**Sacramento Urban Development**

*Quantifying and Mapping Urban Heat to Inform Urban Planning Initiatives in Sacramento, California*

***Project Team:***

Nicole Holstein

Karina Alvarez

Anjelica Petsch

Elspeth Gates

***Advisors & Mentors:***

Dr. Kenton Ross (NASA Langley Research Center)

***Team POC:*** Nicole Keller, nic.holstein@gmail.com

***Partner POC:*** Jossie Ivanov, jossie@dyettandbhatia.com

**Project Overview**

***Project Synopsis:***

The City of Sacramento, California is updating the City’s General Plan, which includes strategies to combat the urban heat island effect. Along with urban planning firm, Dyett & Bhatia, they are seeking quantitative, high-resolution spatial information about urban heat and heat-vulnerable populations to prioritize infrastructure development and tree canopy investments most efficiently. This project used Landsat 8 OLI/TIRS Provisional Surface Temperature and ECOSTRESS products to create maps of urban heat distribution throughout Sacramento. These maps are then integrated with sociodemographic data to create a city-wide relative heat risk index. Heat mitigation maps were also created using scenario results from the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) urban cooling models to assist planners in prioritizing cooling interventions to minimize future heat risk.

***Abstract:***

The combined effects of increasing urbanization and changing climatic conditions have exacerbated the urban heat island (UHI) effect and heat-related risks for city dwellers. Vulnerability to heat-related illnesses is further compounded by risk factors such as demographics, socioeconomic status, and pre-existing health conditions. The City of Sacramento, as California’s fastest-growing city by population, is particularly invested in combatting the UHI effect. The team collaborated with the City of Sacramento and urban planning firm, Dyett and Bhatia, on three main goals: assessing urban heat at the neighborhood scale, identifying priority areas for cooling interventions, and assessing heat risk to the population. This project utilized NASA Earth observation products to identify hotspots within the communities of Sacramento and create maps of urban heat, the heat-mitigation index, and heat risk from 2016-2020. The team used the Surface Reflectance product from Landsat 8 Operational Land Imager (OLI) and Thermal Infrared Sensor (TIRS) and the ECOsystem Spaceborne Thermal Radiometer Experiment on Space Station (ECOSTRESS) thermal infrared sensor. Additionally, the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) urban cooling model was used to assess the impact of increased tree canopy scenarios. Urban hotspots were identified in central Sacramento and along major transportation corridors such as Stockton Boulevard, while the highest risk areas were identified in the communities of Fruitridge/Broadway and North Sacramento. This project identified these high-opportunity areas for heat mitigation to inform the City of Sacramento's General Plan and reduce citizen risk by addressing urban heat islands.

***Key Terms:***

InVEST urban cooling model, Landsat 8, ArcGIS Pro, ECOSTRESS, ecosystem services, heat mitigation

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

***Study Location:*** City of Sacramento, CA

***Study Period:*** 2018 – 2020 (May – September)

***Community Concerns:***

* The City of Sacramento anticipates growth of nearly 200,000 people over the next 20 years. This growth must be sustainable, equitable, and inclusive.
* Warming temperatures and new development in the city will likely exacerbate the urban heat island (UHI) effect.
* Vulnerable populations, such as older adults, low-income households, non-Hispanic black residents, and residents with pre-existing health conditions, are more susceptible to heat-related illness or death.
* The city aims to increase community resilience and promote equity by strategically prioritizing the implementation of green infrastructure and vegetation planting.

***Project Objectives:***

* Create urban heat maps identifying hotspots and opportunities for improved mitigation using Earth observation products
* Create a heat risk index and map by integrating heat exposure with social, economic, and health factors
* Create City of Sacramento Index for Heat Mitigation Map under various future scenarios to identify priority areas for cooling interventions

**Partner Overview**

***Partner Organizations:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **City of Sacramento** | Remi Mendoza, Project Manager  Nguyen N. Nguyen, Assistant Planner  Josh Cannon, GIS Specialist | End User | No |
| **Dyett & Bhatia** | Jossie Ivanov, Associate  Rajeev Bhatia, Partner and President | Collaborator | No |

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

The City of Sacramento is equipped with an array of tools to affect change in the built environment, including street design, zoning requirements, urban tree planting, amount of impervious surfaces, and building and rooftop albedo, to name a few. The urban planning firm, Dyett & Bhatia, has been tasked with updating Sacramento’s General Plan, which is the policy guide for future development and preservation of resources within the city. Currently, the City does not incorporate remote sensing data into its decision process. It is up to the City and planning team at Dyett & Bhatia to balance the social, economic, and environmental costs and benefits of these decisions.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 8 OLI** | Land Surface Temperature, Albedo | The OLI/TIRS Provisional Surface Reflectance product was used to calculate daytime land surface temperature and hotspots for 2018-2020. This product was also used to calculate albedo values to be used as an input for the InVEST model. |
| **Landsat 8 TIRS** | Land Surface Temperature, Albedo | The OLI/TIRS Provisional Surface Reflectance product was used to calculate daytime land surface temperature and hotspots for 2018-2020. This product was also used to calculate albedo values to be used as an input for the InVEST model. |
| **ISS ECOSTRESS** | Land Surface Temperature, Evapotranspiration | Nighttime measurements of land surface temperature were gathered from ECOSTRESS to enhance the partners’ understanding of urban heat dissipation and consequent neighborhood-level health concerns. Evapotranspiration rates were gathered from ECOSTRESS for use in the InVEST model. |

***Ancillary Datasets:***

* Multi-Resolution Land Characteristics Consortium (MRLC) USA National Land Cover Database (NLCD) 2016 USFS Tree Canopy Cover (CONUS) – Spatially explicit and reliable national land cover and land cover change to derive tree cover information as input for InVEST Urban Cooling Model
* City of Sacramento Building Cartography – Footprint of buildings in the City of Sacramento as input for InVEST urban cooling model
* City of Sacramento Community Plan Areas – Footprint of sub-city “community areas” to provide community-specific recommendations
* U.S. Census Bureau American Community 2017 5-year Estimates Survey – Senior household information down to the census tract for use in the heat risk assessment
* California Office of Environmental Health Hazard Assessment (OEHHA) CalEnviroScreen – Exposure, environmental effect, sensitive population, and socioeconomic factor indicators for use in the heat risk assessment
* City of Sacramento Road Diet – Feature class of roadways under consideration for lane reduction for overlay with InVEST urban cooling model outputs
* City of Sacramento City Owned Property Areas – Feature class of city owned property for overlay with InVEST urban cooling model outputs
* 2018-2019 City of Sacramento’s 311 Reports – Point class of reported homeless encampments for use in the heat risk assessment

***Modeling:***

* Natural Capital InVEST Urban Cooling Model – Calculate heat mitigation and cooling capacity indexes

***Software & Scripting:***

* Esri ArcGIS Pro 2.6.2 – Creation of urban heat island, heat risk index, heat mitigation, cooling capacity, and temperature anomaly maps and subsequent analysis
* RStudio 1.3.1073 – File processing to extract and apply cloud mask to .tif images captured during nighttime hours (11pm – 4am PST)
* Google Earth Engine – Landsat 8 OLI/TIRS image processing and calculation of daytime LST and albedo
* Esri ArcGIS Online – Creation of a StoryMap presentation

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Products** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Sacramento County Urban Heat Maps** | Landsat 8 OLI/TIRS, ISS ECOTRESS | Partners will use maps of urban heat and hot spots to identify priority areas for cooling initiatives and additional green infrastructure, as outlined in the General Plan. | N/A |
| **City of Sacramento Index for Heat Mitigation Map** | Landsat 8 OLI/TIRS, ISS ECOTRESS | Partner will use mitigation maps to understand benefits of current and proposed urban cooling interventions. | N/A |
| **City of Sacramento Heat Risk Index Map** | Landsat 8 OLI/TIRS, ISS ECOTRESS | Partners will use heat vulnerability maps to identify neighborhoods or corridors with highly susceptible populations to better prioritize cooling initiatives that will have the greatest societal benefit. | N/A |
| **City of Sacramento Change in Temperature Anomaly Maps** | Landsat 8 OLI/TIRS, ISS ECOSTRESS | Partners will use change in temperature anomaly maps to identify feasibility of priority areas to provide urban cooling benefits. | N/A |
| **Esri ArcGIS StoryMap** | Landsat 8 OLI/TIRS, ISS ECOTRESS | Partners will use the StoryMap to conceptualize Urban Heat and Cooling Capacity findings into a narrative for community engagement. | N/A |

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

These assessments of urban heat and areas of cooling potential will provide the planners at Dyett & Bhatia and the City of Sacramento with tools to inform equitable solutions to mitigate urban heat islands within the city. Understanding the confluence of the urban heat island effect, social vulnerability, and opportunities for urban cooling can help planners prioritize resources for particular projects. Integrating spatial information about urban heat and heat-vulnerable populations in Sacramento will help to select infrastructure development effectively.

**References**

Hulley, G., Shivers, S., Wetherley, E., & Cudd, R. (2019). New ECOSTRESS and MODIS land surface

temperature data reveal fine-scale heat vulnerability in cities: A case study for Los Angeles County, California. *Remote Sensing*, *11*(18), 2136. <https://doi.org/10.3390/rs11182136>

Wang, C., Myint, S., Wang, Z., & Song, J. (2016). Spatio-temporal modeling of urban heat island

in the Phoenix metropolitan area: Land use change implications. *Remote Sensing*, *8*(3), 185. <https://doi.org/10.3390/rs8030185>