Urban Heat Resilience and Housing

Urban areas exhibit higher temperatures than their rural counterparts due to changes in land cover, a phenomenon known as the urban heat island (UHI) effect (cite). Urbanization leads to more impervious surfaces, which absorb more energy from solar radiation and re-emit it as heat (cite). In contrast, rural areas contain more natural landscapes (e.g., "trees, vegetation, water bodies") that provide cooling effects via solar deflection, shade, and evapotranspiration (cite). In addition, intra-urban temperatures exhibit stark differences due to land cover variations between neighborhoods (cite, cite). Global warming will continue to intensify UHIs (cite), so urban communities face a severe burden of climate change (cite). However, the burden of urban heat is not shared equally. Studies have found that there are racial and socioeconomic disparities in urban heat exposure in the United States, in part due to marginalized communities having less greenspace and more impervious surfaces (cite, cite, cite, cite). Moreover, extreme heat can pose public health risks, including mortality, hospitalization, heat stroke, and other heat-related illnesses, which have been shown to disproportionately impact people of color and low income communities in urban areas (cite, cite, cite, cite).

This phenomenon is an issue because marginalized communities may not have the resources or appropriate conditions to properly prepare and respond to extreme heat, impairing vulnerable communities' resilience to climate change. Of course, social justice plays a prominent role in urban heat resilience. For example, the Census Bureau's Community Resilience Estimates (CRE) for Heat, developed with the notion that socioeconomic vulnerabilities determine resilience, provides individual and household risk factors for heat (cite). According to the American Planning Association, urban areas can achieve heat resilient communities through heat mitigation (i.e., "reducing the built environment's contribution to urban heat") and heat management (i.e., "preparing and responding to chronic and acute heat risk") (cite). In addition, there is growing recognition that development of capacity for urban heat resilience must incorporate short-term (e.g., mobilizing resources) and long-term (e.g., analyzing trends, leading educational campaigns) policies and programs (cite).

Housing plays a pivotal role in climate resilience for urban communities who face heightened heat stress due to the built environment and climate change. For instance, housing factors (e.g., housing costs, crowded housing, and mobile homes) feature in the CRE for Heat (cite). Unfortunately, people of color and low income communities tend to have higher housing burden (i.e., spending more than 30 percent of a household's income for housing) (cite, cite) and energy burden (i.e., the percent of a household's spent on energy consumption) (cite). Both housing and energy burden can impact the use of air conditioning, which is a critical component of resilience to extreme heat, especially in the context of public health. The financial circumstances of some urban dwellers may force them to choose eating and paying rent rather than responding to heat with air conditioning (cite). In fact, low income households often do not increase spending on energy during extreme weather unlike their counterparts (cite). This issue contributes to grave public health effects. One study found that differences in central AC access contributed to increased heat mortality in Black people compared to white people in four urban areas (cite). In general, there are numerous studies that contribute the lack of air conditioning to heat mortality and hospitalization in urban areas (cite, cite, cite, cite). Of course, air conditioning may also intensify urban heat, presenting a double edged sword. That is, energy consumption to respond to heat stress often uses fossil fuels, contributing to air pollution and climate change (cite). Moreover, marginalized communities may be subject to older and crowded housing (cite). Unfortunately, housing age and crowded housing are highly positively correlated with heat-related illness (cite). In addition, housing age is important since it is a proxy for energy efficiency. Older housing is often less energy efficient and less insulated, which can result in a higher energy burden.

Goal

You have been hired as a data scientist by the American Planning Association to provide a national analysis on housing barriers to urban heat adaptation. They would like an in-depth report to share with their contacts at the Justice40 Initiative to promote resource allocation for those extremely susceptible to urban heat but with few financial means to respond to it with respect to housing.

You gather data from a previous study (cite) and the Climate and Economic Justice Screening Tool (CEJST) to examine the relationship between urban heat island disparities and climate resilience, or the ability to respond and adapt to extreme heat in urban areas. Your goal is to analyze various factors related to race, socioeconomic status, and housing that present barriers to extreme heat response for marginalized communities. For your analysis, you use machine learning to model climate resilience to urban heat based on race, socioeconomic status, and housing factors.

Data Exploration

Spearman Correlation Analysis

How does race and poverty correlate with housing factors and SUHII? Which variables are most correlated with SUHII? How does this relate to the research discussed in the introduction?

Probability Density Estimation

What do the distributions reveal about race, socioeconomic status, housing factors, and SUHII? How does this relate to the research discussed in the introduction?

Data Dissection
Divide the data using the low income indicator, race bins (e.g., 0-20%, 20-40%,...,80-100%), and housing bins. Find the average SUHI for each bin. Is there a monotonic pattern? Count how much of the data falls into each bin. Feel free to use kernel density estimates as a tool to examine the different groups as well.

Regional Examination
Compute the county and state average SUHII; county and state weighted average SUHII by race; and county and state weighted average SUHI by race and low income indicator. Which regions have the highest average SUHII? Which regions have the highest disparities?

Freestyle
Formulate a question that can be answered through data exploration. This could include taking one of the previous approaches a step further. Perform 1-2 extra data exploration techniques to answer your question. Discuss your findings.

Model Development

Model Performance
RMSE is the standard deviation of the residuals. Based on the RMSE, how did the model perform? Based on the R^2, how well did the model capture patterns in the data? Compute the residuals, and create scatter plots of residuals by race and socioeconomic status. How does performance vary across demographics? How does model performance impact your communication of the model to your team?

Predictive Factors of SUHII
Using the SHAP values, discuss the most predictive factors of SUHII. Why do you think these are the most predictive factors? How does this compare to the previous research discussed in the introduction?

Feature Interactions
Using SHAP scatter plots, discuss how racial/socioeconomic composition of a tract and housing factors impact SUHII (i.e., use housing factors as a heat map by race). Explain the disparities that these plots illuminate. How does this compare to the previous research discussed in the introduction?

Summary

Summarize the findings for your team. Based on your analysis, how does housing harm urban heat resilience by race and socioeconomic status?