Urban Heat Island (UHI) Mapping and Tree Disparities in Laredo, Texas

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Urban Heat Island, Extreme Heat, Green Spaces, Tree Canopy, Environmental Justice, Climate Resilience

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SCIENCE INFLUENCERS

TEXAS A&M INTERNATIONAL UNIVERSITY

NOVEMBER 2024

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Introduction and Background

Extreme heat is the deadliest weather hazard in the United States, and it is responsible for more fatalities than hurricanes, floods, and tornadoes combined. As the rate of climate change rapidly intensifies, extreme heat events are becoming more frequent and severe, disproportionately affecting urban areas with minimal green infrastructure. Urban Heat Islands (UHIs) are regions where dense development, paved surfaces, and minimal vegetation trap heat, elevating ambient temperatures. Vulnerable populations, particularly those in underserved neighborhoods or communities, are at greater risk of heat-related illnesses and mortality. As global urbanization increases, the link between city living and heat-related dangers will become even more pressing (Adams-Fuller, 2023 Jul 1). People who live in historically underserved communities suffer from a disparity of resources such as public cooling spaces, infrastructure for renewable energy, and green spaces.

The City of Laredo, Texas, exemplifies these challenges of climate vulnerability. Laredo relies heavily on the distressed Rio Grande for its drinking water supply in a hot, semi-arid climate. As temperatures rise, the impacts become deadly — last summer's heatwave resulted in 15 heat-related deaths, a stark increase from previous years (two in 2022, one in 2021, and three in 2020, according to Laredo Vital Statistics). Basic heat island maps from the Trust for Public Land paint most Laredo neighborhoods in deep red or scarlet, indicating extreme heat driven by poor development practices and insufficient tree cover. Many public and private spaces lack shade trees. At the same time, local agencies and academic institutions have not established sustainability or climate planning departments to develop climate initiatives or resilient water security frameworks.

In collaboration with the National Oceanic and Atmospheric Administration's (NOAA) Climate Program, and as part of a national effort involving 14 U.S. cities, the Rio Grande International Study Center (RGISC) — a 30-year-old frontline environmental advocacy organization — partnered with NOAA to lead Laredo's first ever Urban Heat Island (UHI) Mapping campaign. This groundbreaking initiative called an effort to map heat inequities in 14 U.S. cities, including Laredo.

CALOR (Spanish for "heat"), or *Climate Action for Laredo to Organize Resilience,* aimed to document heat inequities, raise awareness, and drive solutions to mitigate urban heat islands in Laredo.

On August 3rd, 2024, RGISC launched Laredo's first-ever UHI mapping campaign. Covering a 70.4-square-mile area across nine city-wide routes, the campaign successfully engaged over 100 volunteer-citizen scientists who collected over 47,000 temperature and humidity measurements at multiple daily intervals. Volunteers used specialized car-mounted heat sensors, which recorded data at 1-second intervals during morning, afternoon, and evening traverses. These sensors captured extremely granular, hyper-local insights into heat and humidity patterns across parks, residential areas, and industrial zones throughout Laredo, as well as the nearby cities of Rio Bravo and El Cenizo, providing the detailed, actionable data and maps needed to address Laredo's climate challenges.

This report will provide a comprehensive overview of the campaign's purpose, objectives, methods, results, and recommendations. It will highlight the critical insights gained from the data, demonstrate how they can inform urban planning and climate adaptation, and outline the next steps for building a more resilient and livable Laredo. Through this work, RGISC continues its mission to empower communities, foster climate resilience, and advocate for environmental justice along the South Texas border.

Purpose and Objectives

Laredo's climate challenges are deeply intertwined with long-standing public health issues exacerbated by neglect and historic underinvestment. According to the County Health Rankings & Roadmaps from the University of Wisconsin, Webb County ranks among the least healthy in Texas. Over one-third of residents report being in poor or fair health, compared to the state average of 21%. Additionally, 42% of adults are classified as obese, and 39% report no leisure-time physical activity outside of work — far higher than state averages (Texas A&M AgriLife, 2020). Rising temperatures further worsen these conditions, as low tree density and lack of shaded spaces force people indoors, limiting physical activity and increasing isolation. These issues are compounded by the absence of climate planning in Laredo to address the growing overlap between public health and environmental challenges. A lack of data and awareness linking climate change with health outcomes has made it difficult for the city to pursue meaningful climate health assessments or build resilient infrastructure.

The CALOR campaign (Climate Action for Laredo to Organize Resilience) was designed to tackle these challenges head-on by generating hyper-local heat data that will guide climate strategies, tree-planting initiatives, and the development of public cooling hubs. As the southernmost city in this year's NOAA mapping cohort and home to the largest inland port in the Western Hemisphere, Laredo faces extreme heat risks that intersect with environmental injustices. The CALOR campaign was driven by a desire to empower residents, fill critical data gaps, and develop resilient infrastructure to mitigate heat-related impacts.

The campaign's primary objectives were to map heat distribution across diverse land uses, such as residential, commercial, and industrial zones, and to collect environmental data in three intervals—6-7 AM, 3-4 PM, and 7-8 PM—to capture temperature fluctuations throughout the day. The campaign aimed to engage citizen scientists in a community science event. Additionally, the campaign sought to develop high-resolution, high-quality heat maps to guide city planning and public health policy interventions. Another key objective was to create public awareness about the health impacts of extreme heat, especially for vulnerable populations. The campaign promoted environmental justice by focusing on neighborhoods with limited green spaces and higher levels of heat exposure.

Methodology

The Laredo UHI mapping campaign employed a structured process via guidance from CAPA Strategies, NOAA, and other local partners:

Route Design

RGISC staff worked closely with CAPA Strategies and the Laredo Metropolitan Planning Organization (MPO) for weeks to carefully plan the study area and map the route designs. This collaborative effort ensured that the selected routes reflected Laredo's environmental vulnerabilities and vital social factors. The 70.4-square-mile study area was divided into nine routes, prioritizing areas with environmental and social challenges, such as neighborhoods with low tree canopy indexes. Critical landmarks like North Central Park and downtown Laredo were included to capture diverse land-use types and ensure comprehensive spatial coverage.

Volunteer Recruitment and Training

RGISC used a multi-channel outreach strategy to recruit volunteers, leverage social media platforms, distribute flyers throughout the community, and collaborate with local organizations and networks. Every effort was made to engage as many community members as possible, ensuring diverse participation in the campaign.

RGISC hosted a public training event one week before campaign day at the Joe A. Guerra Public Library. This event provided an in-depth demonstration of the procedures and expectations for collecting heat data on August 3rd, 2024. Volunteers were trained to operate the specialized car-mounted heat sensors, follow their assigned routes, and ensure proper data collection during the three scheduled intervals. The hands-on approach allowed volunteers to familiarize themselves with the technology and safety protocols, building confidence and ensuring smooth execution on the campaign day.

Marketing, Branding, and Outreach Strategy

RGISC also implemented a broad outreach strategy to ensure city-wide community engagement and build momentum for the CALOR campaign. The campaign was officially launched with a press conference on June 28th, 2024. It featured elected officials from Laredo, Rio Bravo, and El Cenizo, as well as public health experts and media personalities. Key speakers included Councilmember Vanessa Perez, Mayor Amanda Aguero of Rio Bravo, Mayor Carina Hernandez of El Cenizo, Dr. Richard Chamberlain, Laredo Public Health Director, and Richard "Heatwave" Berler, Laredo's Chief Meteorologist and a local celebrity. Media coverage highlighted the campaign's focus on heat-related health risks, urban inequities, and the need for green infrastructure solutions.

Figure 2-7. KGNS Head Meteorologist Richard "Heatwave" Berler speaks at the CALOR press conference on June 28, 2024

The CALOR campaign became a recognizable initiative within the community, reflecting the urgency of addressing rising temperatures. In the weeks leading up to the event, RGISC engaged the community through local media outlets, radio stations, and social media channels, ensuring widespread visibility. RGISC developed bilingual branding and used social media platforms, flyers, and other community events to recruit volunteers and raise awareness about the campaign. Public messaging emphasized the importance of citizen science in addressing local challenges and called for community participation to collect data on campaign day. A volunteer registration drive provided residents with multiple ways to get involved. Officials and community leaders amplified the message, helping to secure broad participation from a cross-section of the community.

Data Collection (Campaign Day)

The Mile One building in downtown Laredo served as the central hub for volunteers on the campaign day. Volunteers gathered throughout the day to receive instructions, collect equipment, and rest between data collection intervals. RGISC provided food, drinks, and music to create a welcoming atmosphere and energize participants, helping to reinforce the sense of community around the event.

Working in teams, volunteers used specialized car-mounted heat sensors provided by CAPA Strategies — to record temperature, humidity, and GPS data at 1-second intervals. Data was collected during three intervals throughout the day on August 3rd: 6-7 AM, 3-4 PM, and 7-8 PM — capturing diurnal temperature changes and hyper-local heat patterns throughout the day. Each team followed designated routes, checking in regularly with RGISC staff to ensure a comprehensive dataset across Laredo, El Cenizo, and Rio Bravo.

Figure 8-12. Highlights from the CALOR campaign day showing Tesla Cybertruck with heat sensor and Heat Watch magnet, campaign leaders Marisol Vazquez & Edgar Villaseñor, and Volunteers at Mile One

Data Analysis

CAPA Strategies employed a three-step geospatial modeling process to transform raw traverse data into high-resolution temperature maps. The process began by downloading and filtering raw heat data via cloud storage, aligning it with our field notes, and trimming the dataset to the relevant time windows, speeds, and study areas.

Next, multi-band land cover data from Sentinel-2 satellites was integrated to calculate spectral indices reflecting vegetation cover and surface features. CAPA transformed these land cover rasters using moving window analysis, allowing for the identification of fine-scale patterns in urban heat.

In the final step, CAPA combined the heat and land cover data into a geostatistical model, generating predictive surface maps for each measurement period via machine learning.

The accuracy of these models was validated through k-fold cross-validation, ensuring reliability for planning and policy applications.

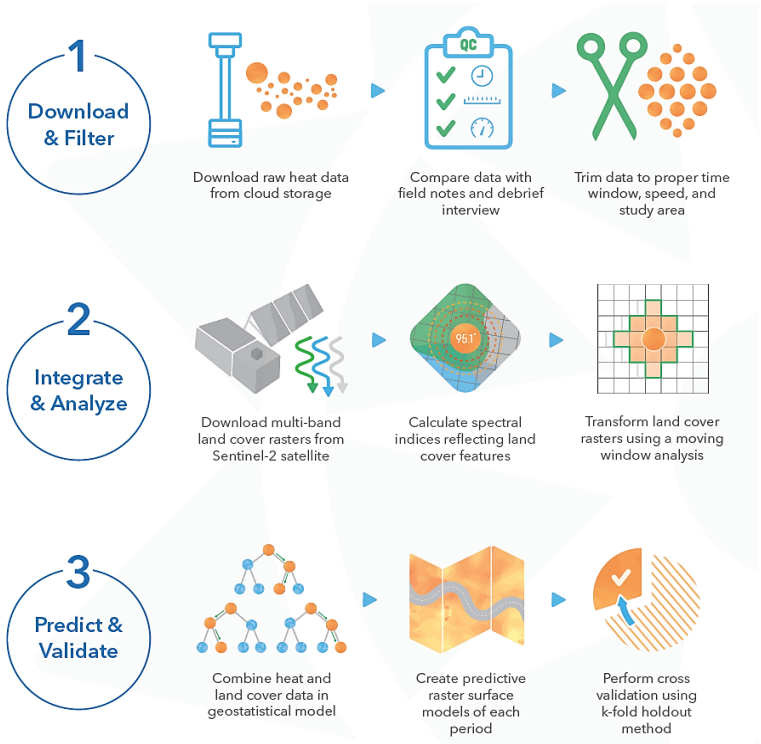

Figure 13. CAPA Strategies' three-step methodology for processing heat data.

Results

The CALOR campaign yielded extensive data, with approximately 47,647 individual temperature and humidity measurements collected across Laredo, Rio Bravo, and El Cenizo. These data points, captured during morning, afternoon, and evening intervals, revealed critical insights into the city's heat distribution. Afternoon temperatures peaked at 106.7°F, with a temperature differential of 11°F between the

hottest and coolest areas, showcasing stark variations across different land uses and environments.

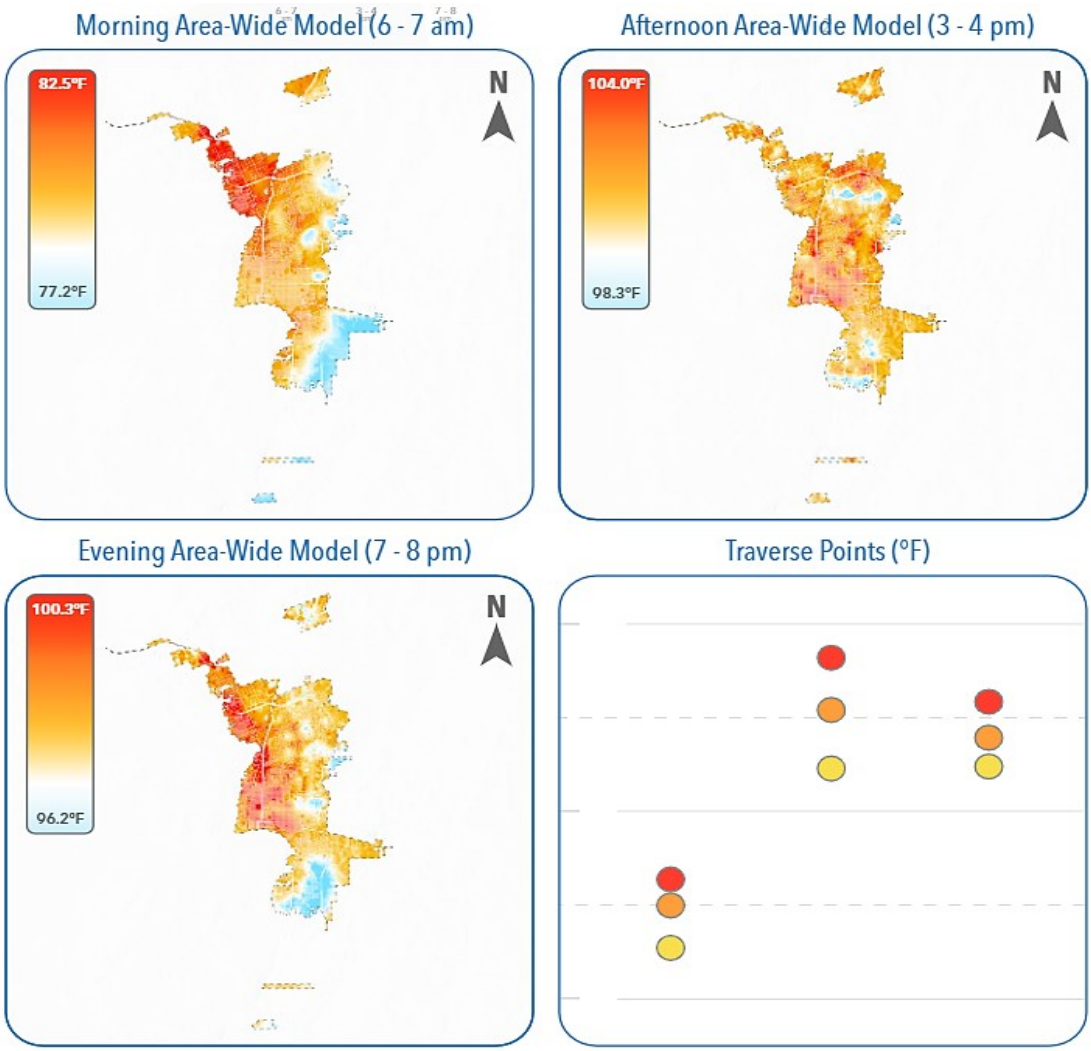

Figure 14. Area-wide temperature models for Laredo, Rio Bravo, and El Cenizo, during morning, afternoon, and evening intervals, showing heat distribution and traverse points (°F) across the city.

The results from our study demonstrate that heat hotspots were concentrated in industrial zones and densely urbanized neighborhoods with minimal green infrastructure. These areas consistently experienced higher temperatures due to impervious surfaces, such as concrete and asphalt, which absorb and retain heat.

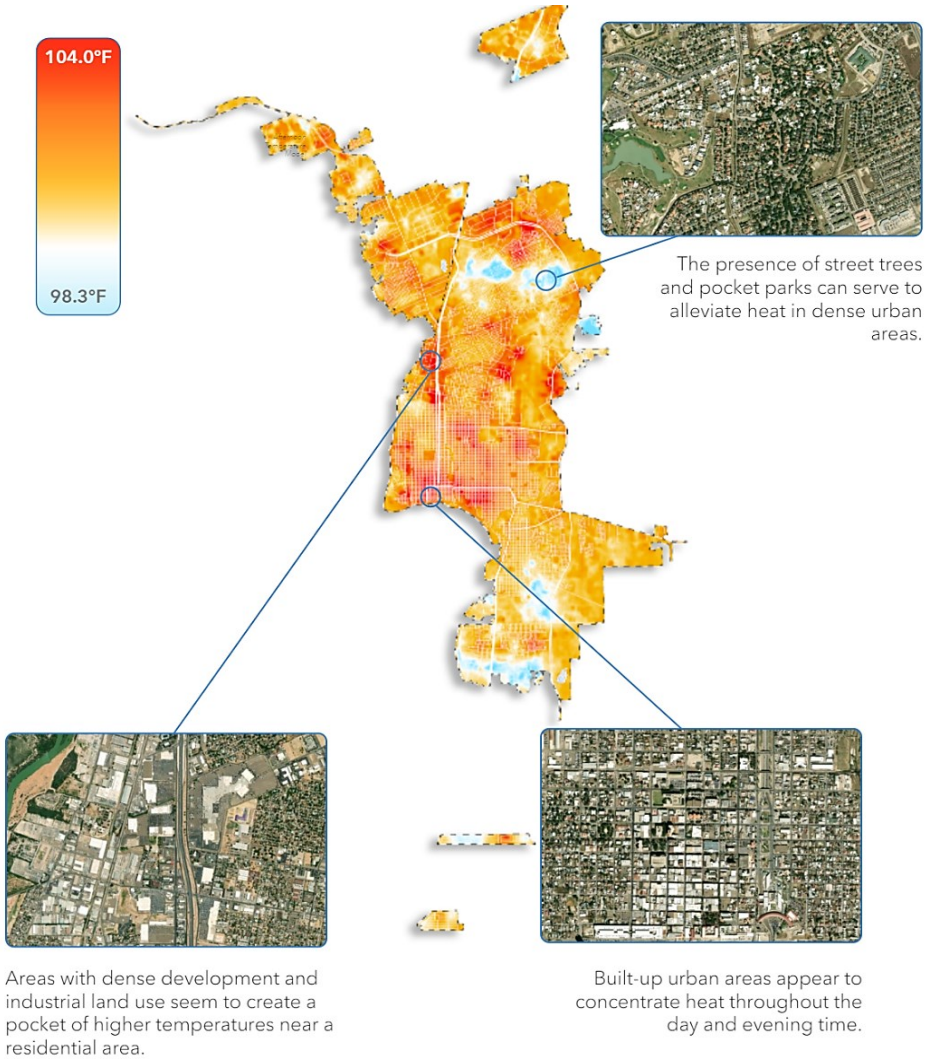

Figure 15. Afternoon heat distribution in Laredo, highlighting areas of concentrated heat in dense urban and industrial zones, with cooler pockets near street trees and parks.

In contrast, Laredo parks and areas with tree cover exhibited significantly lower temperatures. For example, temperature reductions of up to 5°F were recorded in green spaces compared to adjacent built environments. West, Central, and South Laredo areas demonstrated higher temperatures due to industrial activity, high-density residential zones, and limited green space. South Laredo also has a lower socioeconomic profile, which often correlates with fewer resources for cooling infrastructure. Furthermore, the downtown area, with its dense urban development, high heat index, and fewer large green spaces, is likely to contain various heat islands, especially during the afternoon hours.

The study also identified specific neighborhoods such as La Ladrillera, El Trece, Four Corners, Chacon, El Azteca, and Las Cruces, where heat exposure disproportionately impacted lower-income, historically marginalized communities in Laredo.

Accuracy Assessment

CAPA Strategies implemented a **70:30 holdout cross-validation method to ensure the predictive temperature models' reliability**. This approach involved using 70% of the data for model training, while the remaining 30% was reserved for testing the model's predictive accuracy. Randomly selecting the test data helped evaluate how well the model generalized to new, unseen data points. The model's performance is measured using an Adjusted R-squared value, which indicates the strength of the predictions. An Adjusted R-squared value of 1.0 reflects perfect predictability, while 0 signifies no predictive power.

Accuracy Assessment*	
Model Period	Adjusted R-Squared
6 - 7 am	0.95
3 - 4 pm	0.58
7 - 8 pm	0.80

Figure 16. Adjusted R-squared values for model accuracy at each time interval: 6-7 AM (0.95), 3-4 PM (0.58), and 7-8 PM (0.80).

This assessment ensured that the heat maps produced by CAPA are precise and reliable for informing decision-making processes. Applying the holdout cross-validation method enhances confidence in the data, making it suitable for developing actionable interventions such as tree planting and urban planning policies to mitigate heat exposure. Further details about this method and its application in urban heat island studies can be found in the referenced work by Voelkel and Shandas (2017), which provides a thorough analysis of urban heat island prediction models.

Conclusions and Applications

The CALOR campaign successfully achieved its objectives by creating high-resolution heat maps that detail temperature distribution across various land uses, including residential, commercial, and industrial zones in Laredo, Rio Bravo, and El Cenizo. These maps pinpoint critical heat hotspots, particularly in neighborhoods with limited tree canopy and higher exposure to extreme heat. The data collected will equip city planners with the tools to develop targeted climate mitigation strategies, prioritizing these vulnerable communities.

Utilizing insights from the CALOR maps, city officials can implement urban design strategies, such as reflective building materials, cool pavements, and expanding Laredo's urban tree canopy. Such efforts aim to reduce heat absorption and promote natural cooling effects, enhancing the overall livability of Laredo, especially in marginalized areas that have historically faced neglect.

In addition, this campaign demonstrated the importance of public engagement in environmental research. Citizen scientists engaged through CALOR played a pivotal role in data collection, building community awareness, and fostering a sense of

ownership and empowerment. Public involvement will ensure long-term community support and participation in future climate initiatives.

Lastly, the data provided through CALOR has established a foundation for continuous monitoring and evaluation of climate interventions in Laredo and Webb County. Future data comparisons against these initial findings will enable RGISC and city officials to assess the effectiveness of strategies and adapt them as necessary. This iterative process ensures that Laredo remains responsive to changing climate conditions and continues enhancing resilience through informed, evidence-based approaches. The insights and community-driven data from the CALOR campaign have paved the way for building a climate-resilient Laredo, where proactive measures and public engagement combine to create a healthier, safer, and more sustainable environment for all residents.

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