and wetness | This dataset provided the temporal (16 days) and spatial (30 m2) resolution needed for environmental predictive variables employed via an impact map for Moloka’i. The dataset was also used to calculate turbidity.  |
| **Sentinel-2 MSI** | Surface reflectance,NDVI, NDMI, NDTI | This dataset provided the spatial (10 to 60 m2) resolution needed to derive environmental predictive variables for modeling and calculating turbidity for the turbidity maps.  |
| **SRTM** | Elevation | This dataset was used to mask out specific elevations in our forest health maps. |

***Ancillary Datasets:***

* North American Land Data Assimilation System 2 (NLDAS-2) Mosaic Precipitation, Soils, Surface Water – environmental predictor variables data for modeling
* Pu’u O Hoku Ranch *in situ* point data – for validation of forest health indices
* USGS National Land Cover Database (NLCD) – environmental predictor variables data for modeling
* LANDFIRE Existing Vegetation Type – raster data showing forest type distributions for determining 'ohi'a and rose apple distribution on Molokai
* The Nature Conservancy 'Ohi'a Distribution Shapefile – shapefile showing the distribution of 'ohi'a in the study area
* The Nature Conservancy Fenced Exclosures – polygon data of fenced exclosure borders

***Modeling:***

* Random forest (RF) classification model (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – this algorithm was used to help indicate forest health on the island of Moloka’i from predictor indices
* Boosted regression trees (BRT) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – this algorithm was used to help indicate forest health on the island of Moloka’i from predictor indices
* Generalized linear model (GLM) (POC: Dr. Catherine Jarnevich, USGS Fort Collins Science Center) – this algorithm was used to help indicate forest health on the island of Moloka’i from predictor indices

***Software & Scripting:***

* Esri ArcMap – image processing and end product generation
* R – statistical analyses and raster processing
* Google Earth Engine API – large scale image analysis
* ACOLITE – data preprocessing and turbidity calculations

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **'Ohi'a Forest Impact Map Series**  | Landsat 8 OLISentinel-2 MSISRTM | These maps will help our partners better understand the geographic distribution and severity of the rust outbreak. Partners will be able to use this information to better inform their management practices. | II |
| **Exclosure Assessment** | Landsat 8 OLISentinel-2 MSISRTM | This assessment will provide partners with numerical insights into the effectiveness of exclosures in mitigating impacts associated with the rust outbreak. | II |
| **Coastal Turbidity Maps** | Landsat 8 OLISentinel-2 MSI | The turbidity maps demonstrate the relationship between changing forest health and the surrounding watershed. Our partners can use this information to help shape conservation efforts on land to better protect the fragile coastal ecosystems, particularly the surrounding coral reefs.  | II |

**Project Handoff Package**

***Transition Plan:*** The team hosted a seminar on August 8, 2019, to disseminate project results and decision support tools to Rudi Hunke of the Pu’u O Hoku Ranch, Stephanie Dunbar of The Nature Conservancy, and Dr. Helen Soafer of the USGS Fort Collins Science Center. A short training workshop on the use of the methods, data, and tutorial followed the seminar with our partners at the USGS and The Nature Conservancy. Our handoff package was stored as a Google Drive folder, and the link to the folder was sent to our partners through an email attachment.

***Team POC:*** Nicole Pepper, nicolelpepper@gmail.com

***Partner POC:*** Helen Soafer, hsofaer@usgs.gov

***Handoff Package:***

* 'Ohi'aForest Impact Map Series
* Exclosure Assessment
* Coastal Turbidity Maps
* Technical Paper
* Presentation
* Project Video
* Tutorial

**References**

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*on means to prevent introduction of additional strains to Hawaii* (USGS Survey Open-File Report 2010-1082). Retrieved from <https://pubs.usgs.gov/of/2010/1082/of2010-1082.pdf>

United States Geological Survey Pacific Coastal and Marine Science Center. (n.d.). *Coral reef project.* Retrieved June 13, 2019, from https://www.usgs.gov/centers/pcmsc/science/coral-reef-project?qt-science\_center\_objects=0#qt-science\_center\_objects