**Peru Health & Air Quality**

*Land Use Change in the Rapidly Developing Peruvian Amazon and Implications on Zoonotic Disease Incidence*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Rapid land use change in the Peruvian Amazon increases the risk of zoonotic diseases such as leishmaniasis and dengue fever. Partnering with the Peruvian Ministries of the Environment and Health, our team used Landsat 7 and 8 satellite imagery to classify land use and land cover types and assess land cover change over the last decade. We used our results in conjunction with spatialized disease reports to evaluate correlations between key land cover changes and incidence of dengue fever and leishmaniasis. Our work will help partners better understand zoonotic disease risk across the region and make more informed public health and environmental policy decisions.

***Abstract:***

In the Madre de Dios region of the Peruvian Amazon, forests are being cleared for mining, timber harvesting, road construction, and hydroelectric dam development. These rapid land use changes are increasing human presence in previously sparsely-populated areas, disrupting ecosystems and increasing the proximity of human settlement to zoonotic disease vectors. Dengue fever and leishmaniasis are two neglected tropical diseases which are prevalent in Madre de Dios and have been associated with urbanization and road construction.  In partnership with the Peruvian Ministries of Health (MINSA) and the Environment (MINAM) and other in-country collaborators, our team examined Land Use Land Cover (LULC) correlations with reported dengue and leishmaniasis incidence in the Madre de Dios region to help partners understand the spatial relationship between land use change and zoonotic disease incidence. We created a Land Use Land Cover (LULC) classification script using Google Earth Engine (GEE) with Landsat 5 Thematic Mapper (TM) and Landsat 8 Operational Land Imager (OLI) imagery to classify land cover in 2010, 2015, and 2020 and evaluate changes over this time period. We then used the quantified results of the LULC assessment in conjunction with reported disease cases to evaluate correlations between disease incidence and key land cover changes across Madre de Dios’s 11 districts. In the second term, the team will use these products to develop more detailed disease incidence risk maps and models. High risk areas will then be classified, using PeruSat-1 that allow for even higher resolution mapping at less than 3 meters. These products will allow the partners to understand hotspots of land cover change in Peru and the relationship with outbreaks to inform public health decision making and environmental policy.

***Key Terms:***

land use, LULC, zoonotic diseases, health risk, Random Forest, GEE, deforestation

***National Application Areas addressed:*** Health & Air Quality, Urban Development

***Study Location:*** Madre de Dios, Peru

***Study Period:*** January 2010 – June 2021

***Community Concerns:***

* In recent decades, Madre de Dios, Peru has become a hotspot for rapid land use changes. Gold mining has increased dramatically since the 1980s and the completion of the Interoceanic Highway in 2012 through the eastern portion of the region further exposed this area to development and deforestation.
* As deforestation and urbanization continue, interactions between humans and zoonotic disease vectors increase, potentially increasing the spread of such diseases. Currently, dengue fever and leishmaniasis are two diseases of particular concern to the Peruvian Ministry of Health.
* Dengue incidence in the Amazon has risen notably since 2000 due to rapid urbanization increasing habitat for the disease’s vector, the *Aedes aegypti* mosquito.
* Leishmaniasis, which is transmitted by sand flies of the family *Psychodidae*, tends to be associated with forest habitats; as human development continues to encroach on forested areas, MINSA is concerned about increased incidence.
* These health concerns are compounded by the lasting effects of the COVID-19 pandemic which has already stretched the healthcare system thin in the region.

***Project Objectives:***

* Employ NASA Earth observations through Google Earth Engine to map land use and land cover in the Madre de Dios region
* Assess changes in land use and land cover in the Madre de Dios region of Peru focusing on forest degradation and transitions to urbanization, mining, and agricultural uses
* Explore patterns in zoonotic disease incidence and examine correlations between key land cover changes and zoonotic disease occurrence

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Ministry of Health (Peru) (MINSA)**   | César Munayco, Director of Epidemiological Research and Evaluation of Health Intervention  National Center for Epidemiology, Prevention and Disease Control  | End User  | No  |
| **Ministry of the Environment (Peru) (MINAM)**  | William Augusto Llactayo, General Director of Environmental Territorial Planning; Tatiana Pequeño, Director for Monitoring and Evaluation of Natural Resources; Germán Marchan; Raul Tinoco; Luis Quispe  | End User  | No  |
| **Universidad Peruana Cayetano Heredia, Lab for EcoHealth and Urban Ecology (UPCH)**  | Armando Valdes-Vasquez, Director; Ellen Delgado, Junior Researcher; Camila Llarena Cayo, Junior Researcher; Viviana Sanchez, Junior Researcher  | Collaborator  | Yes  |
| **Asociación para la Conservación de la Cuenca Amazónica (ACCA)**  | Sidney Novoa, GIS Director; Milagros Becerra, Research Project Assistant; Judith Westveer, Science Director | Collaborator   | No  |
| **Peruvian Service for Natural Protected Areas, Ministry of Environment (Peru)**  | Marcos Pastor, Director of Strategic Development; Edgar Vicuña, Director of the Information Management Unit   | Collaborator   | No  |
| **Instituto del Bien Común (IBC)** | Miguel Macedo, Coordinator of the Area of Public Policy and Management of the Commons; Sandra Ríos Cáceres, GIS Specialist; Kathrin Hopfgartner; Andrea Bravo | Collaborator | No |
| **The National Commission for Aerospace Research and Development (Peru)**  | Gustavo Henriquez Camacho, Head of the Office of Cooperation and International Relations; Jose Pasapera Gonzales, Director of Spatial Applications and Geomatics  | Collaborator | No |

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

The Ministry of Health (MINSA) sources information on disease incidence from over 8,000 surveillance units (health centers) across Peru to determine areas of concern. These data include weekly reports starting in 2000 and include the originating district for each disease case. While MINSA has used satellite data to map risk of cold fronts and several other public health hazards it has not used satellite data to investigate potential hotspots of infectious zoonotic diseases. Although MINSA has explored creating risk maps for specific diseases but has not explored this data in relation to land cover change.  The Ministry of the Environment (MINAM) assesses the need for protected areas and expanded conservation efforts based on data received from regional governments and the Peruvian Service for Natural Protected Areas. It currently uses some satellite data in their analyses, such as GeoBosques, a platform used to monitor forest loss in near real time through Global Land Analysis & Discovery (GLAD) alerts, but has not used this in combination with health data.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 Thematic Mapper (TM)**  | Surface reflectance  | Landsat surface reflectance data were used to train the land cover classification for the year 2010. These classifications feed into the LULC change assessment and outbreak risk maps.  |
| **Landsat 8 Operational Land Imager (OLI)** | Surface reflectance  | Landsat surface reflectance data were used to train the land cover classification for the years 2015 and 2020. These classifications feed into the LULC change assessment and outbreak risk maps.  |

***Ancillary Datasets:***

* GeoBosques, Use and Change of Land Use (2016) – Used to help define classes and train land use land cover classifications for 2010-2020.
* MapBiomas, Annual Land Cover and Land Use Maps of the Amazon (1985-2018)– Used to help define classes and train land use land cover classifications for 2010-2020.
* Geoservidorperu (Sideteva) - Used to help define mining areas for the land cover classification for 2010-2020.
* MINSA weekly zoonotic disease reports, 2000-2021 – used to assess spatial and temporal trends in dengue and leishmaniasis occurrence and evaluate correlations with land cover change
* Peru National Census, 2007 and 2017 – population count by district used to normalize disease rates by district

***Modeling:***

* Random Forest (POC: Sergio Bernardes, University of Georgia) – Used to generate LULC maps in Google Earth Engine

***Software & Scripting:***

* Google Earth Engine – Platform used for image processing, and generating LULC maps from Landsat data
* ArcGIS Pro – GIS software used to visualize disease incidence reports and conduct spatial and statistical analyses between land cover classifications and disease incidence.
* R Studio – Software using R language used to process and analyze datasets and run statistical correlations between land cover change and disease incidence.

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Land Cover Classifications and Change Maps****2010 – 2020**  | Landsat 5 TMLandsat 8 OLI | Mapping land cover for 2020 will provide the most up-to-date land cover classification available for this region; mapping patterns of land cover change will help the partners understand development trends and potential hotspots for zoonotic disease | N/A  |
| **Disease Incidence Maps and Statistical Analysis** | N/A | Understanding the possible linkages between land cover and land change and disease outbreaks will help partners determine where to invest in health and environmental preservation measures. This product will also serve as an important input to future outbreak risk models to be developed in Fall of 2021.  | N/A  |
| **ArcGIS StoryMap**  | N/A | The partners can use this StoryMap to easily explore the key findings of the project and increase public engagement and awareness around the issue of zoonotic diseases.  | N/A  |

***Product Benefit to End User:***

The Ministry of the Environment will use the land cover change maps and analysis to inform decisions around expansion and management of protected areas. The Ministry of Health will use the maps of land cover change and zoonotic disease outbreak analysis to make decisions on where to focus support and research for prevention of infectious zoonotic diseases.

***Project Continuation Plan:***

This project will continue in a second term in Fall of 2021. The summer team will pass off the finalized land cover classification maps from 2010, 2015, and 2020 produced in Google Earth Engine. The zoonotic disease incidence analysis and risk mapping that will occur in the spring may be expanded to include rabies incidence data for the Madre de Dios region, in addition to leishmaniasis and dengue fever. Furthermore, with these risk maps an even higher resolution land use and land cover classification may be conducted utilizing PeruSat-1, with an even higher resolution than that of Landsat sensors at 3 meters.

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