**Peru Health & Air Quality II**

*Leveraging Earth Observations and Health Data to Map Outbreak Risk and Inform Public Health Interventions for Zoonotic Disease Prevention*

**Project Team**

***Project Team:***

Jennifer Rogers (Project Lead)

Melanie Cabrera

Gayatri Girirajan

Julianne Liu

***Advisors & Mentors:***

Dr. Marguerite Madden (University of Georgia, Center for Geospatial Research)

Dr. Xiao Feng (Florida State University)

***Past Contributors:***

Elizabeth Stapleton

Ariel Calle

Nataly Chacon

Nelson Huffaker

Oliver Nguyen

***Team POC:*** Melanie Cabrera, melanie.cabrera@ufl.edu

***Software Release POC:*** Jennifer Rogers, jar15h@my.fsu.edu

***Partner POC:*** Ellen Delgado Florian, eldeflorian@gmail.com

**Project Overview**

***Project Synopsis:***

Our project assisted the Peruvian Ministries of Health (MINSA) and Environment (MINAM) in their efforts to better understand the climatic, topographic, and land-use factors amplifying the risk of contracting two zoonotic diseases: dengue fever and leishmaniasis. We used NASA Earth Observations and additional remotely sensed data to analyze the correlations between these environmental variables and disease incidence. We subsequently created a risk matrix and risk map which visualized the vulnerability of each district in Madre de Dios. These products can support project partners in identifying at-risk areas and distributing resources to health posts and protected lands.

***Abstract:***

Peru's Madre de Dios region is a hotspot for dengue fever and leishmaniasis due to its tropical Amazonian climate. Though treatable, these zoonotic diseases are debilitating for under-resourced communities whose already close proximity to mosquito and sandfly vectors continues to increase via rapid urbanization and deforestation. Peru’s Ministries of Health (MINSA) and Environment (MINAM) are working to better understand the environmental factors amplifying the risk of dengue fever and leishmaniasis transmission. The first term of this project classified the land use and land cover of Madre de Dios’ 11 districts for 2010, 2015, and 2020 and identified a correlation between both diseases and urbanization. Our team expanded this analysis by creating urban-forest edge maps and incorporating climatic and topographic variables with data from Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI), the Global Precipitation Measurement (GPM) Integrated Multi-satellitE Retrievals for GPM (IMERG), and the Shuttle Radar Topography Mission (SRTM). We determined these variables’ impacts on disease incidence by assessing existing literature and running regression models. Dengue fever correlated with urban-forest edge, urban area, slope, temperature, and precipitation. Leishmaniasis primarily correlated with forest-edge area and elevation, but lacking additional statistical significance prevented further work, a decision supported by the literature. Thus, the risk matrix and risk map which we scripted in R to visualize the risk of disease posed to districts alongside health post locations addresses only dengue fever. The results and products will inform MINSA and MINAM in public health interventions, resource distribution, and policy initiatives.

***Key Terms:***

Madre de Dios, South America, dengue fever, leishmaniasis, risk matrix, risk map, remote sensing, land use

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

***Study Location:*** Peru

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

***Community Concerns:***

* Madre de Dios has undergone drastic and rapid land use changes in recent decades, particularly in regards to deforestation caused by urbanization, expanded gold mining, and the construction of the Interoceanic Highway. The unprecedented interactions between humans, wildlife, and the environment have contributed to the emergence and spread of zoonotic diseases in the region.
* Urbanization is expanding the habitable areas for the *Aedes aegypti* mosquito, a vector for dengue fever, and forest encroachment is enlarging the habitable areas for sand flies of the *Psychodidae* family, vectors for leishmaniasis. Also, changing temperature and precipitation patterns driven by climate change are extending the life cycle and transmission-related behaviors of these disease vectors.
* Dengue fever and leishmaniasis are endemic to Peru and are classified as neglected tropical diseases. The country has some of the highest cases of both diseases in the world and, domestically, Madre de Dios is among the areas with the highest infection incidence.
* Both dengue fever and leishmaniasis can result in morbidity and death if untreated, and many cases go unreported and occur in areas without access to healthcare. Additionally, the visible lesions and destroyed nose, mouth, and throat membranes of those infected with cutaneous or mucocutaneous leishmaniasis are often attached to severe stigma and can negatively impact quality of life.
* Dengue fever and leishmaniasis contribute to the disease burden on Peru’s healthcare system and infrastructure, which have already been stressed by the COVID-19 pandemic.

***Project Objectives:***

* Determine the climatic, topographic, and land-use factors amplifying the risk of dengue fever and leishmaniasis transmission in Madre de Dios
* Visualize the degree of risk for dengue fever and leishmaniasis outbreaks in each district alongside the current distribution of health posts to illustrate the accompanying extent of health resources
* Increase awareness about zoonotic disease in Madre de Dios and the applications of remote sensing

***Previous Term:***

Summer 2021 (GA) – Peru Health & Air Quality I

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Ministry of Health (Peru)**  | 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)**  | Tatiana Pequeño, Director for Monitoring and Evaluation of Natural Resources | End User | No |
| **Universidad Peruana Cayetano Heredia, Lab for EcoHealth and Urban Ecology** | Armando Valdes-Vasquez, Director; Ellen Delgado, Junior Researcher | Collaborator  | Yes |
| **Asociación para la Conservación de la Cuenca Amazónica** | Sidney Novoa, GIS Director | Collaborator | No |
| **Instituto del Bien Común**  | Miguel Macedo, GIS Specialist  | 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:***

MINSA monitors disease outbreaks using data from health posts, medical centers which record incidence at a local level. With approximately 8,000 health posts collecting data since the beginning of the 21st century, MINSA has used this data in their contributions to scientific literature on the spatial and temporal understanding of zoonotic disease outbreaks. They have also utilized satellite data to map other threats to public health. However, they have not incorporated remote sensing data to analyze zoonotic disease. Similarly, MINAM has utilized remote sensing in other contexts, such as understanding and addressing land conservation and deforestation, but has not yet applied it to civilian health initiatives.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 Thermal Mapper** | Surface Reflectance, Normalized Difference Vegetation Index, (NDVI), Normalized Difference Water Index (NDWI), Enhanced Vegetation Index (EVI) | Landsat 5 TM data were used in the first term to train land cover classification and create a Land Use Land Cover (LULC) assessment for 2010. Our team analyzed the correlations between their LULC assessment and disease incidence to inform our creation of risk matrices and risk maps. |
| **Landsat 7 Enhanced Thematic Mapper Plus** | Temperature | Temperature data for 2010 from Landsat 7 ETM+ were used to analyze correlations with disease incidence and inform the creation of risk matrices and risk maps. |
| **Shuttle Radar Topography Mission**  | Digital Elevation Model | Elevation and slope data from SRTM were used to analyze correlations with disease incidence and inform the creation of risk matrices and risk maps. |
| **Landsat 8 Operational Land Imager** | Surface Reflectance, NDVI, NDWI, EVI, Temperature | Landsat 8 OLI data were used in the first term to train land cover classification and create a LULC assessment for 2015 and 2020. Our team analyzed the correlations between their LULC assessments and disease incidence to inform our creation of risk matrices and risk maps. We also derived temperature data for 2020 which underwent the same process. |
| **Global Precipitation Measurement (GPM) Integrated Multi-satellitE Retrievals for GPM (IMERG)** | Precipitation | Precipitation data for 2010 and 2020 from GPM IMERG was used to analyze correlations with disease incidence and inform the creation of risk matrices and risk maps. |

***Ancillary Datasets:***

* MINSA weekly zoonotic disease reports, 2000 to 2021 – Assess spatial and temporal trends in dengue and leishmaniasis occurrence and evaluate correlations with climatic and topographic variables as well as land cover change
* Peru National Census, 2007 and 2017 – Normalize disease rates by population at the district-level as well as incorporate into risk matrix to represent the risk consequence.
* Plataforma Nacional de Datos Georreferenciados Geo Perú, Health Post locations – Map health posts over final risk maps to identify areas with high transmission risk but low health infrastructure
* GeoBosques, Use and Change of Land Use 2000 to 2016 – Define classes and train land use land cover classifications for 2010 to 2020
* Geoservidorperu (Sideteva) – Used during Term I to help define mining areas for the land cover classification for 2010 to 2020.

***Modeling:***

* Random Forest (POC:  Dr. Sergio Bernardes, University of Georgia) – Model was used to generate LULC maps in Google Earth Engine

***Software & Scripting:***

* Google Earth Engine – Processing images and sourcing data for temperature, precipitation, elevation, slope, and urban-forest edges
* R Version 4.1.0 – Analyzing statistical significance of the climatic, topographic, and land-use variables on disease incidence and scripting the risk matrix and risk map

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **A Method for Building Integrated ENvironmental and Topographic Exports (AMBIENTE) Script** | Landsat 7 ETM+, Landsat 8 OLI, GPM IMERG | Partners will use this script to download the most updated temperature and precipitation data to feed into the disease outbreak risk matrix and risk map script. | V |
| **Visualizing Environmental Controls to Overlay Risk (VECTOR) Script** | Landsat 5 TM, Landsat 7 ETM+, Landsat 8 OLI, SRTM, GPM IMERG | Partners will use this script to generate two visualizations for the degree of risk for dengue fever transmission in Madre de Dios. A district’s level of risk will be plotted along axes of population and likelihood, defined by thresholds of climatic, topographic, and land-use variables. Through the risk map, partners can compare the overall district-scale risk alongside the current distribution of health posts. Partners can then direct resources and mitigation strategies towards high-risk districts. | V |
| **Project Video**  |  | Partners will be able to showcase the video in their outreach campaigns. | N/A |

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

Our statistical correlations for both dengue fever and leishmaniasis in addition to our script to generate risk matrices and maps for dengue fever will inform MINSA’s resource distribution and prevention strategies as well as MINAM’s land management and protection designations. The risk maps will provide additional support in visualizing different levels of risk compared to health post resources, and the script will allow end users to continue exploring other transmission scenarios. Moreover, MINSA, MINAM, along with our collaborating partners, can integrate our project video into education and outreach initiatives to bring awareness to the risk factors for dengue fever and leishmaniasis. Our partners can ultimately utilize these products to make informed decisions about public health interventions and advocate for ecologically safe practices in urban planning, public sanitation, and resource management.

**References**

Chowell, G., Torre, C. A., Munayco-Escate, C., Suárez-Ognio, L., López-Cruz, R., Hyman, J. M., & Castillo Chavez, C. (2008). Spatial and temporal dynamics of dengue fever in Peru: 1994–2006. *Epidemiology and Infection*, *136*(12), 1667–1677. <https://doi.org/10.1017/S0950268808000290>

World Health Organization. (2021, May 19). *Dengue and severe dengue.* <https://www.who.int/news-room/fact-sheets/detail/dengue-and-severe-dengue>

World Health Organization. (2021, May 20). *Leishmaniasis.* <https://www.who.int/news-room/fact-sheets/detail/leishmaniasis>