Identifying Disadvantaged Communities Using Cumulative Environmental Burdens

Technical Documentation

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As developers of this Capstone Project documentation, we archive this documentation on the Bren School's website such that the results of our research are available for all to read. Our signatures on the document signify our joint responsibility to fulfill the archiving standards set by the Bren School of Environmental Science & Management.

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The Capstone Project is required of all students in the Master of Environmental Data Science (MEDS) Program. The project is a six-month-long activity in which small groups of students contribute to data science practices, products or analyses that address a challenge or need related to a specific environmental issue. This MEDS Capstone Project Technical Documentation is authored by MEDS students and has been reviewed and approved by:

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Abstract

The Climate and Economic Justice Screening Tool (CEJST) was developed by the U.S. federal government in 2022 to identify marginalized communities disproportionately impacted by climate change. This interactive mapping tool identifies disadvantaged communities based on the presence of low-income residents and one of eight climate, environmental, or other burden categories. Communities that meet these criteria were eligible for funding from the Justice40 initiative, which sought to direct 40% of overall benefits from investments in climate, clean energy, and sustainable housing into these communities—designated as Justice40 communities. While CEJST includes a wide range of indicators to evaluate burden categories, it does not include any measure of overall community risk or harm due to a combination of multiple burdens. This project seeks to extend and improve CEJST's model by assessing the cumulative impacts of climate and environmental burdens across communities in the U.S. By analyzing and incorporating cumulative burdens using cutting-edge geospatial techniques, the revised screening tool will promote more meaningful and equitable investment into overburdened disadvantaged communities facing the greatest risk from climate change.

Table of Contents

Executive Summary

Background

In January 2021, the U.S. federal government launched the Justice40 Initiative, which sought to direct 40% of overall benefits from investments in climate, clean energy, affordable housing, workforce development, remediation, pollution reduction, and clean water infrastructure to disadvantaged communities (DACs). As part of this initiative, the Council on Environmental Quality created a web-based Climate and Economic Justice Screening Tool (CEJST) to identify which communities (census tracts) are designated as disadvantaged and in need of federal funding based on the presence of low-income residents and at least one of eight burden categories.

CEJST includes a wide range of useful indicators to evaluate burdens and designate DACs. It relies on a binary classification scheme that identifies U.S. census tracts as either DACs or non-DACs. A community qualifies as a DAC when it has both low income and at least one environmental, climate, health, or socioeconomic indicator that exceeds the specified threshold.

Motivation

While CEJST provides valuable data for identifying disadvantaged communities, it does not include any measure that represents cumulative burdens or overall harm to communities that occurs due to a combination of climate, environmental, health-related, and socioeconomic burdens (Shrestha 2023). A DAC that meets multiple criteria or indicator thresholds is assigned the same designation as a DAC meeting a single criterion and does not receive any special prioritization for federal funding.

This inability to distinguish between areas with severe, moderate, or lower burdens hinders the model's effectiveness, as identified in the recent National Academies of Sciences, Engineering, and Medicine consensus report (NASEM 2024). Communities facing multiple environmental and climate burdens simultaneously experience compounded disadvantages that are not captured in the current binary approach.

Problem Statement

The existing CEJST framework identifies disadvantaged communities using a binary approach that fails to account for the cumulative impact of multiple environmental and economic burdens. This project seeks to build on and extend the CEJST framework by developing a more comprehensive approach that quantifies overlapping burdens, which creates a more equitable system for identifying communities most in need of assistance. This improved framework will better inform funding allocation decisions and help highlight whether remediation efforts should be implemented at the local, state, or national levels – ultimately ensuring that communities facing multiple burdens receive fair and equitable support.

Objectives

This project aims to improve the White House Council on Environmental Quality's (CEQ) methodology for identifying U.S. communities disproportionately affected by the impacts of climate change and environmental burdens. These improvements will lead to a more equitable and precise allocation of Justice40 funds and other forms of governmental support. In order to achieve this goal, the project will focus on the following objectives:

- Add a cumulative burden assessment and spatial analysis component to CEJST to identify communities overburdened with multiple climate and environmental stressors.
- Demonstrate how cumulative and spatial statistical approaches can be used to evaluate the combined effects of environmental/climate burdens and map areas of higher concern.
- Document the racial and ethnic characteristics of disadvantaged communities in the U.S. experiencing disproportionately high exposure to climate and environmental burdens.

Sections Outline

1. Approach

The approach consists of several components designed to meet the project's objectives (Fig. 1). The first step is to download and clean all data from the APIs. An important step in our analysis is to understand the original documentation and code from the original CEJST. Once the tool operation is fully understood, it can be expanded upon.

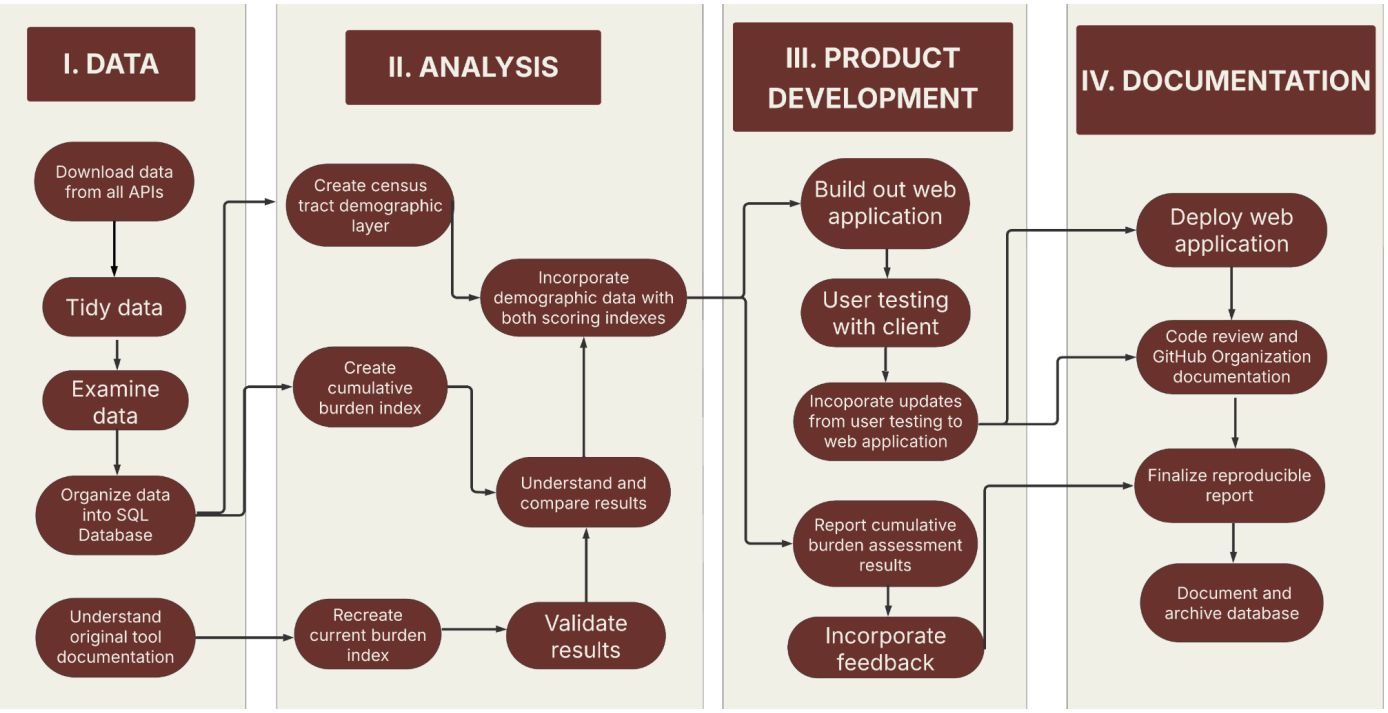

Figure 1. Conceptual model of the approaches that are taken to complete this capstone project.

The original CEJST organized burdens into eight categories. Each of the eight burden categories comprise 2-5 individual indicators, with a total of 31 indicators. Table 1 below shows the burdens and their corresponding indicators. In the original CEJST framework, in order to qualify for a burden, a census tract must exceed the threshold or percentile value for at least one of its indicators and its socioeconomic burden. In all of the burdens except for workforce development, this socioeconomic burden is low income, which is detailed below the table. For workforce development, the

socioeconomic burden is the percentage of high school education. If a census tract qualified for the burden and its corresponding socioeconomic burden, it would be considered a DAC.

Table 1. CEJST Burden and Indicator thresholds.

Burden	**Indicators**	**Socioeconomic Burden**
Climate change	1. Expected agriculture loss rate ≥ 90th percentile OR 2. Expected building loss rate ≥ 90th percentile OR 3. Expected population loss rate ≥ 90th percentile OR 4. Projected flood risk ≥ 90th percentile OR 5. Projected wildfire risk ≥ 90th percentile	Low Income*
Energy	1. Energy cost ≥ 90th percentile OR 2. $PM_{2.5}$ in the air ≥ 90th percentile	Low Income*
Health	1. Asthma ≥ 90th percentile OR 2. Diabetes ≥ 90th percentile OR 3. Heart disease ≥ 90th percentile OR 4. Low life expectancy ≥ 90th percentile	Low Income*
Housing	1. Historic underinvestment = Yes OR 2. Housing cost ≥ 90th percentile OR 3. Lack of green space ≥ 90th percentile OR	Low Income*

	4. Lack of indoor plumbing ≥ 90th percentile OR 5. Lead paint ≥ 90th percentile	
Legacy pollution	1. Abandoned mine land present = Yes OR 2. Formerly Used Defense Site (FUDS) present = Yes OR 3. Proximity to hazardous waste facilities ≥ 90th percentile OR 4. Proximity to Superfund or National Priorities List (NPL) sites ≥ 90th percentile OR 5. Proximity to Risk Management Plan (RMP) sites ≥ 90th percentile	Low Income*
Transportation	1. Diesel particulate matter ≥ 90th percentile OR 2. Transportation barriers ≥ 90th percentile OR 3. Traffic proximity and volume ≥ 90th percentile	Low Income*
Water and wastewater	1. Underground storage tanks and releases ≥ 90th percentile OR 2. Wastewater discharge ≥ 90th percentile	Low Income*
Workforce development	1. Linguistic isolation ≥ 90th percentile OR 2. Low median income ≥ 90th percentile OR 3. Poverty ≥ 90th percentile OR 4. Unemployment ≥ 90th percentile	Less than high school education > 10%

*Low income = 65th percentile or above for percentage of people in households whose income is less than or equal to twice the federal poverty level

This project aims to take all eight CEJST burdens into account and give each census tract a cumulative burden score as opposed to a binary assessment. This will be accomplished through two approaches:

1.1 Cumulative Approach

The cumulative approach simply sums or adds together the total number of CEJST thresholds exceeded by the census tract . This means each census tract will have a score of 0-8 (based on burdens) or 0-31 (based on indicators).

1.2 Hotspot Analysis

The hotspot analysis will use Getis-Ord Gi* (Gi*) to identify spatial clusters that represent statistically significant hot or cold spots, based on the total number of burden or indicator thresholds exceeded. Gi* examines an individual census tract and its neighbors to assign a z-score based on the global statistics for the entire United States (Getis & Ord 1992). The z-score will be mapped to identify hot or cold spots that show areas of significantly high or low burdens, respectively, compared to areas with no significant clustering.

These new approaches will generate census tract-level cumulative burden scores that better reflect the total impact of climate stressors on communities, as compared to the original CEJST scoring index. Additionally, there will be a demographic layer that will not affect the scoring index but be used to compare demographic composition of DACs in the original CEJST and in the new approaches.

1.3 Public Web Application

To make the findings accessible and interactive, a web application will be deployed. This public web application will allow users to explore the new and old approaches for identifying census tracts that qualify as DACs. Users will be able to compare different classification approaches, in addition to viewing the demographic and socioeconomic characteristics of each census tract.

2. Methods

2.1 Cumulative Approach

A cumulative approach has proven to be a valid way to evaluate cumulative impact in other web-based geospatial mapping tools. For example, the Department of Energy's Environmental Justice Mapping Tool (EJMT) utilized an additive approach in order to account for multiple stressors within census tracts (NASEM, 2024, p. 94). The New Jersey EJ Mapping, Assessment and Protection Tool, for example, also estimates cumulative burdens based on the total number of stressors deemed 'adverse' in a given community.

This cumulative approach is based on counting or summing all burdens or indicators that exceed their respective threshold, in a census tract. This results in every census tract having a score of 0-8 for burdens or 0-31 for indicators.

2.2 Hotspot Analysis

The hotspot analysis utilizes the Getis-Ord Gi* statistic (Gi*) for spatial cluster detection. This method identifies "hot-spots" and "cold-spots", or clusters of census tracts with significantly higher or lower counts of burdens/indicators relative to the overall mean. It does this by examining values in both a census tract and its neighbors, and summing together the local features (burden/indicator thresholds exceeded). It then compares that local sum proportionally to the sum of all features, and returns a p-value per census tract. The p-value can be interpreted into hot and cold spots, with very high positives being hot spots and very low negatives being cold spots.

GeoDa, an exploratory spatial data analysis software tool created by Dr. Luc Anselin, is used to calculate the Gi* statistic across the U.S. for both burden and indicator values. The results from GeoDa are then uploaded into the data pipeline for the web application, so the hot and cold spots are viewed as an additional layer that can be toggled.

2.3 Demographic Calculations

In order to show the demographic breakdowns of burdens and indicators, data visualizations will be made. The demographic breakdown for both the cumulative

and hotspot methods will be visualized on the web application. The web application will also include the demographic information for each census tract when it is clicked.

2.4 Web application development

The web application was created using the original CEJST Github repository. The original data pipeline did not work the way it was intended due to limited access to the data sources. After much parsing through original documentation, the team was able to use a single spreadsheet that had census information, burden data, and indicator data to rework it into the data pipeline and launch the application. The four new layers that were added to the map were done so by following the same methods from the original Github repository. Detailed methodology for the web application can be found in the application's github repository README files. Table 2 in this document lays out the web application architecture.

3. Results Report

3.1 Demographic Breakdown for Cumulative Method

Figures 2 and 3 below are bar charts that show the distribution of racial/ethnic groups across the number of burden or indicator thresholds exceeded. One key takeaway is that as exceeded thresholds increase, the proportion of people that identify as Black or African American also increases. Similarly, the proportion of people that identify as white decreases as the thresholds increase. It is important to note that these numbers are percentages, meaning it only represents the proportional breakdown across each threshold value.

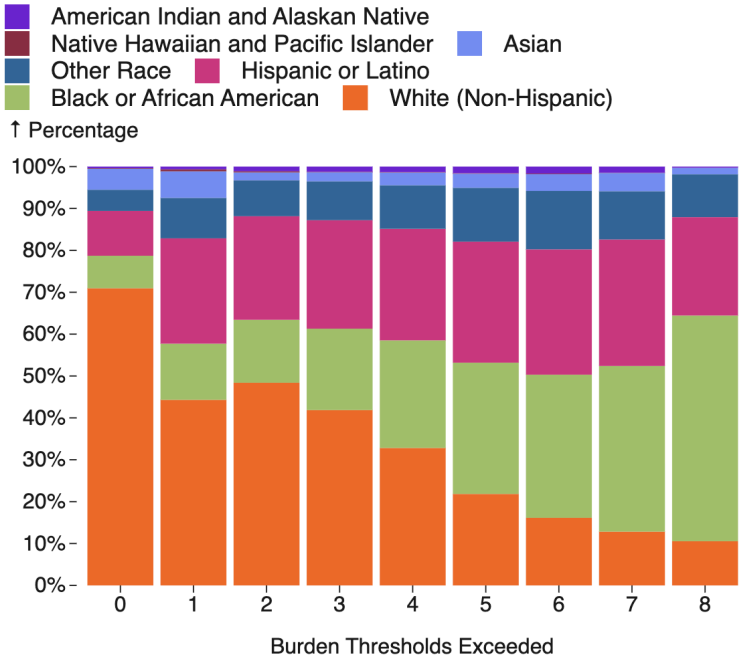

Figure 2. Demographic breakdown of cumulative burden method

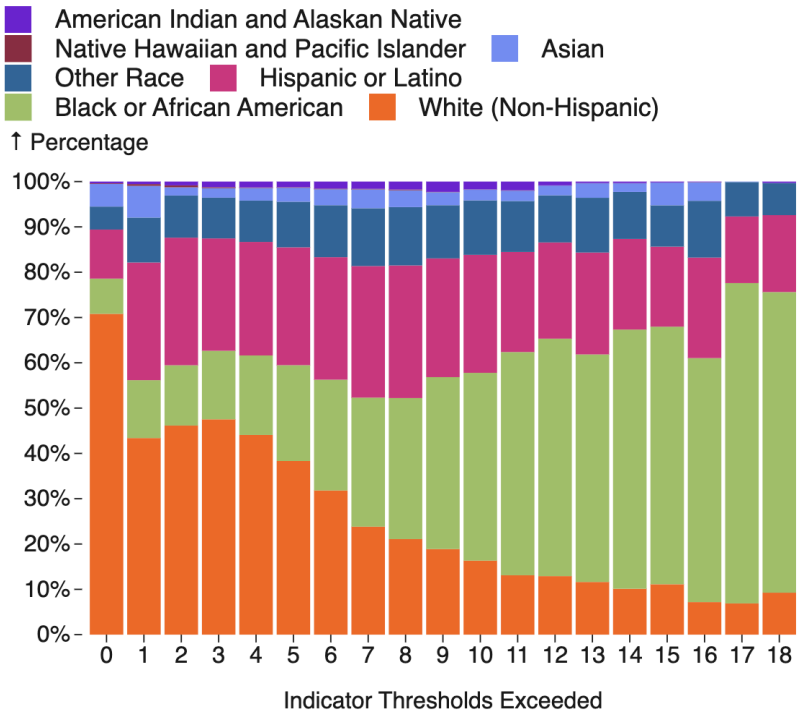

Figure 3. Demographic breakdown of cumulative indicator method

3.2 Demographic Breakdown for Hotspot Method

Figures 4 and 5 below are bar charts that show the distribution of racial/ethnic groups across cluster classification. One key takeaway is that white populations make up 70-80% of the census tracts that are cold spots. Cold spots represent areas that have significantly fewer thresholds exceeded when proportionally compared to the average thresholds exceeded across the United States. People that identify as Black or African American or Hispanic or Latino both compose between 20-30% of census tracts that are hot spots. Hot spots represent areas that have significantly more thresholds exceeded when proportionally compared to the average thresholds exceeded across the United States. It is important to note that these numbers are percentages, meaning it only represents the proportional breakdown across each cluster classification.

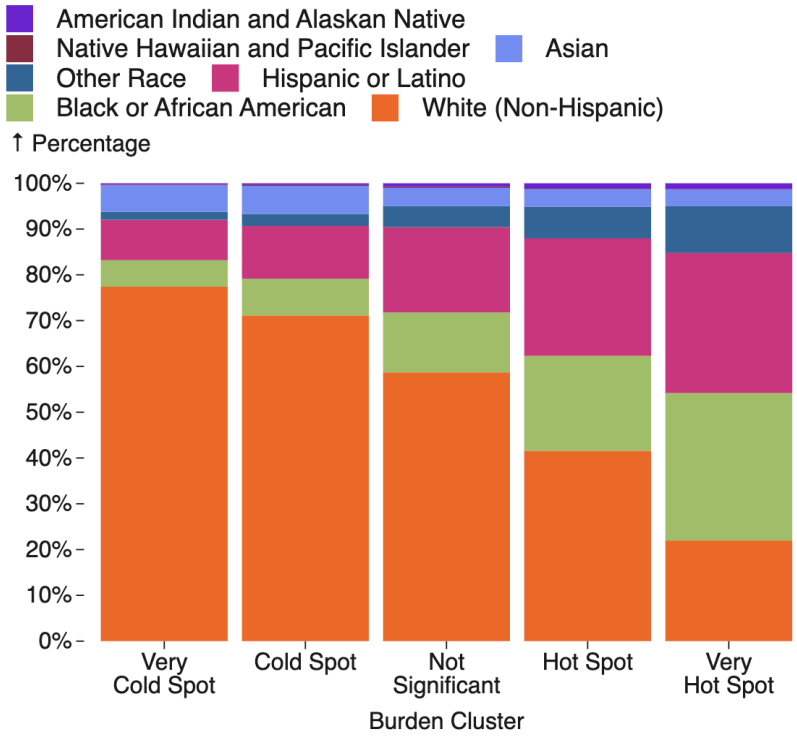

Figure 4. Demographic breakdown of hotspot burden method

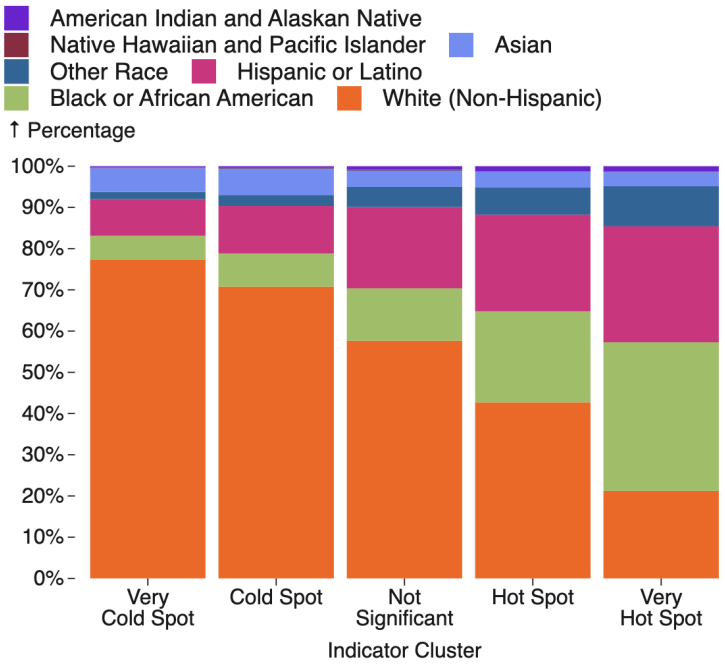

Figure 5. Demographic breakdown of indicator hotspot method

3.3 Distribution of Hotspots and Coldspots Across Census Tracts

Figure 6 and 7 below are bar charts that show the distribution of cluster categories across all U.S. census tracts. About half of all census tracts have no cluster classification. Approximately 26,000 census tracts are identified as cold spots and 10,000 are identified as hot spots. Hot spots and cold spots at both the 95% and 99% significance level are included in this visualization.

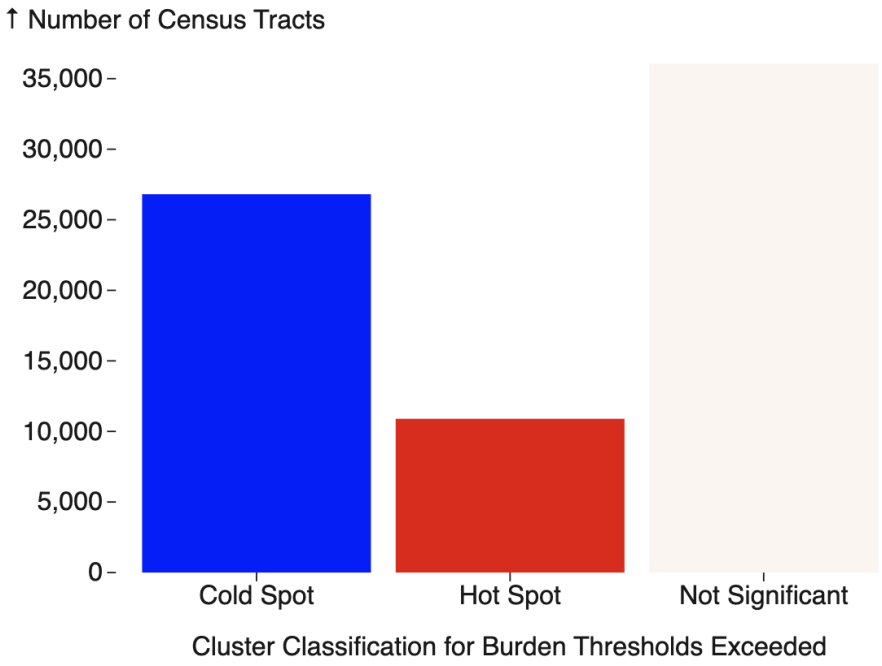

Figure 6. Distribution of burden hotspot method

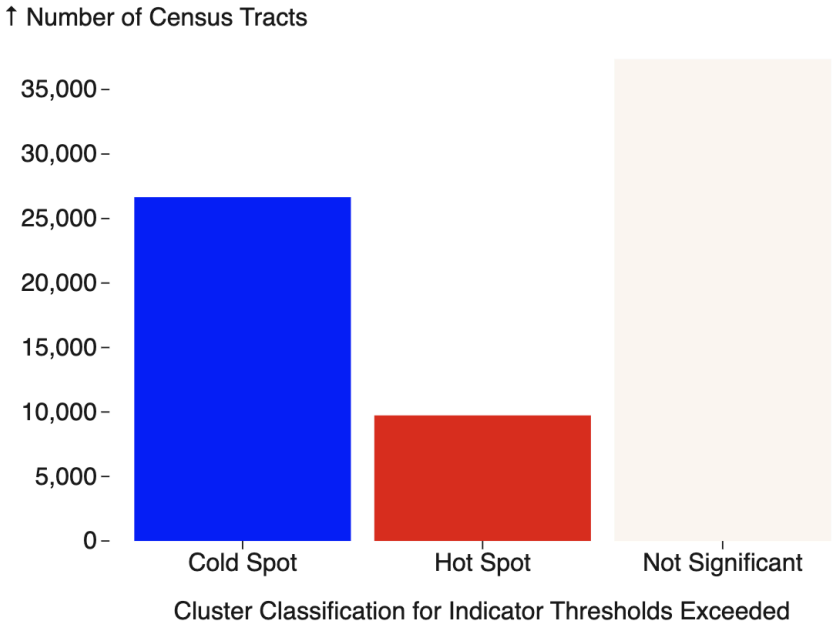

Figure 7. Distribution of indicator hotspot method

4. Product Description

4.1 Interactive Web Application for Viewing Disadvantaged Communities

To visit the web application, click this link.

https://apps.bren.ucsb.edu/justice40/en/

Product Overview

CEJST+ is a React and JavaScript-based interactive web application that builds on the original Climate & Economic Justice Screening Tool by visualizing and analyzing the cumulative effects of environmental burdens across communities. A key improvement from the original framework is its ability to more accurately and equitably represent census tracts facing multiple burdens, clearly showing the cumulative impact on communities where more than one environmental challenge exists. Using nationally-consistent datasets, it helps identify disadvantaged communities facing climate, environmental, health, and economic burdens. The tool provides an easy-to-navigate map covering all U.S. states, the District of Columbia, and territories, with interactive features allowing users to toggle between different burden layers and explore various spatial statistical approaches to better understand spatial patterns across regions.

Technical Architecture

Table 2. Web Application Architecture.

Architecture	**Description**
Frontend	React.js framework for component-based user interface development

Backend	Data-server (http-server) • Serves tile data and associated metadata to the frontend • Handles user queries for specific census tracts
Geospatial Processing	Vector tiles were created with Mapbox's Tippecannoe Server-side rendering of map tiles for application via MapLibre GL JS and TileServer-GL
Data pipeline	Extract, transform, and load (ETL) processes in Python for ingesting and cleaning data for pipeline
Deployment	Date pipeline, data server, and application client are all packaged into Docker containers for deployment.

Key Features

- Interactive mapping tool for visualizing all U.S. state, territories, and tribal lands
- Census tract level precision using vector tiles
- Cumulative burden index layer
- Hot and cold spot clustering layer to visualize spatial patterns
- Ability to toggle between different burden indicator views
- Data visualizations including demographic breakdowns of all methods

Target Users

This tool was designed for public use and to help local and state decision makers understand the environmental context of regions of interest within the United States, territories, and tribal lands.

4.2 App Deployment and Maintenance

This section will detail anticipated problems surrounding maintenance and deployment, along with potential solutions and resources for further troubleshooting.

Deployment

The web application will be publicly available and deployed on the Bren School network. The data server will be closed off from the public, and will only be used to serve data locally to the web application.

The deployment process consists of two main parts: data server deployment and web application deployment. Each part has a Docker container associated with it. To deploy the data server, complete the following steps:

1. Clone the Github repository located here: https://github.com/Justice40-MEDS/j40-cejst-2
2. Install all Javascript packages needed using npm and the package.json located in the root of the Github repository.
3. If raw data is needed, it can be downloaded from the data server located here:
    a. https://apps.bren.ucsb.edu/data/data-pipeline/data_pipeline/data/
    b. Once the data folder is downloaded, place the full data folder into the following directory: /data/data-pipeline/data_pipeline/data/ in the local folder
4. Run the following in the terminal of the local machine:
    a. docker compose up j40_score_server

The data server needs to be deployed before moving on to deploying the web application. To deploy the web application, complete the following steps;

1. For development deployment, run the following in the terminal:
    a. docker compose up j40_website
2. For production deployment, navigate to the /client/ directory. Then run the following in the terminal:
    b. npm run build
    c. npm run serve – -p 3000

Maintenance Plan

The client and data server should not need troubleshooting since all three components are containerized using Docker and are designed with reproducibility in mind. If additional analyses are needed, the client will need to contract a software developer to add new functionality. General instructions on how to add new variables and functionality will be provided in the Github repository.

5. User Manual

5.1 Introduction

This web application helps users visualize and analyze multiple environmental, climate, health, and socioeconomic burdens across U.S. census tracts. Unlike the original CEJST's binary approach, this tool provides a comprehensive view of cumulative impacts to better inform resource allocation.

The tool shows information about the burdens that communities experience. It uses datasets to identify indicators of burdens. The tool shows these burdens in census tracts. Census tracts are small units of geography. Census tract boundaries for statistical areas are determined by the U.S. Census Bureau once every ten years. The tool utilizes the census tract boundaries from 2010. The tool also shows land within the boundaries of Federally Recognized Tribes and point locations for Alaska Native Villages.

The tool ranks most of the burdens using percentiles. Percentiles show how much burden each tract experiences compared to other tracts. Certain burdens use percentages or a simple yes/no.

A community is considered to be disadvantaged if they are located within a census tract that meets the tool's methodology or are on land within the boundaries of Federally Recognized Tribes.

5.2 Getting Started

Accessing the Application

- Open your web browser and navigate to https://apps.bren.ucsb.edu/justice40
- Ensure you have a stable internet connection for optimal performance

Understanding the Application Layout

- **Explore the Map Panel**: Home page and the central interactive map displaying census tract data
- **Explore the Data Panel**: Located in the top-right, contains interactive visualizations of data used for the map.

5.3 Navigating the Map

Map Controls

- Zoom: Use the "+" and "-" buttons in the top-left corner or your mouse scroll wheel.
- **Pan**: Click and drag anywhere on the map.
- **State/territory controls**: Click the states or territories abbreviated on the left of the map to be taken to that area. 48 corresponds to the contiguous United States.
- **Current Location**: Click the location pin icon located next to the search bar to center the map on your location (requires location permissions)

- **Select Layer:** Use the drop down menu in the top-right corner to choose a layer to visualize.

Switching Map Layers

1. Click the Select Layer drop-down menu in the top-right corner of the map
2. Select from the following layers:
    - **CBurden Thresholds Exceeded (default)**: Displays total burden counts (0-8) that a census tract exceeds
    - **Indicator Thresholds Exceeded**: Displays total indicator counts (0-31) that a census tract exceeds
    - **Burden Hotspots**: Highlights statistically significant clusters of high (red) and low (blue) burden threshold exceeded areas
    - **Indicator Hotspots**: Highlights statistically significant clusters of high (red) and low (blue) indicator threshold exceeded areas
    - **Legacy CEJST Layer**: Displays the original binary DAC/non-DAC classification

Color Legend

- A color legend appears at the bottom of the map
- For Cumulative layers: Darker colors indicate higher burden/indicator counts
- For Hotspot layers: Red indicates hot spots (high clustering), blue indicates cold spots (low clustering)
- For legacy tool: Blue represents DACs

5.4 Using the Sidebar

Viewing Census Tract Information

- Click on any census tract on the map to load its detailed information in the sidebar
- The sidebar contains multiple tabs:

Summary Tab

- Census tract ID and location information

- Population size and demographic information
- Cumulative burden/indicator thresholds exceeded count (thresholds exceeded layers)
- Hotspot/coldspot status (hotspot layers)
- DAC status under original CEJST methodology (legacy tool layer)

Burden/Indicators Tab

- All burdens listed with exceeded thresholds highlighted
- For each burden:
    - Category name (Climate change, Energy, Health, etc.)
    - Specific indicator values with national percentiles
    - Threshold status (exceeded thresholds are highlighted)

5.5 Explore the Data Panel

Available Charts and Graphs

- **Demographic Comparison of Thresholds Exceeded**: Charts comparing demographic profiles across burden/indicator thresholds exceeded levels.
- **Hot Spot and Cold Spot Distribution**: Charts comparing the distribution of census tracts across different cluster classifications.
- **Interactive National Percentile for Burdens/Indicators Distribution**: Interactive chart exploring the distribution of burden/indicator national percentiles at the state and county levels.

Interacting with Graphs

- **Filters**: Use dropdown menus above the burden/indicator distribution chart to filter by state, county, or specific burdens/indicators.
- **Hover Information**: Hover over chart elements to view detailed information

5.6 Tips and Troubleshooting

Common Issues

- If the map fails to load, try refreshing the page

- If sidebar data doesn't appear, ensure you've clicked directly on a census tract
- For any persistent issues, use the contact information tab to reach out

6. Data Access

The tile server and associated application data will also be served on the Bren network via shinyapps.bren.ucsb.edu for at least 12 months. Table 2 shows files and data the project will archive.

6.1 Code Repository

All code used for this project will be publicly available on the Justice40-MEDS Github organization for non-commercial use. General instructions on how to install necessary software and spin up a local instance of the web application will also be provided in the repository's README.

Github Organization URL: https://github.com/Justice40-MEDS

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