

Conceptualizing and mapping a Water Justice Index in the US

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Research Problem Statement or Purpose

Access to clean and safe water is not only a fundamental human right essential for sustaining life and promoting public health, as outlined in the United Nations Sustainable Development Goals (SDGs), particularly Goal 6 but also a critical challenge facing marginalized communities. Despite global efforts to achieve this goal, marginalized communities still face persistent disparities in water access and quality (Boelens et al., 2018; Cleaver, 2018; Kallho, 2014). Particularly affected are marginalized urban households and rural smallholder families, including Black, Hispanic, Puerto Rican, and Alaska Native populations. These groups often grapple with multifaceted issues like flooding, contamination from industrial and mining activities, privatization of public water utilities, and frequent water service disruptions (Bhattarai et al., 2023; Nartey et al., 2023). The persistence of these injustices has led to pronounced trends in drinking water violations and inadequate plumbing infrastructure (Cleaver, 2018; Lin et al., 2022; Nartey, et al., 2023). Further exacerbating these challenges are issues of water affordability and increased health risks (Cardoso & Wichman, 2022; Nartey, et al., 2023; Remington et al., 2015; Teodoro & Saywitz, 2021).

Recent studies have shifted towards evaluating water vulnerabilities using individual indicators, focusing primarily on technical indicators (Doria, 2006; Jones et al., 2006; Meehan et al., 2020; Young et al., 2019, 2021). These include water and sewer affordability, lack of plumbing, water violations, and the availability of water utilities (Bhattarai et al., 2023; Nartey et al., 2023; Nelson et al., 2023; Switzer et al., 2020). However, this approach, while valuable, tends to overlook the broader socio-economic and environmental contexts that intensify water-related difficulties in these communities. This includes socioeconomic vulnerabilities and the heightened risks individuals or communities face in dealing with water issues due to income, education, and social status (Cleaver, 2018; Kallho, 2014). It also involves health vulnerabilities, referring to the greater likelihood of health issues in certain groups because of poor access to safe and clean water, often exacerbated in marginalized communities (Cleaver, 2018; Davies & Mazumder, 2003; Mcleod et al., 2014; Nartey et al., 2023; Teodoro & Saywitz, 2021).

To bridge the gaps in existing research, we propose the development of a Water Justice Index (WJI) designed to comprehensively capture the complexity of water-related challenges. The WJI is designed to comprehensively capture the complexity of water-related challenges by integrating water insecurity indicators with socio-economic and health-related vulnerabilities. This multifaceted approach allows for a more nuanced understanding and assessment of water injustice. We demonstrate the practical application of this index by mapping it across various counties in the United States, employing a methodology that considers a range of indicators to reflect the diverse challenges faced by different communities.

Furthermore, the paper highlights the critical role of community engagement and cross-sectoral collaborations in addressing water injustices. By involving communities in the development and application of the WJI, we ensure that the index is grounded in the realities and specific needs of those most affected. This innovative methodology research advances the objectives of sustainability and resilience, advocating for a water-secure future that transcends systemic barriers and promotes equity and inclusion in engineering practices.

Research Methodology and Approach

The Water Justice Index (WJI) presented in this paper represents a comprehensive effort to assess water justice within the context of modern global engineering and construction project organizations. This interdisciplinary index draws inspiration from established methodologies and leverages data from authoritative sources such as the United States Environmental Protection Agency (EPA), the United States Census Bureau, and extensive web-based surveys.

The foundation of the Water Justice Index lies in the selection of appropriate variables that collectively capture the dimensions of water justice. These variables have been meticulously gathered over a five-year period spanning from 2016 to 2021. These variables are categorized into four core groups, each reflecting a dimension of the index.

Socioeconomic vulnerability is influenced by income, education level, wealth, age, exposure to traumatic, adverse childhood experiences, and social status, which affect people's ability to access clean water, proper sanitation, and cope with water scarcity or contamination. Water technical indicators include objective measures such as water system violations, indicative of regulatory compliance and system efficacy, and the lack of plumbing facilities, which reflect the infrastructure's ability to deliver safe water. Social Indicators include factors like water insecurity perception scales, accessibility to safe drinking water, sanitation facilities, the impact of water scarcity on daily life, and community engagement in water resource management. These subjective measures are crucial for understanding the social impact of water-related issues. Health vulnerability includes populations with limited access to clean water and are more susceptible to illnesses such as cholera, cancer, diabetes, heart disease, diarrhea, and other infections. This group includes the prevalence of diseases such as cancer, diabetes, and heart disease, which may be exacerbated by water quality and access issues.

To assess the spatial distribution of these variables and identify areas of high and low vulnerability, a spatial analysis technique was employed using the Getis-Ord G_i^* tool. This tool calculates a z-score for each census tract, allowing the identification of statistically significant hot spots and cold spots—areas with high and low concentrations of the measured factors.

The research focused on pinpointing areas with the highest vulnerability by identifying census tracts with high-value clusters. After generating the hot spot maps, each census tract was assigned a z-score. To ensure meaningful aggregation of results from the four vulnerability factors, a normalization process was undertaken. The z-scores were scaled to a range from 0 to 1, with the lowest z-score set to 0 and the highest z-score set to 1. Subsequently, the normalized z-scores from the four factors were aggregated to determine the census tracts with the highest vulnerability scores. Each tract's vulnerability score was calculated on a scale ranging from 0 (lowest vulnerability) to 100 (highest vulnerability), considering all four dimensions.

To visualize the spatial autocorrelation and clustering of vulnerability data, spatial autocorrelation statistics, such as the Getis-Ord G_i^* statistic, were employed, leveraging a base map from ArcGIS Pro.

Key Findings and Implications

Preliminary findings reveal significant and insightful evidence of clusters, indicating that certain counties have notably high factors that contribute to the complexity of water justice. Below, maps display technical indicators like the lack of Plumbing (Fig.1) and Health Violations (Fig.2) across the U.S., highlighting counties most affected by these issues.

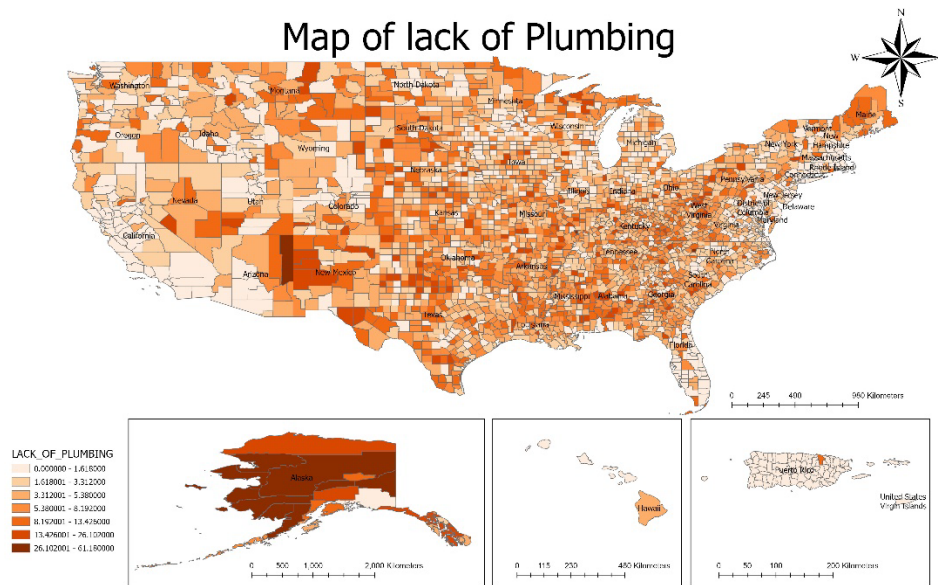


Fig. 1 Map showing the lack of plumbing in the US

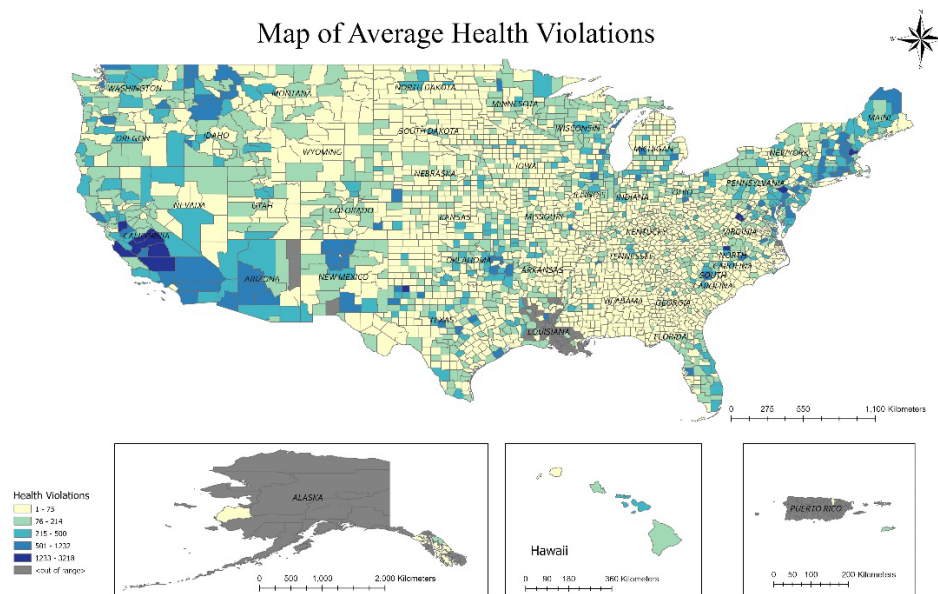


Fig. 2 Map showing Average Health Violations in the US

As data analysis and mapping progress, the anticipated outcomes of this study are expected to reveal the most vulnerable counties and the key factors influencing their situation. These insights will be fundamental in developing the WJI and guiding targeted solutions. The WJI will aid in

creating more effective, sustainable practices by acknowledging the varied water security challenges in different communities. Additionally, it will be a valuable resource for policymakers, facilitating decisions that promote equitable water resource management and infrastructure planning.

In summary, the anticipated outcomes of this research offer more than just a profound insight into the water-related challenges faced by vulnerable communities. They also provide a basis for pragmatic, community-driven solutions that emphasize the health and welfare of the residents, ultimately contributing significantly to achieving Sustainable Development Goal 6 (SDG 6).

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