**Guatemala & Panama Urban Development**

*Evaluating the Effects of Urban Expansion on Social and Environmental Vulnerability in Guatemala and Panama*

**Project Team**

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**Project Overview**

***Project Synopsis:***

Central America is one of the fastest urbanizing regions in the world, with the urban population expected to double by 2050. Rapid and unregulated urban expansion in Central America is driving a myriad of socioeconomic and environmental risks including infrastructure inequities, housing accessibility issues, loss of biodiversity, vulnerability to natural disasters, and negative health outcomes. Using satellite Earth observation data and the Google Earth Engine Landtrendr algorithm, the team characterized changes in urban extent and roofing material type in Guatemala City, Guatemala and Panama City, Panama, to better understand potential vulnerabilities related to urban expansion.

***Abstract:***

Central America is experiencing rapid and unregulated urban expansion, which is contributing to an increase in socioeconomic and environmental risks including inequities in infrastructure and housing accessibility, biodiversity loss, vulnerability to natural disasters, and negative health outcomes. NASA DEVELOP, in partnership with NASA SERVIR, Sistema de la Integración Centroamericana (SICA), Secretariat of Central American Social Integration (SISCA), Deutsche Gesellschaft für Internationale Zusammenarbeit (GIZ), and Centro de Coordinación para la Prevención de los Desastres en América Central y República Dominicana (CEPRENEDAC), examined changes in urban extent, characterized roofing material type, and analyzed vulnerability within urban areas in two Central American cities, Guatemala City and Panama City. The team used land cover imagery from Landsat 5 Thematic Mapper (TM), Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI), and Landsat 9 OLI-2 to map urban extent, and surface reflectance data from Maxar Worldview to identify roofing material types. Socioeconomic and environmental data were used to assess vulnerability. Results depict how the two cities have expanded from 2000 to present day and highlight areas of greatest vulnerability within each urban area. The supervised classification of roofing materials performed well but could be improved with a few enhancements. Findings can help partner organizations improve monitoring of urbanization and inform their planning and decision-making while prioritizing disaster prevention, public health, and environmental integrity. Additionally, these case studies can be used to inform future, similar work elsewhere in Central America to aid in understanding urbanization and its associated challenges.

***Key Terms:***

Urban development, NDVI, Landsat, roofing material, Central America, Google Earth Engine

***National Application Area Addressed:*** Urban Development

***Study Location:*** Guatemala City, Guatemala and Panama City, Panama

***Study Period:*** January 2002 to October 2022

***Community Concerns:***

* Unregulated urbanization is amplifying infrastructure inequities, resulting in a lack of formal, accessible housing in both Guatemala City and Panama City.
* Rapid deforestation is occurring due to unregulated urban expansion, which is ultimately resulting in environmental degradation and the loss of biodiversity in the region.
* Communities on the outskirts of the cities, where informal housing is prevalent, are more vulnerable to landslides and other natural disasters.
* Materials used by vulnerable, impoverished communities to build roofs are not only less likely to withstand damage from natural disasters, but they are also more likely to result in health problems for the inhabitants.

***Project Objectives:***

* Analyze and map the rate of urban expansion in Guatemala City and Panama City using GEE’s LandTrendr algorithm
* Develop a methodology to identify infrastructure vulnerability to natural disasters by analyzing roofing materials
* Evaluate social, economic, and ecological vulnerabilities using Earth observations and remote sensing data sets with the goal of improving local policy makers’ decision-making

**Partner Overview**

***Partner Organizations***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Sistema de la Integración Centroamericana (SICA)** | Jorge Cabrera Hidalgo, Technical Advisor | End User |
| **Secretariat of Central American Social Integration (SISCA)** | Yanira Quiteño, Executive Director | End User |
| **Deutsche Gesellschaft fur Internationale Zusammenarbeit (GIZ)** | Dr. Abner Jimenez, Technical Advisor | End User |
|  **Centro de Coordinación para la Prevención de los Desastres en América Central y República Dominicana (CEPRENEDAC)** | Claudia Herrera, Executive Secretary | End User |
| **NASA SERVIR** | Betzy Hernández, Central America Regional Science Coordination Lead | Collaborator |

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

SERVIR, SICA, CEPREDENAC, SISCA, and GIZ are already collaborating in Central America to create urban environments that are able to equitably support urban expansion and are resilient to the changing hazards posed by climate change. They have already implemented projects in Guatemala City and Panama City that are specifically focused on mapping disasters and disaster risk. Some examples include SERVIR Global Service Catalogue, the Plataforma de Monitoreo de Amenazas by CEPREDENAC, and the NASA-SICA WorldView System. Specifically, the NASA-SICA WorldView System uses Earth observations and GIS in order to create maps highlighting relevant topics of interest in Central America. Additionally, projects promoted by partners that currently affect urban expansion in the regions of Guatemala City and Panama City are focused on supporting sustainable urban development that creates socially and infrastructurally resilient cities that are better able to withstand natural disasters and other concerns. Some examples include Pillar 3 of Plan 3R and Prinau-SICA which are being supported by both regional and international organizations.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 5 TM** | Land cover | Multispectral imagery accessed via Landtrendr was used to map the extent of urban area to assess urban expansion and identify surrounding ecological disturbances for 1999 – 2013. |
| **Landsat 7 ETM+** | Land cover | Multispectral imagery accessed via Landtrendr was used to map the extent of urban area to assess urban expansion and identify surrounding ecological disturbances for 1999 – 2022. |
| **Landsat 8 OLI** | Land cover | Multispectral imagery accessed via Landtrendr was used to map the extent of urban area to assess urban expansion and identify surrounding ecological disturbances for 2013 – 2022. |
| **Landsat 9 OLI**–**2** | Land cover | Multispectral imagery accessed via Landtrendr was used to map the extent of urban area to assess urban expansion and identify surrounding ecological disturbances for 2021 – 2022. |
| **Maxar WorldView-2** | Surface reflectance | Surface reflectance data were used to identify types of roof materials used, which are associated with social and environmental vulnerabilities. |
| **Maxar WorldView-3** | Surface reflectance | Surface reflectance data were used to identify types of roof materials used, which are associated with social and environmental vulnerabilities. |
| **SRTM** | Elevation data | Elevation data were manipulated to quantify slope to assess urban population vulnerability from a geomorphological standpoint. |

***Ancillary Datasets:***

* Humanitarian Data Exchange (HDX) Demographic data – Population density and distribution | utilize as a parameter in the vulnerability analysis
* VIIRS Lights-at-Night Grids (500m) - Average radiance grids | identify areas that lack electricity as an indicator of economic vulnerability
* SICA Natural Disaster Data – Landslide vulnerability | utilize as a parameter in Guatemala City’s vulnerability analysis

***Software & Scripting:***

* Google Earth Engine Java Script API – Collect and preprocess Earth observation satellite data
* Google Earth Engine LandTrendr algorithm – Visualize the extent of urban development
* Esri ArcGIS Pro 3.0.2 – Conduct spatial analyses and create maps

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Urban Extent Maps** | Landsat 5 TMLandsat 7 ETM+Landsat 8 OLILandsat 9 OLI-2 | These maps will display changes in urban extent from 2012 to 2022. This will inform partners as they assess urbanization and its social and ecological impact, and plan for sustainable urban growth. | N/A |
| **Roof Material Type Maps**  | Maxar WorldView-2Maxar WorldView-3 | These maps will illustrate differences in roof materials used within the communities. This will allow partners to assess building vulnerability to natural disasters and identify public health hazards. | N/A |
| **Maps of Vulnerable Settlements** | SRTM | These maps will demonstrate the degree of vulnerability within and around the urban area. Partners will use this visualization to inform their decisions and policies regarding urbanization.  | N/A |
| **Methodology Tutorials** | N/A | Partners will use this tutorial to understand the methodology the team used to acquire, analyze, and visualize the data collected. | N/A |

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

This project will allow SICA, SISCA, GIZ and CEPRENEDAC to better understand the overall patterns and implications of urban expansion in Guatemala City and Panama City across different timescales. The study will provide insight into the vulnerability of community members and infrastructure within the study area. The partners will receive various maps containing data related to deforestation, slope, population distribution, access to electricity, roof materials, and disaster occurrences that will inform their policy and decision-making as they work toward creating socially, structurally, and environmentally resilient urban areas. The project’s methodology can be applied to other Central American cities and countries experiencing similar urbanization trends.

**References**

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