**Maya Forest Water Resources II**

*Mapping Inundation Below the Forest Canopy in the Maya Tri-National Forest*

**Project Team**

***Project Team:***

Stephanie Jiménez (Project Lead)

Karen Alvarez

Rene Castillo

Daniel Nohren

Stephanie Lawlor

***Advisors & Mentors:***

Benjamin Holt (NASA Jet Propulsion Laboratory, California Institute of Technology)

Dr. Bruce Chapman (NASA Jet Propulsion Laboratory, California Institute of Technology)

Dr. Emil Cherrington (SERVIR, NASA Marshall Space Flight Center)

***Past or Other Contributors:***

Madelyn Savan

Kathryn Tafoya

Lara O’Brien

Tamara Rudic

***Team POC:*** Stephanie Jiménez, jimenez.steph.01@gmail.com

***Software Release POC:*** Rene Castillo, renecast522@gmail.com

***Partner POC:*** Dr. Anabel Ford (MARC)- anabel.ford@ucsb.edu

**Project Overview**

***Project Synopsis:***

To monitor seasonal flooding within the tri-national Maya Forest, the DEVELOP team improved and completed the methodology started by the Summer 2021 term to analyze changes in forest flood dynamics throughout 2017 and 2020. Products include Google Earth Engine (GEE) scripts outlining the process for pre-processing data and analyzing the imagery to map land cover and forest inundation using L-band synthetic aperture radar (SAR), ScanSAR, LiDAR, and multi-spectral imagery. With these products, partners can better understand where inundation occurs below the forest canopy to understand hydrological dynamics, particularly during extreme weather events.

***Abstract:***

To monitor seasonal flooding within the tri-national Maya Forest, the team completed the methodology started by the Summer 2021 term to analyze changes in inundation dynamic throughout 2017 and 2020. The team analyzed inundation dynamics in Google Earth Engine (GEE) using Earth observation products from the Landsat 8 Operational Land Imager (OLI), Advanced Land Observing Satellite (ALOS) Phased Array type L-band Synthetic Aperture Radar (PALSAR) 2, and International Space Station (ISS) Global Ecosystem Dynamics Investigation LiDAR (GEDI). The team improved the landcover classification using the Random Forest algorithm in GEE by adding canopy height data derived from GEDI, elevation and slope data from Copernicus, monthly ScanSAR data from 2017 and 2020, and additional multispectral band ratios from Landsat 8. The pixel-based land cover classification produced an overall accuracy of 92%. Experiments measuring inundation extent using L-band SAR included comparing results with a priori knowledge, topography datasets, and auxiliary datasets. We iteratively tested and found threshold values for identifying forested inundation using the ratio for HH divided by HV. The resulting methodology and products helped end users from Belize’s Land Information Center (LIC) and Forest Department, Guatemala’s Center for Monitoring and Evaluation (CEMEC), and Mexico’s El Colegio de la Frontera Sur (ECOSUR) manage land and water resources and protect communities.

***Key Terms:***

ALOS-2 PALSAR-2*,* L-band SAR, Random Forest, Google Earth Engine, flooding, LiDAR, canopy height

***National Application Area(s) Addressed:*** Water Resources, Disasters

***Study Location:*** Maya Tri-National Forest – Belize, Mexico & Guatemala

***Study Period:*** Dry season: January – May, Wet season: June – December of 2017 & 2020

***Community Concerns:***

* The Maya Forest is the largest remaining tropical rainforest in North and Central America and contains forested wetlands that provide essential ecosystem services to nearby communities, such as flood mitigation, water filtration, carbon storage, and erosion reduction.
* Archaeological research in the Maya Forest region can incorporate remote sensing, geographic information systems (GIS), and Indigenous Knowledge of past inundation management to help mitigate future flooding events.
* The Maya Forest ecosystem is highly vulnerable to land-use change, including deforestation, which may increase the impact of extreme weather events that are increasing in severity and frequency across the region.
* It is vital to understand the extent of forested inundation by monitoring flood-prone areas so community members and environmental departments can make more informed management decisions regarding forests, agriculture, and development.

***Project Objectives:***

* Refine methods for combining L-band SAR, ScanSAR, LiDAR, and multi-spectral satellite imagery for mapping inundation below the forest canopy.
* Revise and add to last term's Google Earth Engine scripts to analyze sensor data including running a Random Forest classifier, pre-processing SAR and ScanSAR images, and finally mapping forest inundation through the application of L-band SAR and ScanSAR backscatter thresholds.
* Create a set of observed seasonal forest inundated maps that detect change between the dry and wet seasons throughout 2017 and 2020.

***Previous Term(s):***

2021 Summer (JPL) – Maya Forest Water Resources: *Using NASA Earth Observations to Map Forested Inundation in the Maya Forest*

**Partner Overview**

***Partner Organization(s):***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Ministry of Forestry, Fisheries, Environment & Sustainable Development, Forest Department (Belize)** | Edgar Correa, Forest Officer | End User | No |
| **Ministry of Natural Resources, Land Information Center (Belize)** | Alfred Cal, GIS Analyst | End User | No |
| **National Council of Protected Areas, Center for Monitoring and Evaluation (Guatemala)** | Victor Hugo Ramos, Adjunct Director, CEMEC | End User | No |
| **El Colegio de la Frontera Sur (Mexico)** | Dr. Jorge Mendoza-Vega, Victor Ku, Department of Agriculture, Society, and Environment | Collaborator | No |
| **University of California Santa Barbara, MesoAmerican Research Center** | Dr. Anabel Ford, Director; Thomas Crimmel, GIS Manager; Sherman Horn, Research Affiliate | Collaborator | No |
| **Boles Environmental Consulting** | Dr. Ed Boles, Ecologist | Collaborator | No |

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

The Forest Department and Land Information Center (LIC) of Belize are national agencies responsible for land use management. The Belize Forest Department regulates national forest extraction activities and oversees the management of terrestrial protected areas, which include forested wetlands. Additionally, the Forest Department has a geospatial monitoring unit and uses LiDAR for flood planning purposes. LIC is involved in overseeing Reducing Emissions from Deforestation and Forest Degradation (REDD+) objectives and contributing to the country’s climate change adaptation and mitigation plans. It inventories and assesses land tenure to report on forest management practices as well as assess flood risk. The Forest Department and LIC use NASA products in their decision-making, including the Fire Information for Resource Management System (FIRMS) and Landsat imagery. In Guatemala, the Center for Monitoring and Evaluation (CEMEC) monitors all protected areas, which include wetlands that are protected Ramsar sites. CEMEC uses remote sensing in its forest cover and fire monitoring, but current wetland monitoring and surface water mapping efforts do not incorporate remote sensing methods.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **ISS GEDI** | Level 3A Gridded Land Surface Metrics, 30-meter resolution (2020) | The canopy height model was used to capture forest and land cover type and produce a land cover classification. |
| **ALOS PALSAR-2** | Fine beam L-band ascending backscatter, horizontal transmit/vertical receive polarization (HV), horizontal transmit/horizontal receive polarization (HH), Radiometric and Terrain Corrected (RTC), 10-meter resolution (2017) | Backscatter values were used to analyze inundation and map water body extent, specifically where forest canopy is present. |
| **ALOS PALSAR-2 ScanSAR** | Wide beam, L-Band, ascending HH+HV Polarized. 100-meter resolution (2017 & 2020) | Backscatter values were used to map inundation and water body extent, specifically where forest canopy is present. |
| **Landsat 8 OLI** | Vegetation indices, water indices, true color composites, 30-meter resolution (2016-2018) | Surface reflectance data were used to create a land cover map over the study region and to collect training points. |

***Ancillary Datasets:***

* European Space Agency (ESA) Copernicus 90-meter Digital Elevation Model (2020) – Used to measure elevation and detect changes in elevation to indicate levels of inundation
* NASA’s Shuttle Radar Topography Mission (SRTM) 90-meter Digital Elevation Model (2005) – Used to create a Digital Terrain Model (DTM) and forest change map
* MesoAmerican Research Center: Regional Hydrological, Archaeological, Infrastructural, Geological, and Soil shapefiles – Provided regional context during the inundation identification iterative process
* Instituto Nacional de Estadística y Geografía (INEGI) Wetlands Cartographic Model (2014) - Potential wetlands in Mexico shapefile used to identity and refine inundation thresholds

***Software & Scripting:***

* Google Earth Engine – Wrote scripts for land cover and inundation analyses
* Google Earth Pro – Collect land cover training points to train a random forest classifier

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Land Cover Classification Map** | ISS GEDI  Landsat 8 OLI | Partners may use land cover classes (forest, settlement, open water, other) to better understand land use, inform forest management, and mitigate flood risk. | I |
| **Inundation**  **Maps** | ALOS-2 PALSAR-2 | These maps identify inundation under the Maya Forest canopy and can be used to plan for flood mitigation and better understand seasonal inundation dynamics. | I |
| **Forested Inundation Code** | ISS GEDI  ALOS-2 PALSAR-2  Landsat 8 OLI | This code will allow the end user to reproduce this project’s methodology and implement the methods throughout the Maya Tri-National Forest. | IV |

***Product Benefit to End Users:***

LIC in Belize will use these end products to identify areas prone to highly variable inundation levels and flooding in anticipation of future climate events. Belize’s Forest Department will use the end products to monitor current and potential wetlands in Belize’s national protected areas system to practice sustainable forest management strategies. Guatemala’s CEMEC plans to use the end products to help reduce the cost associated with the ground-based monitoring methods currently employed. Future research at El Colegio de la Frontera Sur (ECOSUR) will integrate our methodology for mapping below-canopy inundation and utilize potential wetland flood extents to inform resource management planning. The objective of this research is to better understand the hydrology and past and present land usage of the Maya Forest. This study may be adapted to help local communities make future decisions related to conservation, archaeology, and emerging problems due to extreme weather events caused by the changing climate.

**References**

Lang, M., Kim, V., McCarty, G., Li, X., Yeo, I., Huang, C., & Du, L (2020) Improved detection of inundation below the forest canopy using normalized LiDAR intensity data. *Remote Sensing, 12,* 707–728. https://doi.org/10.3390/rs12040707.

Lang, L. & McCarty, G. (2009). Lidar intensity for improved detection of inundation below the forest canopy. *Wetlands, 29(4)*, 1166–1178. DOI:10.1672/08-197.1.

Simmons and Associates, Ltd. (2014). A National Climate Change Policy, Strategy and Action Plan to Address Climate Change in Belize. Prepared for the Caribbean Community Climate Change Centre and Government of Belize. http://extwprlegs1.fao.org/docs/pdf/blz169290.pdf.