**Lambayeque Water Resources**

*Assessing Hydrologic Patterns Using NASA Earth Observations to Address Tree Mortality in Peru’s Coastal Mesquite Forests*

**Project Team**

***Project Team:***

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***Advisors & Mentors:***

Dr. Kenton Ross (NASA Langley Research Center)

Dr. Venkataraman Lakshmi (University of Virginia)

**Project Overview**

***Project Synopsis:*** Mesquite (*Prosopis* spp.) forests on the coast of northern Peru are a fundamental ecosystem for both humans and wildlife, as they provide a number of anthropogenic uses and environmental services to the region. In recent decades, forest decline due to tree mortality has threatened the balance of this important habitat. To aid in the Lambayeque Regional Government’s policy and management decisions, this project examined the relationship between tree mortality of mesquite forests and the region’s hydrologic trends through a time series of precipitation, soil moisture, and vegetation health.

***Abstract:***

The mesquite (*Prosopis* sp.) forests in Northwestern Peru have had a significant increase in tree mortality in the past fifty years. Within this time frame, 17% of the forest extent was lost and the forest saw an average annual declination rate of 0.33% (Ektvedt, Vetaas, & Lundberg, 2012). These habitats support the region's rich biodiversity and play an important role in local community economies. Several hydrologic causes for mesquite mortality have been hypothesized, but local researchers lack spatially comprehensive techniques to address the problem. While *in situ* research is currently being utilized in an attempt to explain this recent anomaly, landscape-level visualizations through remote sensing have not been produced to find connections between hydrologic trends and the health of Northwestern Peru’s mesquite forests. Climate Hazards Group InfraRed Precipitation with Station data and Global Land Data Assimilation System data were analyzed to assess hydrologic patterns pertaining to precipitation and soil moisture in the Lambayeque region of Peru. These data were then paired with vegetation indices derived from Terra Moderate Resolution Imaging Spectroradiometer (MODIS) and Suomi National Polar-orbiting Partnership (NPP) Visible Infrared Imaging Radiometer Suite (VIIRS) to display how changing hydrologic patterns relate to the health of mesquite trees. These data were then compiled on a monthly basis over the 30-year study period to create a time series product, which was later referenced with background research to find the likely causes of recent forest decline. The results will assist in the Lambayeque Regional Government’s understanding of recent biological declination and will help them design strategies to mitigate forest decline in Lambayeque, Peru and surrounding regions.

***Keywords:***

remote sensing, *Prosopis,* mesquite, precipitation, tree mortality, soil moisture, vegetation indices, conservation

***National Application Areas Addressed:*** Water Resources, Food Security & Agriculture

***Study Location:*** Lambayeque, Peru

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

***Community Concerns:***

* As the health of mesquite forests decline, the Lambayeque region continues to lose a principal source of biodiversity, food, fuel, and other natural resources.
* The tree’s ability to propagate has diminished due to a series of environmental and anthropogenic factors, including precipitation, soil moisture, agricultural land shifts, and deforestation.
* Only small areas exist where the tree is protected, including a region of 7,000 hectares known as the Huacrupe la Calera Reserve Zone. Even within this protected zone, the tree is experiencing a high mortality rate.
* Understanding the relationship between *Prosopis* sp. mortality and hydrologic trends can educate land managers, policy makers, and the public about conservative agricultural practices, infrastructure development, and water management that can ensure the health of mesquite forests.

***Project Objectives:***

* Create a time series of precipitation, soil moisture, and NDVI for the regions of Lambayeque, Tumbes, Piura, Cajamarca, and La Libertad, Peru
* Examine the correlation between changing hydrologic patterns and *Prosopis* sp. mortality
* Improve the Lambayeque Regional Government’s understanding of the region’s hydrologic trends to promote informed land management decisions

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Gobierno Regional de Lambayeque, Gerencia Regional de Recursos Naturales y Gestion Ambiental, Gerencia Regional de Agricultura** | Juan Chapoñan Sanchez, Regional Manager of Agriculture | End User | No |
| **Universidad Nacional Pedro Ruiz Gallo** | Professor Eleazar Rufasto, Professor of Agronomy | End User | Yes |
| **Clark University, George Perkins Marsh Institute** | Dr. Deborah Woodcock, Research Fellow | Collaborator | Yes |

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

Land managers from the Lambayeque Regional Government currently oversee the region’s mesquite forests through *in situ* data collection. When evaluating areas that have been impacted by the mesquite decline, researchers have been surveying on the ground level. This process does not take into account landscape-scale spatiotemporal data for precipitation, soil moisture, or NDVI, leaving a limited amount of field-collected data to work with. They do not currently utilize remote sensing or GIS to analyze changes occurring in the region’s land cover or hydrologic patterns.

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

The time series analysis generated from this project will allow the Lambayeque Regional Government and their colleagues at Universidad Nacional Pedro Ruiz Gallo to understand the correlation between hydrologic cycles and tree mortality on a landscape scale, providing land managers a more complete understanding of the changes that are depleting the health of the region’s mesquite forests. These data will allow decision-makers to assess crucial steps that need to be taken to combat the region’s forest decline. This research also opens up opportunities for further study of additional hydrologic parameters in Lambayeque that could further promote an understanding of forest health, including evapotranspiration and groundwater indices.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Terra MODIS** | Normalized Difference Vegetation Index (NDVI) | The dataset was used to evaluate the change in floral biomass seen in the Department of Lambayeque over time. |
| **Suomi-NPP VIIRS** | NDVI | The dataset was used to evaluate the change in floral biomass seen in the Department of Lambayeque over time. |
| **SMAP L-Band Radiometer** | Soil moisture | SMAP was used to calculate soil moisture levels and the impacts anomalous (high and low) levels had on vegetation health. |

***Ancillary Datasets:***

* Rio Chancay discharge data, Provincia y Region Lambayeque (soil study and forest report) – Provide context from field survey and *in situ* measurements, as well as a comparison to areas defined in the report as potential forest remediation sites.
* Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) – interpolated ground station data used to assess anomalies and make comparisons to vegetation health over the study period.

***Software & Scripting:***

* Esri ArcGIS Pro 2.3.0 – Raster manipulation and analysis, image processing, and map production
* Python 3.7.4 – Conversion of files to TIF files, large volume raster downloads

***Modeling:***

* Soil & Water Assessment Tool (SWAT) (POC: Dr. Venkataraman Lakshmi, University of Virginia) – used to analyze water discharge in comparison to precipitation and vegetation

***End Product:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Time Series of Hydrologic Parameters from 2000 to 2019** | SMAP L-Band Radiometer  Terra MODIS  Suomi-NPP VIIRS | Calculations of hydrologic conditions on a monthly basis over multiple years will help quantify environmental factors such as precipitation, soil moisture, and vegetation health to understand relevant factors of tree decline and enhance decisions concerning sustainable management strategies. | N/A |

**Project Handoff Package**

***Transition Plan:*** In week 10, the products were presented to the partners using Google Hangouts in order to provide all information directly to the end users. All maps, data files, descriptions of project methodology, and written reports were transferred to each of the project end users and collaborators using NASA Large File Transfer.

***Handoff Package:***

* Time Series of Hydrologic Parameters from 1989 to 2019
* Statistical charts
* Technical Paper
* Poster
* Presentation

**References**

Ektvedt, T. M., Vetaas, O. R., & Lundberg, A. (2012). Land-Cover Changes During the Past 50 Years in the Semi-Arid Tropical Forest Region of Northern Peru. *Erdkunde, 66*(1), 57-75. doi:10.3112/erdkunde.2012.01.05