Cali Urban Development II
Investigating the Impacts of Land Use Change on Urban Heat and Social Vulnerability in Cali, Colombia

Project Team

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Project Overview

Project Synopsis:
The Cali Urban Development II project aimed to assess the spatial relationships between surface temperatures, land use, and social vulnerability by mapping the distribution of urban heat islands within the city of Cali, in southwestern Colombia. In collaboration with the city's municipal government and a local nonprofit organization, the team utilized NASA Earth observations to investigate the effects that sustained development and vegetation loss had across the decade from 2013 to 2023. End products will help users make more informed decisions on future sustainable development and green interventions within the city.

Abstract:
The surface urban heat island (SUHI) effect is an environmental phenomenon resulting in cities with higher temperatures than rural areas due to increased pavement and decreased cooling from vegetation. The city of Santiago de Cali in Colombia faces SUHI challenges exacerbated by land use change. The Colombian municipal government agency, Departamento Administrativo de Gestión del Medio Ambiente and the community organization, Fundacion Dinamizadores Ambientales partnered with this NASA DEVELOP team to evaluate communities in Cali most vulnerable to urban heat. This project illustrated the utility of

using NASA Earth observations to evaluate the relationship between land use, temperature, and social factors in Cali, Colombia between 2013 and 2023. The team used Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS), Landsat 9 OLI-2/TIRS-2 and the Aqua Moderate Resolution Imaging Spectroradiometer (MODIS) to generate land surface temperature (LST), normalized difference vegetation index (NDVI), and albedo maps in Google Earth Engine through NASA DEVELOP's Urban Heat Exposure Assessment Tempe 2.0 tool. In ArcGIS Pro, the team found that LST was significantly higher in urban areas than in wetlands or forests. Using R Studio, the team ran a principal component analysis and found that health care and green space access were negatively correlated, and Afro-Colombian ethnicity was positively correlated with LST. With awareness of the most impacted and vulnerable regions, the partner organizations can prioritize green space establishment in those areas to reduce the impacts of urban heat. Cloud cover limited the project feasibility, but it improved with Landsat 9 data.

Key Terms:
Colombia, land surface temperature (LST), land use/land change (LULC), remote sensing, socioeconomic vulnerability, surface urban heat islands (SUHIs), urban development, vegetation loss

Application Area: Urban Development
Study Location: Cali, Colombia
Study Period: January 1, 2013, to December 31, 2023.
Community Concerns:

- Cali's urban and agricultural development, accompanied by deforestation and wetland declination, increased temperatures in the city, especially in the highly urbanized areas.
- In Cali, some of the most socially and economically vulnerable communities are in neighborhoods with more degraded ecosystems, which contributes to an inequitable distribution of how urban heat is felt by the population.
- Our partners hope to use the findings from this feasibility study to determine exactly how and where heat is concentrated in Cali, and to plan policy and action in response, for example, planting trees in areas that experience the most heat.

Project Objectives:

- Identify temperature hot spots within the city
- Generate landcover maps to determine land use patterns
- Compare the relationship between surface temperature, land use, and socioeconomic factors

Partner Overview

Partner Organization(s):

Organization(s)	Contact (Name, Position/Title)	Partner Type	Sector
Fundación Dinamizadores Ambientales	Sebastian Oyola, Project Coordinator	End User	International
Departamento Administrativo de Gestión del Medio Ambiente	Franklin Castillo-Sanchez, Deputy Director of Environmental Quality; Viviana Huetio-Vergara, Environmental Engineer, Urban Environmental Assessment Group; Andrés Felipe Zamudio Suaréz, Graphical Information, Ecosystem Conservation Group; Viviana María Sánchez Escobar, Climate Change Group Leader.	End User	International

Decision-Making Practices & Policies:
The Departmento Administrativo de Gestión del Medio Ambiente (DAGMA) is a part of Cali's municipal government focused on environmental stewardship and developing programs for citizen participation. DAGMA is divided into nineteen subcategories, each focused on different environmental concerns including urban tree cover, water resources, adoption of green spaces, and risk management. They pass regulations like tree planting compensation and generate plans, guides, and manuals for sustainable forestry and construction. The Fundación Dinamizadores Ambientales is a Cali-based environmental justice non-profit focused on protecting city wetlands and their surrounding communities. Fundación Dinamizadores Ambientales often works with DAGMA to provide resources and information to communities. Both organizations have remote sensing experience but lack the tools, time, and personnel to conduct an analysis on urban heat vulnerability. This project introduced methodologies and limitations of NASA Earth observations to inform the partner's decisions on addressing social vulnerability to the urban heat island effect within Cali.

Earth Observations & End Products Overview

Earth Observations:

Platform & Sensor	Parameter(s)	Use
Landsat 7 ETM+	Surface Temperature	ETM+ provided daytime land surface temperature data from 2013-2023.
Landsat 8 OLI	Surface Reflectance	OLI provided RGB true color imagery for 2013, 2015, 2018, 2020, and 2023, which was used to run a land cover classification model.
Landsat 8 TIRS	Surface Temperature	TIRS provided daytime land surface temperature data from 2013-2023.
Landsat 9 TIRS-2	Surface Temperature	TIRS-2 provided daytime land surface temperature data for 2022 and 2023.
Aqua MODIS	Surface Temperature	MODIS provided daytime land surface temperature data from 2013-2023, which was used to validate the Landsat 7-9 data.

Ancillary Datasets:

- Alcaldía de Santiago de Cali, Cali en Cifras 2023 – Statistical data used to create a social vulnerability index and run a principal component analysis
- Alcaldía de Santiago de Cali, Consulta de perfiles por comunas – Comuna-specific data used to create a social vulnerability index and run a principal component analysis
- Alcaldía de Santiago de Cali, Informacion Censo 2018 Barrio-comuna – Census information used to create a social vulnerability index and run a principal component analysis

Models:

- UHEAT 2.0 (POC: Dr. Kenton Ross, DEVELOP National Program Office) – Land surface temperature, albedo, and NDVI data generation
- Landcover Classification Model (Landsat 8) (POC: Lisa Tanh, Esri) – Esri deep learning model for LULC classification

Software & Coding Languages:

- Google Earth Engine – Landsat imagery consolidation for land surface temperature medians
- ArcGIS Pro 3.2 - Landcover classification and change analysis, comuna based analysis of temperature, vulnerability, and urban development

- QGIS 3.10.14 – Social vulnerability maps and green space access analysis
- R Studio 4.4.1 – Principal component analysis for social vulnerability

End Product(s):

End Product(s)	Earth Observations Used	Partner Benefit & Use
Urban Heat Maps	Landsat 7 ETM+, Landsat 8 TIRS, and Landsat 9 TIRS-2	This map collection contains continuous temperature, median temperature by comuna, and change in temperature from 2013-2023 maps. The partners can use these maps (both over the entire study area and by comuna) to examine which communities experience the highest temperatures in hotter and cooler years.
Landcover Maps	Landsat 7 ETM+, Landsat 8 OLI, Landsat 8 TIRS, and Landsat 9 TIRS-2	This map collection contains land use classification, the change in land use, percent developed by comuna, change by comuna, and temperature related different landcover types. The partners can use these maps to predict and communicate how urban expansion will affect temperature within different communities.
Social Vulnerability Package	Landsat 7 ETM+, Landsat 8 TIRS, and Landsat 9 TIRS-2	This package contains maps showing social vulnerability by comuna, heat risk, and access to green space overlaid with urban temperatures. The package also contains the results of the social vulnerability PCA, with and without LST. The partners can use this package to identify which communities are at greatest risk and where further green spaces would be valuable.
Creative Communications One-Page Flyer	Landsat 7 ETM+, Landsat 8 OLI, Landsat 8 TIRS, and Landsat 9 TIRS-2	This creative communication deliverable is an educational tool that the partner organizations can distribute to the public to explain the urban heat island effect and which communities are the most impacted.

Product Benefit to End User:

The partner organizations can use the end products to focus their urban heat mitigation efforts in the comunas that need the most support. The heat risk map highlights comunas at the greatest risk due to social factors and heat, but also areas that could be at risk in the near future. Our social vulnerability analysis and green spaces map underscore how implementing green spaces and increasing medical facilities in the highest-risk comunas could prevent future heat illness. These products will also inform partners about the social variables which influence vulnerability to heat, which partners can utilize to reach out to the most affected communities to allocate resources and address environmental justice concerns. The urban development and land surface temperature bivariate graph identifies the positive correlation between temperature and development, which is important for city planning purposes. If further urban expansion is planned carefully and balanced with maintaining green spaces, our partners can prevent the continuation of rising temperatures in less developed comunas. Bilingual informational deliverables will be valuable tools for the partners to use

in community outreach and sharing the urban heat island effects with the residents of Cali to increase public involvement in urban heat mitigation efforts.

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