NASA

Assessing Land Cover Change Dynamics in the Peruvian Amazon to Map Outbreak Risk and Inform Public Health Interventions for Zoonotic Disease Prevention

Nataly Chacon-Buitrago[1,2] (nchaconbuitrago@mymail.mines.edu), Elizabeth Stapleton[1,2] (elleestapleton@gmail.com), Nelson Huffaker[1,2] (nrh5226@psu.edu), Oliver Nguyen[1,2] (einna.oku@gmail.com)
[1] NASA DEVELOP National Program, [2] Science Systems and Applications, Inc.

ABSTRACT

Dengue fever and leishmaniasis are two tropical diseases prevalent in the Madre de Dios Region of Peru and have been associated with urbanization and road construction. Rapid land use changes such as mining, timber harvesting, and hydroelectric dam development lead to denser human presence in previously sparsely-populated areas which increases the proximity of human settlements to zoonotic disease vectors. In partnership with the Peruvian Ministries of Health (MINSA), the Environment (MINAM), and other in-country collaborators, a NASA DEVELOP team examined Land Use Land Cover (LULC) changes and reported dengue and leishmaniasis incidence in the Madre de Dios region. This sought to help MINSA and MINAM understand the spatial relationship between land use change and zoonotic disease incidence. We created a 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. The team then compared the quantified results of the LULC assessment in conjunction with reported disease cases to evaluate disease incidence and key land cover changes across Madre de Dios's 11 districts. Follow on work will use these products to develop more detailed outbreak risk maps. These products will allow MINSA, MINAM, and other partners to develop more detailed hotspots of land cover change in Peru and the relationship with outbreaks to inform public health decision makers and environmental policy.

BACKGROUND

MADRE DE DIOS, PERU

- Amazon Basin of Southeastern Peru
- Biodiversity Hotspot
- Capital: Puerto Maldonado
- Study Period: 2000-2021
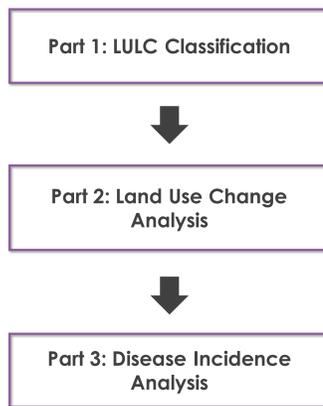

Figure 1. The Madre de Dios region in southeastern Peru

COMMUNITY CONCERNS

- Rapid land use change
  - Illegal/legal gold mining
  - Deforestation
  - Urban & agricultural expansion
- Zoonotic disease exposure
  - Increased incidence of dengue fever since 2000
  - Ongoing incidence of leishmaniasis
  - Lasting impacts of Covid-19 pandemic
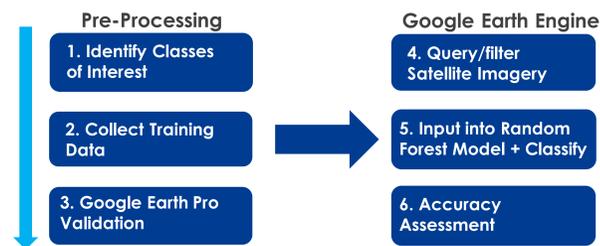

Figure 2. Illegal mining in a river in the Madre de Dios region. Image Credit: Planet Labs, Inc.
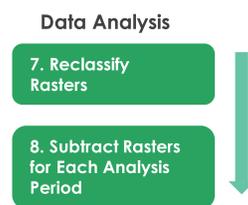
OBJECTIVES

Part 1: LULC Classification
↓
Part 2: Land Use Change Analysis
↓
Part 3: Disease Incidence Analysis

METHODOLOGY

LULC CLASSIFICATION

Pre-Processing
1. Identify Classes of Interest
2. Collect Training Data
3. Google Earth Pro Validation

Google Earth Engine
4. Query/filter Satellite Imagery
5. Input into Random Forest Model + Classify
6. Accuracy Assessment

LAND USE CHANGE

Data Analysis
7. Reclassify Rasters
8. Subtract Rasters for Each Analysis Period

Correlate Land Cover and Disease Incidence

Correlate Land Changes and Disease Incidence

DISEASE INCIDENCE

RESULTS & DISCUSSION

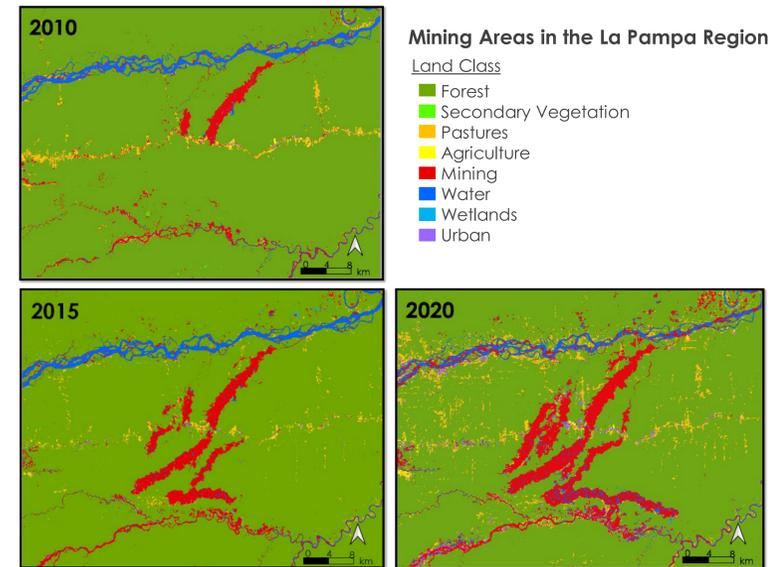Figure 3. Resultant LULC classifications displaying mining areas in La Pampa, Peru (2010-2020).

LAND COVER MAPPING

The supervised classification algorithm successfully classified landcover classes for the region of Madre de Dios, particularly highlighting areas of mining and urbanization. Figure 3 shows images of the La Pampa illegal mining area in Madre de Dios for 2010, 2015, and 2020. The large red area under the Madre de Dios River (blue) are the mining areas. The yellow thin strip of agriculture that cuts across the forested areas boarders the Interoceanic Highway. In 2015 and 2020, the mining areas significantly increased above and below the highway, as well as along the Madre de Dios river. Overall, the region has experienced increases in mining and agriculture, and decreases in forests.

DISEASE INCIDENCE MAPPING AND ANALYSIS

The preliminary exploration of disease incidence revealed substantial differences in the spatial distribution of dengue fever and leishmaniasis across the districts. Figure 4 shows districts classified by total number of dengue and leishmaniasis cases compared with the population normalized rates for each disease between 2010 and 2020. Without controlling for population, both diseases were most prevalent in urban districts, most notably Tambopata, which includes the region's largest city of Puerto Maldonado. When population was controlled for, we saw that dengue continued to be more associated with urban areas while leishmaniasis prevalence was highest in the rural district of Manu.
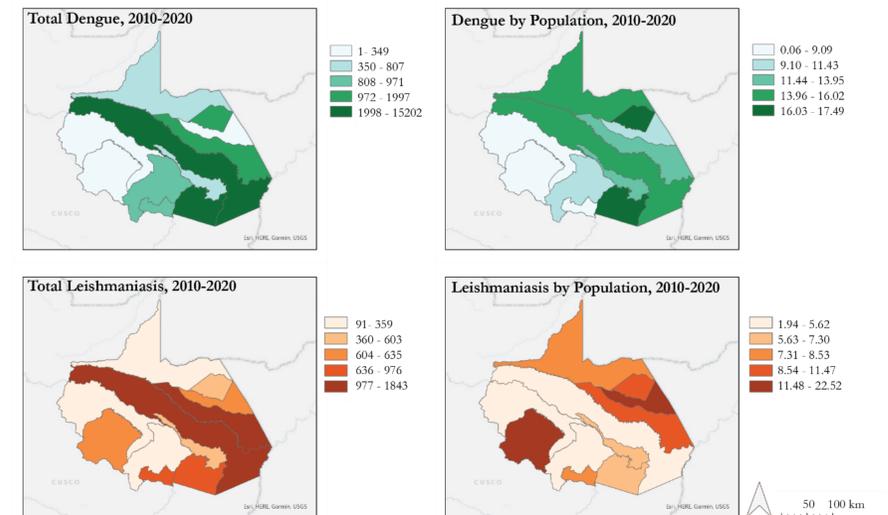

Figure 4. Disease incidence maps for 2010-2020 comparing total cases of dengue and leishmaniasis by district with cases per 1000 residents; data is visualized using quantile classification to better allow comparison across years.

CONCLUSIONS

We created a relatively fast, cloud-based approach to classifying a large, important region in Peru by using Google Earth Engine and developed a preliminary strategy for comparing these results to disease incidence at the district level. Using the partners' previous land classification maps and expertise in identifying important land classes, this method of using Random Forest classification is helpful in classifying newer and higher resolution satellite imagery. By quantifying the increase and decrease of certain land cover classes from the LULC maps and overlaying them with the disease incidences by district over 10 years, we found evidence that land experiencing urbanization may increase incidence of zoonotic diseases. For example, the district of Tambopata experienced the highest amount of urban area as well as high number of cases for dengue. The districts of Inambari and Huepetuhe experienced the greatest transitions to mining and urban land classes and the greatest loss of forest. These districts are where the Interoceanic Highway cuts through, which may indicate that districts with more road access are susceptible to more land cover changes especially mining, urban, agriculture. Districts that contain this highway also have the highest incidences of dengue. The highest cases for leishmaniasis occurred in more rural areas, such as the Manu district, which experienced high rates of deforestation. These outcomes confirm what past studies have suggested, that dengue incidence is typically higher in urbanized areas while leishmaniasis tends to occur when human populations settle near forested areas. The results will help our partners gain a preliminary look at how land use change spatially relates to zoonotic disease incidences, and to focus their efforts on addressing health concerns in districts that are more at-risk.

KEY REFERENCES

- Caballero Espejo, J., Messinger, M., Román-Dañobeytia, F., Ascorra, C., Fernandez, L.E., & Silman, M. (2018). Deforestation and forest degradation due to gold mining in the Peruvian Amazon: A 34-year perspective. Remote Sensing, 10(12),1903. https://doi.org/10.3390/rs10121903
- Mastel, M., Bussalleu, A., Paz-Soldán, V.A., Salmón-Mulanovich, G., Valdés-Velásquez, A., & Hartinger, S.M. (2018). Critical linkages between land use change and human health in the Amazon region: A scoping review. PLoS ONE, 13(6), 1–16. https://doi.org/10.1371/journal.pone.0196414

PERU Health & Air Quality

For more information visit: