**Costa Rica & Panama Ecological Forecasting**

*Detecting Land Change Along the Mesoamerican Biological Corridor in Costa Rica and Panama for Targeted Resource Management*

**Project Team**

***Project Team:***

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***Past or Other Contributors:***

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**Project Overview**

***Project Synopsis:*** The Mesoamerican Biological Corridor (MBC) extends from southern Mexico to Panama and was created to encourage sustainable economic development throughout Central America by integrating and protecting the biodiversity of the areas it encompasses. In partnership with the Central American Integration System (SICA), our team used NASA Earth observations to examine land use and land cover (LULC), forecast potential land use changes to the year 2029, and modify an existing Forest Change Detection Tool in the southern region of Costa Rica and La Amistad park in Panama.

***Abstract:***

La Amistad International Park connects southern Costa Rica and northern Panama as part of the Mesoamerican Biological Corridor. Despite the existence of conservation programs within this region, human-induced and natural ecological disturbances threaten native species and alter forest ecosystems. To assess these threats, the NASA DEVELOP Costa Rica & Panama Ecological Forecasting team partnered with the Ministry of Environment and Energy in Costa Rica and the National Environmental Authority in Panama to create products that monitor land use and land cover (LULC) change in La Amistad and surrounding areas. The team mapped LULC changes from 1999 to 2019 using Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), and Landsat 8 Operational Land Imager (OLI). The time series maps were then used in QGIS to forecast LULC in 2029. The 2029 forecast map projected major LULC conversions and highlighted regions of significant change over time. To map short-term forest changes, the project team used a Forest Change Detection Tool (FCDT) developed in Google Earth Engine’s API. The tool used the aforementioned Earth observations and Sentinel-2 Multispectral Instrument (MSI) to ensure that any month of interest can be observed by partners. Analyses of the LULC maps and the development of the FCDT helped partners involved in protecting the corridor to identify areas in need of attention and conservation resources.

***Keywords:***

land use land cover, protected areas, forecast map, Landsat, Google Earth Engine, QGIS

***National Application Area Addressed:*** Ecological Forecasting

***Study Location:*** La Amistad International Park in Costa Rica and Panama

***Study Period:*** January 1999 to July 2019, Forecasting to 2029

***Community Concerns:***

* Central America is home to 7 percent of all scientifically known life forms, but the region faces wide-spread environmental disruption and deforestation.
* Countries within the MBC have invested in conservation initiatives and land manager trainings, but there is not an effective communication strategy to keep the lands connected.
* Deforestation threatens the biodiversity of protected areas within the Mesoamerican Biological Corridor, including La Amistad International Park.
* Regional ecosystems and indigenous communities are negatively impacted by the financial strains of natural resource management.

***Project Objectives:***

* Use NASA Earth observations to map LULC changes from 1999 to 2019
* Produce a forecast map in the QGIS to determine the regions that may be exposed to land cover change in the future
* Adapt an existing Forest Change Detection Tool developed in Google Earth Engine to produce monthly land use change maps

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Ministerio de Ambiente y Energía, Centro Nacional de Información Geoambiental (Costa Rica)** | Rafael Monge Vargas, Director | End user | Yes |
| **Autoridad Nacional del Ambiente (Panama)** | Roney Samaniego, GIS Analyst | End user | Yes |

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

The Costa Rican Centro Nacional de Información Geoambiental and the Autoridad Nacional del Ambiente of Panama are active in regulating the balance of economic development and ecological sustainability in cooperative regions like the MBC. The Ministerio de Ambiente y Energía in Costa Rica is responsible for resource management and environmental protection, while the Autoridad Nacional del Ambiente of Panama proposes policies and laws and advises organizations on environmental standards and resource management. These organizations monitor protected areas through online satellite imagery data sources, but there is no current tool to frequently check land cover change and forest cover change.

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

This project will provide regular automated visualizations of deforestation to aid officials in conserving protected areas in Costa Rica and Panama. The final products can help land managers monitor and assess forest disturbances since the establishment of the MBC. The 2029 forecast model will highlight the areas that could potentially undergo land use change so officials can properly prepare and minimize the effects on biodiversity.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | Surface reflectance | Landsat 5 TM imagery was used to map LULC in the year 1999 and to produce Normalized Difference Vegetation Index (NDVI), 2-band Enhanced Vegetation Index (EVI 2), and Relative Greenness maps in the Forest Change Detection Tool 2.0. |
| **Landsat 7 ETM+** | Surface reflectance | Landsat 7 ETM+ imagery was used to map LULC in the year 2009. In addition, it was used to produce NDVI, EVI 2, and Relative Greenness maps in the Forest Change Detection Tool 2.0. |
| **Landsat 8 OLI** | Surface reflectance | Satellite imagery was used to map LULC in the year 2019. In addition, it was used in the Forest Change Detection Tool 2.0 to produce NDVI, EVI 2, and Relative Greenness maps. |
| **Sentinel-2 MSI** | Surface reflectance | Sentinel-2 MSI was used as supplementary data in the Forest Change Detection Tool 2.0 whenever cloud-free Landsat images were not available. |

***Ancillary Datasets:***

* Japan Aerospace Exploration Agency (JAXA) Advanced Land Observing Satellite Digital Surface Model (ALOS DSM) – Topographic information used for accurately assigning classification cutoffs for land cover
* Costa Rican National Center for Geoenvironmental Information CAPAS TEMATICAS, COBERTURA FORESTAL 2005 – Land cover reference data for the classification process

***Modeling:***

* QGIS 3.0.13 (POC: Dr. Sergio Bernardes, University of Georgia) – Forecasted land cover to 2029

***Software & Scripting:***

* Esri ArcMap 10.7 – Image classification, modeling, and map creation
* Google Earth Engine API – Image processing, including image enhancement, gap filling, mosaicking and classification
* QGIS 3.0.13 – Raster analysis of GeoTiffs to determine NDVI difference thresholds

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Land Use Time Series** | Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | Used to map LULC, these observations provided important information for land managers in Costa Rica and Panama to monitor and investigate the trend of disturbances from 1999 to 2019. | I |
| **2029 Land Use Forecast Map** | Landsat 5 TM  Landsat 7 ETM+  Landsat 8 OLI | The forecast map highlights regions with probable LULC changes. This information helped partners find areas in need of more attention and conservation resources. | I |
| **Forest Change Detection Tool 2.0** | Landsat 5 TM  Landsat 8 OLI  Sentinel-2 MSI | This tool provides monthly change maps for partners to see short-term land cover changes and allows them to determine areas in need of increased conservation efforts. | III |
| **Operating Procedures Manual** | N/A | This manual acts as a guide for the partners while using the Forest Change Detection Tool 2.0. | N/A |
| **Research Methodology Guide** | N/A | This methodology tutorial will help end users understand the project methodology and increase research reproducibility. | N/A |

**Project Handoff Package**

***Transition Plan:*** We created a shared folder in Google Drive to deliver documents and data to partners. Following the release of our end products and deliverables through NASA export control, the team’s Fellow uploaded all items to the shared Google Drive. The team presented the results of the project to partners via Cisco WebEx video conference during week 10 of the term.

***Software Release Plan:*** After the Forest Change Detection Tool 2.0 had gone through internal unit testing to ensure its efficacy in the La Amistad International Park region, the team presented it to partners through Cisco Webex video conference. An established timeline for the final delivery of the code and release of the software was communicated to partners during this meeting. The code was released to partners after it went through the NASA software release process.

***Project Continuation Plan:*** The first term of the Costa Rica & Panama Ecological Forecasting project focused on producing land use time series maps to track forest disturbances. This term also produced a forecast map using QGIS to show the potential LULC in the future. This project will continue for a second term, where the Land Use Conflict Identification Strategy (LUCIS) model will be used to further refine the land use classifications and forecast potential land use conflicts in the study area.

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***Handoff Package:***

* Project Summary
* Technical Paper
* Poster
* Presentation
* Land Use Time Series
* 2029 Land Use Forecast Map
* Operating Procedures Manual
* Research Methodology Guide

**References**

Callihan, M., Ahmed, E., Stone, A., & Xu W. (2018). Honduras ecological forecasting: Utilizing NASA Earth observations to develop a forest change detection tool for land conservation in Honduras. *Technical Report. NASA DEVELOP National Program: Georgia Node, Athens, GA.*

Dettman, S. (2006). The Mesoamerican Biological Corridor in Panama and Costa Rica. *Journal of Sustainable Forestry*, *22*(1-2), 15-34. https://doi.org/10.1300/J091v22n01\_02

Miller, K., Chang, E., & Johnson, N. (2001). *Defining common ground for the Mesoamerican Biological Corridor.* Washington, D.C.: World Resources Institute. Retrieved from https://www.wri.org/publication/defining-common-ground-mesoamerican-biological-corridor