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Shade Equity in Louisville, KY: Considering Environmental Justice in an Analysis of Urban Tree Canopy Inequality and Demographics

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ABSTRACT

As cities build climate resilience and foster equity, tree planting is a priority solution. Urban tree canopy (UTC) provides multiple vital ecosystem services, particularly shade, and mitigates the Urban Heat Island Effect (UHI). This research examines Louisville, KY as a case study for tree canopy disparity, observing inequality in the relationship between tree canopy and demographics, as well as the unevenness in the canopy change over time. This study uses spatial analysis in ArcGIS Pro to investigate the unevenness in the tree canopy gains or losses from 2012-2019, and to compare tree canopy to seven different demographic groups that are historically marginalized or are vulnerable to extreme heat. A disparity index model was followed to produce values and maps indicative of tree canopy inequality for all 587 census block groups. For the analyses of change over time and disparity between demographics and tree canopy, there are many block groups that have disproportionately low tree cover, or are losing tree cover more than others, revealing inequalities and amplified vulnerability to extreme heat.

Key words: urban tree canopy, shade equity, Louisville, disparity, ecosystem services, redlining, green gentrification.

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INTRODUCTION

Around the world cities have seen rapid urbanization in the past several decades, and by accommodating the growing urban population, impervious surfaces and development covers most of the scarce urban land. The ever-growing urban environment renders green space and natural areas more and more scarce. In the era of climate change, when warming temperatures make cities much hotter than the surrounding areas, parks and tree canopy are two critical components of an urban ecosystem that cool down neighborhoods and offer a refuge to residents on extremely hot days. Tree canopy is a place maker in urban ecosystems, defining the landscape and offering benefits to the adjacent living and non-living systems. In the context of the urban heat island, trees serve the most important role as a shade-giver.

Citywide tree canopy assessments reveal unevenness in the localized canopy distribution and identify areas with a lower proportion of canopy cover, [implying they might be more vulnerable to the negative effects of the heat island.] Tree canopy disparity occurs in tension with the natural systems and the social systems; although tree canopy is an element of nature, social, political, and economic forces that exist in socio-ecological systems demonstrate how something natural is carefully controlled by social systems. When looking at inequality in tree canopy, we often see that historical and current demographic distributions, usually on the basis of race and income, are indicators of inequality and present the environmental justice issue of access to green space through historical or current discriminatory land use practices. The main way to remit tree canopy disparity is through deliberate tree planting efforts in neighborhoods with a historically low canopy coverage. Given the inequality in canopy cover and the resulting inequality of shade, the critical EJ issue of shade equity illuminates which areas might be disproportionately affected by the urban heat island. This research investigates shade equity in Louisville, KY, as one city with a unique tree canopy distribution.

[Shade] is a civic resource, an index of inequality, and a requirement for public health. Shade should be a mandate for urban designers. (Sam Bloch, *Shade*)

LITERATURE REVIEW

Urban Heat Island and Health

Urban Heat Islands (UHI) are defined as urban areas that have higher average temperatures than surrounding areas due to a higher proportion of impervious surfaces, such as concrete and steel, that hold heat for longer than pervious surfaces (EPA). UHIs pose health threats, rendering residents who live in the hottest areas of a city more susceptible to heat related illnesses such as heat stroke, heat exhaustion, and even death (Louisville Heat Management Study, 2016). Of all extreme weather events spurred by climate change, heat kills the greatest number of people nationwide, with mortality rates expected to increase by at least 70 percent in the largest US cities nationwide by 2050 (Leahy & Serkez, New York Times). In 2013, Louisville was ranked fifth for the hottest urban heat island (Climate Central, 2014), but in an updated report, Louisville is not even in the top 20 most intense heat islands (Climate Central, 2021).

Tree Canopy Reduces UHI Effect

Urban Tree Canopy (UTC) is an invaluable and irreplicable component of urban ecology due to ecosystem services trees offer such as shade, air filtration, habitat, stormwater runoff, biodiversity, etc., (Schwartz, 2015). An UTC parameterization study combined with collective research on the effects of tree cover lowering city temperatures claim that urban trees can mitigate the UHI effect and lower the near-surface temperatures because of their shading and cooling effects (Loughner et al., 2012).

Both impervious surfaces and vegetation play roles to increase or decrease air temperature throughout the day, with a study in Madison, WI, demonstrating that daytime air temperature linearly increased with an increase in impervious surfaces, and daytime air temperature non-linearly decreased with tree canopy, seeing the greatest decrease when tree canopy was ≥ 40% (Ziter et al., 2019). Heat management is a critical issue for cities everywhere, thus the collective evidence for urban reforestation as a strategy to mitigate the UHI effect, improve biodiversity and ecosystem health of cities is a relevant strategy for cities to develop sustainable and ecologically sound climate plans (McPhearson et al., 2010).

Community members are not equally tolerant to heat pressure, with the youngest and oldest members of the population as most vulnerable to heat waves due to their bodies' reduced capability to regulate heat or reduced mobility. Additionally, people with pre-existing medical conditions and illnesses such as asthma are also more susceptible to heat-related health risks, thus the importance to ensure the equitable distribution of tree canopy (Louisville Urban Heat Management Study, 2016).

Redlining: Lasting effects on the demographic distribution and environmental inequities

Land-use history involving redlining and urban segregation created long-term impacts on the distribution of tree cover. The Home Owner's Loan Corporation Program sent property assessors to develop maps for banks to use to determine who is eligible to receive a home loan (Hoover, 2019). The racial bias of property assessors from the New Deal era resulted in the redlining of many neighborhoods of color in US cities and ranking on a scale of A-D, with D indicating a land parcel ineligible for a home loan (Hillier, 2003). Though race was not the main criteria for the HOLC maps the neighborhood-ranking system incorporated race into the value, rendering poorer, neighborhoods of color likely to receive a grade of C-D and gave predominantly wealthy and white neighborhoods a grade of A, propelling the accumulation of wealth, privilege, and community development in those neighborhoods (Locke et al., 2021). The mechanism of redlining spurred disinvestment in many predominant minority neighborhoods, and decades after redlining was abolished in 1968, the exclusion of people of color from wealth produced lasting impacts on the contemporary issues around urban and environmental gentrification (Tootell, 1996).

WWII suburban development subsidized by the federal government created new, exclusively white geographies that generated enormous new wealth (Locke et al., 2021). The systemic process of redlining propelled lasting inter-urban inequities along the basis of income, race, and environmental risks and hazards (Locke et al., 2021).

The results from the recent study on redlining's impact on tree canopy confirmed the hypothesis, that across 37 cities in the US there is a strong relationship between HOLC zoning grades and tree canopy, with former D-graded neighborhoods having 21% less tree canopy than former A-graded neighborhoods (Locke et al., 2021). Considering the emerging literature investigating environmental outcomes from historic HOLC grades, the study postulates that redlining set a premise for wealth accumulation, linking political power to race and geography, as well as accumulating public investment in park, street, and residential tree establishment (Locke et al., 2021). Similarly, redlining may have created a positive feedback loop in formerly D-graded neighborhoods that were primarily smaller lots intended for housing or industrial purposes, which are now less conducive to tree canopy cover, with less resources and influence in the public sphere to maintain tree cover (Locke et al., 2021). The systems established from redlining created viscous cycles in urban wealth segregation and the distribution of the natural and built urban environment.

Tree Canopy & Sociodemographic variables

Urban tree canopy and green space have been studied in recent years to identify how socioeconomic status relates to the abundance of greenness (Schwartz et al., 2015). Many studies on the distribution of UTC observe a positive correlation between UTC and increasing income, and a negative correlation with tree canopy and low-income and minority neighborhoods (Schwartz et al., 2015; Watkins et al., 2017). A meta-analysis of 61 studies and 332 total events on the effects of urban forest inequity and income found a significant income-based urban forest inequity, regardless of the method choice (Gerrish & Watkins, 2018). In seven US cities, Philadelphia, PA, Baltimore, MD, Los Angeles, CA, New York, NY, Raleigh, NC, Sacramento, CA, and Washington, DC, UTC has a strong positive correlation with increasing income and negative correlations with UTC and race exist in some, but not all cities (Schwartz, et al., 2015). However, one study examining UTC and ecosystem service correlation with several sociodemographic variables across nine U.S. cities show that inequities in ecosystem services and UTC distribution are not universal across all cities and should be further studied in the context of a unique history, sociodemographic distributions, and cultural values. While there are reoccurring trends in large US cities between UTC distribution and sociodemographic variables, localized studies offer more opportunities to understand nuanced demographic trends and to develop tree canopy plans given the unique identity (Riley, 2020).

Other tree canopy trends relate to change over time, with one study from Salt Lake County, Utah recording a relationship between UTC and neighborhood age so that UTC becomes less abundant and diverse as neighborhoods get older and more abundant and robust in newer neighborhoods (Lowry et al., 2012). Though many cities report that income is a predictor of tree canopy, one case in neighborhoods in southeastern Australia show that the historical sociodemographic makeup of a neighborhood is often a better indicator of current tree canopy than the present sociodemographic makeup, even with a time lag of two years (Greene et al., 32 (Luck et al., 2009)). In this example, time is an important factor in demographic shifts and tree canopy growth which presents a less-common case study in demographic and tree canopy analysis.

Hedonic pricing & land value

Hedonic pricing is a market mechanism that evaluates the price of land, of which trees can influence. One study on the impact of urban trees on land value showed that people recognize the benefits of trees on land as well as the positive externalities on an individual from a tree planted on a neighboring or shared property (Sander et al., 2010). The same study looked at values of trees by single-family owners, finding that tree cover is indeed valued by single-family home purchasers and owners in urban areas, and that higher canopy cover within a 100m to 250m radius of a property increase the home sale price (Sander et al., 2010). Single-family owners represent only the private sphere, but the study notes that tree planting initiatives differ in the private versus public sphere and are more difficult to incentive in the private sphere due to the direct increase in land value from trees.

Though trees are often desirable features in an urban or semi-urban landscape, they are not universally accepted as a benefit and can pose a burden due to their inherent costs (resource inputs, exacerbated allergies, stewardship responsibility, etc.) (Schwartz et al., 2015). Three studies done in Poland examining the stakeholder planning process and access to green space indicate that access to urban green space is not always equal to the access of ecosystem services provided by the same green space. Stakeholder decision-makers are not necessarily those who benefit from ecosystem services and urban green spaces and are not ultimately responsible for their delivery or availability (Biernacka & Kronenberg, 2019).

Tree Planting Prioritization

Tree planting is critical when designing livable and sustainable cities. However, the financial impact on home and land value after the planting process can be a determinant for whether certain residents stay or are forced to relocate. Tree planting can have an inadvertent outcome; if neighborhood residents cannot afford their rent, they do not experience the benefits provided by trees that were originally intended to make their neighborhood more livable and sustainable the long run. Both the desire for more trees as well as the capacity to maintain them should be consulted when planning tree planting initiatives. The implementation process of trees in certain neighborhoods can exclude participants as well as propel gentrification through raising land values (Watkins, et al., 2017). One group of scholars developed an environmental justice framework to prioritize tree planting in the Million Trees NYC initiative, based on several variables among New York City neighborhoods, including air quality, urban heat island, socioeconomic level, etc., using the ratings and rankings of the variables to indicate which neighborhoods could benefit from more trees (Locke et al., 2010). American Forests recently release their Tree Equity Score calculator, which is available to everyone their website. The score is comprised of data on health index, temperature, people in poverty, seniors (65+), children < 17, people of color, and unemployment rates, and evaluates those demographics with tree canopy at the census block group level (American Forests, 2021).

Environmental Justice & Green Gentrification: Is Green Always Good?

The field of Urban Political Ecology offers a critical framework at the intersection of urban ecology and environmental justice to consider who benefits from trees, who faces consequences and who decides the logistics of planting (Carmichael et al., 2018). As cities are undertaking greening efforts, environmental gentrification emerges, a process described as the greening of urban spaces through development and gentrification of neighborhoods while screened by an apolitical, positive discourse (Dooling, 2009; Checker, 2011). Anthropologist Melissa Checker engages with environmental gentrification in her ethnographic research in Harlem, NYC, unpacking the paradox between citywide sustainability efforts and resulting gentrification, which is too often a result of regreening urban neighborhoods through redevelopment efforts. The apolitical, sustainability discourse that underlies urban green projects is problematic in that many decision makers do not live in the neighborhood where there is an existing need for parks and trees. Participatory planning in urban park projects is essential to include everyone in the sustainability movement, especially people in marginalized communities who often experience the disproportionate effects of inadequate tree cover and who are also often excluded from important planning conversations (Watkins et al., 2017; Carmichael, 2018; Biernacka, Kronenberg, 2019).

Since the early 2000s, urban geography and planning studies have shown that working-class and lower-class neighborhoods have less access to parks and green space, and that those parks are undermaintained, smaller, and fewer in numbers (Anguelovski et al., 2019). In the US, many urban neighborhood associations are responsible for green infrastructure projects, and it was also those associations that, throughout the early 20th century, supported redlining practices and protected white property owners, thus perpetuating a pattern of a disproportionate abundance of trees to exist in wealthy, white neighborhoods (Boone et al., 2010; Anguelovski et al., 2019). This deep history of redlining, land use, segregation, and disinvestment in low-income neighborhoods of color, offers a more complete perspective on land use history and how it has impacted the urban landscape today. The positive narrative accompanied by urban greening projects can be studied through a critical justice lens to identify where the inequity still remains behind the efforts to green. Given the deep non-linear history in urban areas of the exclusion of certain communities based on income, race, and other demographics, as well as the lasting impacts on the urban ecosystem and access to green space, inequity is deeply interwoven with distribution of green space and more work to undo systemic patterns of disparities.

Shade Equity

While cities must be careful to ensure that urban greening efforts do not create more inequity, the need for a robust and equally distributed tree canopy remains to ensure that cities are livable and ultimately sustainable as climate change evolves. Most cities have a scarcity of trees and green space, thus rendering the privilege to live near greenery. How can we intercept the paradoxical and systemic patterns of inequality and redistribute the burden of extreme heat that most often disproportionately impacts low-income communities and communities of color? Through shade equity, we recognize shade as an irreplaceable ecosystem service offered by trees that can often be predicted by the demographic make-up of a neighborhood. Further, we can identify areas in the city where residents will be more susceptible to heat-related illnesses such as asthma or heat-stroke, connecting the inequality in green infrastructure to an environmental health hazard. Cities cannot be sustainable if all residents are not protected equally from hazards, thus the importance of studying disparities in the urban tree canopy.

Louisville as a case study for shade equity:

Louisville plans for climate resilience

Louisville, Kentucky (Jefferson County) released the most recent tree canopy assessment from 2019 that reported a net gain of 1% tree canopy from 2012-2019, sitting at 39% average tree canopy (Tree Canopy Assessment, 2021). This growth is promising because from 2004-2012, Jefferson County experienced a net loss in canopy cover and projected trends indicated more canopy loss in the years to come (Tree Canopy Assessment, 2015). The report notes that while there is overall growth, the gains and losses throughout the city are uneven at the census block level. Strategies to protect the urban forest include maintaining the existing canopy and planting new trees (Tree Canopy Assessment, 2021). American Forests recommend an average around 40% urban tree canopy for cities, with the recognition that cities have varying climates and vegetation thus, a uniform recommendation is not realistic (American Forests). Louisville has recently set a canopy cover goal of 45% by 2050 which will be essential for citywide health and sustainability.

The Department of Sustainability published their climate action plan, *Prepare Louisville*, in 2020 to plan for climate resilience and prioritize climate equity. The city wants to dismantle historical and current power dynamics that perpetuate climate injustice and reduce inequities that cause the most vulnerable communities to be more susceptible to environmental hazards. The chapter on Equitable Neighborhoods outlines four priority objectives including supporting data and action steps for each: 1) Create cooler neighborhoods, 2) Invest without displacement, 3) Promote environmental justice, and 4) Cohesively address inequity, health affordability, sustainability, and preparedness (Prepare Louisville, 2020). The climate action plan is a key piece of policy that will facilitate the growth of Louisville's urban forest while ensuring that equity and justice is prioritized in the planting and regreening efforts.

Heat Mitigation

Ecosystem service data calculated using InVEST software represents heat mitigation in Louisville (2019). The InVEST model uses data on shade, evapotranspiration, albedo, and the distance from cooling islands (parks) to compute a heat mitigation index. This map is valuable because it shows where in Louisville there is less shade and where neighborhoods might be more vulnerable to suffering from heat-related illnesses. Tree canopy data is factored into the value of heat mitigation, but it is still valuable to visually consider how a map of heat mitigation almost mirrors the changes in tree canopy.

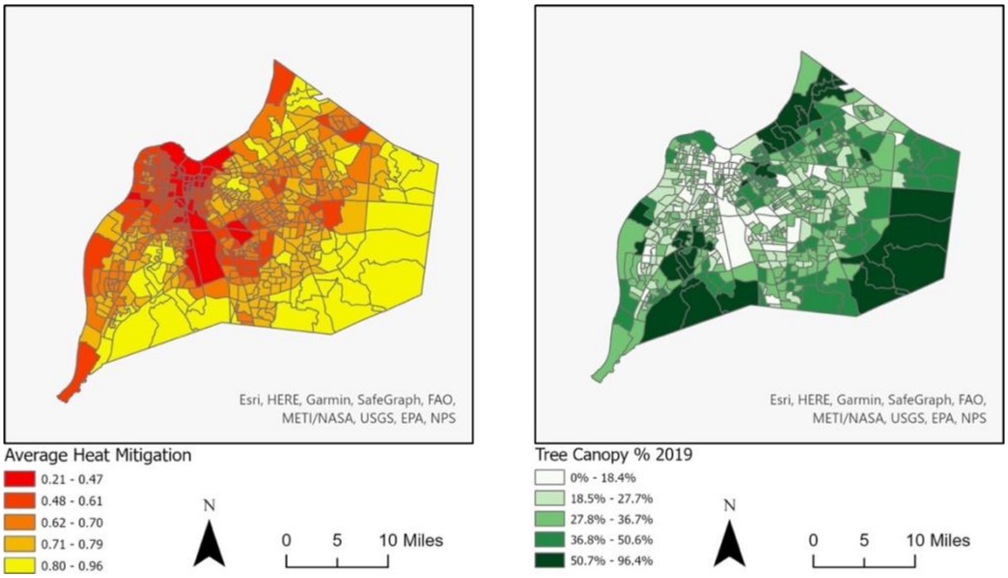


Figure 1. Average Heat Mitigation (left) and % Tree Canopy (right) in Jefferson County. Areas with low heat mitigation are dark red to represent the hottest areas, with bright yellow block groups with the highest heat mitigation. Block groups in dark green represent highest tree canopy, and light green are lowest tree canopy.

Since Louisville identifies the UHI as one of their main climate concerns, consistent and updated research on heat mitigation is important. The index ranges from 0 to 1, with areas in bright red having heat mitigation as low as 0.21, and areas in yellow having heat mitigation as high as 0.80 to 0.96. Based on the research on heat-related illness, strategies to mitigation the heat island effect should continue to be prioritized and implemented in the worst areas.

Redlining

Research on redlining maps from 1937 and data from the 2015 Tree Canopy assessment shows that tree canopy percentage in 2015 was higher in the districts historically marked Grade A and is lowest in the zones marked Grade C-D. Maps of income, poverty, home ownership and other demographics from 2015 reflect similar distribution patterns to the redlining maps showing that zones marked C and D correspond with neighborhoods that have more low-income families, predominantly people of color, renters, and high rates of poverty (Poe, 2017; Marshall, 2017). The ongoing work to study lasting effects of redlining in Louisville is a critical component of the city's efforts to reduce inequalities in the urban forest and ensure shade equity for groups that faced inequities in the past.

Tree Canopy and Income

Considering how redlining has played a significant role in shaping the distribution of many different demographic populations, a comparison of the most recent tree canopy data to median household income provides some insight into correlations between high income and high tree canopy.

Figure 2. Tree Canopy & Median Household Income (2019)

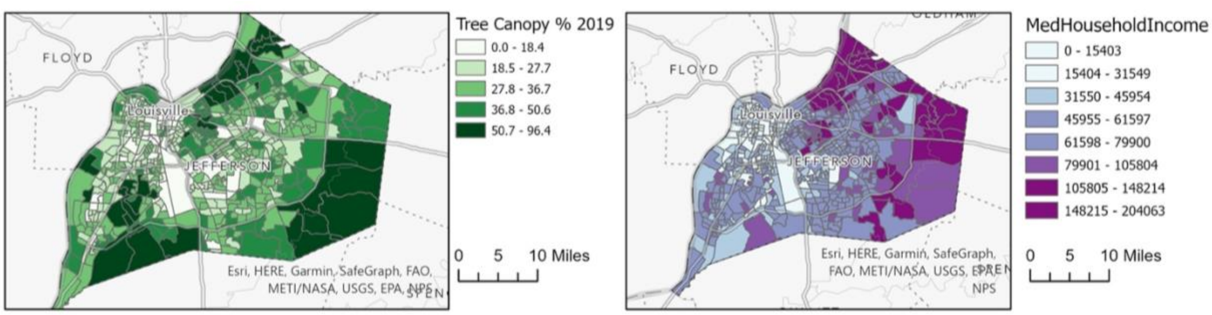
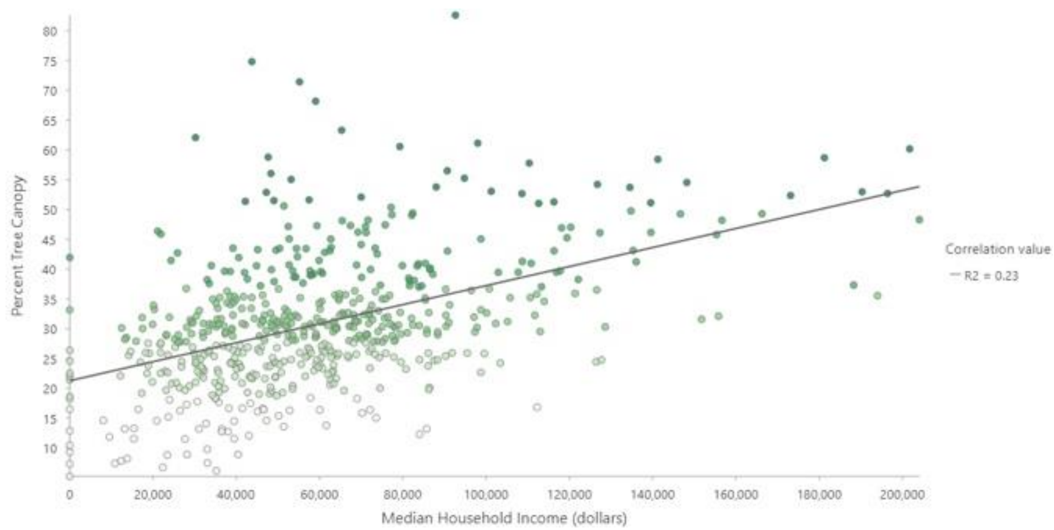


Figure 1.a. Tree Canopy Correlation with Median Household Income



Figures 2 and 2.a. come from preliminary analysis in this research comparing percent tree canopy data from the SAL and median household income from US Census Data (more on data sources in the methods). One can see the many cases in which neighborhoods that are low income overlay on the map with neighborhoods that have a low percent tree canopy, and vice versa, but the two variables have a moderate positively correlated with a value of 0.23, indicating there may not be a very strong relationship between the two variables. Investigating the relationship between median HH income and tree canopy could be cause for future research in Louisville, KY.

Shade Equity in Louisville

Louisville's history of discriminatory land use policies through redlining is an example of how zoning policies had a lasting impact on tree canopy distribution due to community disinvestment, indicating the intimate placemaking relationship between real estate and the landscape. The 2020 climate plan is promising as it acknowledges and lists specific goals to address the lasting inequity while working towards sustainability. The compound effects of the financial impact of trees on land values and cities' efforts to re-green create a striking paradox when considering that green space is essential to human wellbeing and should be equally accessible to all.

RESEARCH QUESTIONS

Tree planting initiatives from local non-profit organizations and the maintenance of existing canopy cover are priority solutions for Louisville to mitigate the negative impacts of their most pressing climate problem, the urban heat island, as well as foster resilience during extreme weather events. To ensure that neighborhoods in Jefferson County have equitable access to the ecosystem services provided from tree cover, neighborhoods that have the most inequality of shade should be identified and prioritized. An environmental justice framework prioritizes tree planting in neighborhoods that have been historically marginalized on the basis of race or income, have groups of people vulnerable to extreme heat, or have low existing tree canopy. There are many dimensions to the issue of urban heat mitigation, and this research works to answer the following questions to understand the relationship between inequalities in the urban forest and demographic distribution. In the lens of shade equity, groups that are historically marginalized or vulnerable to extreme heat will be studied to help tree planting organizations and policymakers to identify neighborhoods that have disproportionately low access to tree canopy and thus less shade.

Tree Canopy Change: Does the relative change in tree canopy from 2012-2019 reveal spatial clusters of neighborhoods that are gaining or losing tree canopy, or are the neighborhoods spread out through the city? What do the demographic characteristics of the neighborhoods with the most losses and most gains indicate about the impact of demographic groups on tree canopy?

Disparity: Among seven demographic groups that are historically marginalized or vulnerable to extreme heat, where are the neighborhoods located within the city that have a disproportionately low tree canopy compared to the demographic group of study?

Method questions: What are the limitations of using a disparity index to indicate shade equity? What aspects of inequity are missing from using only spatial and demographic quantitative data?

METHODS

Data

This project used ESRI's ArcGIS Pro software to summarize data, perform analysis, and create maps. The tree canopy data was collected by the UVM Spatial Analysis Lab (SAL) in 2019 using LiDAR and high-resolution imagery acquired in 2019. The tree canopy data was summarized at the census block group level. Census block groups typically include 600-3,000 people (US Census Bureau). The SAL included ESRI Tapestry Data with the tree canopy data set, including market segmentation groups, LifeMode groups, and Urbanization groups. For the purposes of this project Tapestry data was not the main subject of focus but could be utilized in further research. More information on tapestry segmentation data can be found on ESRI's website.

Demographic data was sourced from the US Census Bureau 2019 American Community Surveys and NHGIS, the National Historical Geographic Information System, a database that formats census data into shape files (format used for spatial data) to use in ArcGIS Pro. The entire tree canopy data set for Jefferson County and the specific demographic data from the Census Bureau was joined into one shape file to perform spatial and statistical analyses in ArcGIS Pro.

Tree Canopy Change

The SAL mapped the tree canopy change from 2012- 2019, identifying the sections of canopy that had no change, gains, or losses. The absolute tree canopy change values are helpful to represent and identify which block groups gained and lost the most tree canopy. The scope of this research does not include an in-depth temporal analysis, but it does give an overview of the block groups with the most gains and most losses, paired with some demographic summarization.

The Disparity Index Model

The model that guided the analysis was developed in 2021 by two members of the Learn ArcGIS online community, Andrew Makowicki and Lauren Scott Griffin, who developed the model to prioritize tree planting locations for Los Angeles and to investigate shade equity. The model works at the census tract level, to identify where there are disparities in tree canopy relative to different demographic groups. The workflow was applied at the census block group level which offers some smaller-scale insights than the tract level. Any city can perform this analysis with a minimum of tree canopy data at the block group or tract level and relevant demographic data. The model further details how to perform a site suitability analysis in ArcGIS to find optimal locations for tree planting, promoting social equity and mitigating the impact of climate change. This feature would be useful for an organization with a specific quantity of trees to allocate.

Variables Analyzed

Category	Demographic group	Description	Alias name in analysis	Reason for choice
Income	Below the poverty level	Ratio of income to poverty level	pbpoverty	Analyzing block groups that have high percent below the poverty level represent communities that are low income and where we expect to see a lower percent tree canopy, given historical zoning history and positive trends between income and tree canopy.
Race	Black	Percent residents who identify as Black	pblack	Black and Hispanic people have suffered from historical discriminatory zoning laws and practices that impact neighborhood investment, land value, and median income.
	Hispanic	Percent residents who identify as Hispanic	phispanic	
Age	Children younger than 5	Percent of residents who are younger than 5	pless5	Children younger than five and adults older than 65 represent populations that are vulnerable to environmental hazards, and exposure to intense heat and poor air quality could cause asthma or other heat-related illnesses.
	People older than 65	Percent of residents who are older than 65	pover65	
Commute to Work	People who take the bus to work	Percent of people who ride the bus to work	pbustowork	People who take the bus (include wait time at the bus stop) or who walk to work presumably have more heat-exposure on hot days than people who drive in a personal vehicle to work. People who ride the bus or walk to work are also more likely to live in densely populated neighborhood due to access to public transportation or reasonable walking distance, and urban neighborhoods have higher impervious surfaces and lower tree canopy than less dense, suburban neighborhoods.
	People who walk to work	Percent of people who walk to work	pwalktowork	

Table 1. Full description of and rationale for using the demographic variables in this analysis. The column titled "Alias" indicates the variable name used in ArcGIS software.

Data Consolidation & Calculations

Demographic data from the US Census Bureau was paired in ArcGIS Pro with block group-level summaries of tree canopy data through a unique spatial identifier code that associates tabular demographic data with the spatial tree canopy data. The goal of the disparity index is to represent tree canopy and demographic distributions across the entire county. The percent demographic and percent tree canopy for each of 587 block groups was derived from the sum of the demographic populations and total tree canopy area in the entire county. Below is the format for a calculation to find percent below poverty and percent tree canopy, and an example from the data set:

Proportion calculation:

Demographics

(Total households below poverty in Block Group 1 / SUM of all households below poverty in Jefferson County) *100 = % Households below poverty in Block Group #

Tree Canopy

(Tree canopy area in Block Group 1 / SUM of all tree canopy area in Jefferson County) * 100 = % Tree canopy in Block Group #

Example calculation:

For Block Group #211110002001 (The first block group in the data set)

(321 HH's below poverty in block group #211110002001 / 106,958 total HH's below poverty in Jefferson County) * 100 = 0.3001 % HH's below poverty in block group #211110002001

(894,015.642 m^2 tree canopy/ 4,149,143,172 m^2 tree canopy in Jefferson County) * 100 = 0.02154 % tree canopy in block group #211110002001

The benefit to calculating the percent demographic at a citywide scale opposed to calculating the demographic make-up out of the sum of the block group population is that the resulting maps will represent the block groups with the most or least tree canopy disparity relative to the entire city. The citywide representation communicates inequality across the county more effectively than an individual block group representation.

Disparity Index calculation

The disparity indices for each demographic group were calculated using the calculated percentages. The equation is formatted below (input any demographic variable):

(% Demographic - % Tree Canopy 2019) = Disparity Index for Demographic

Example:

For Block Group #211110002001:

(0.3001- 0.02154) = 0.29995846

In the example of block group #211110002001, the value is positive because there is a much higher percent of households below poverty than percent of tree canopy, therefore there is a disparity in tree canopy to HH's below poverty, in that block group.

Disparity Index Values Explained

A disparity index was calculated for each of the seven demographic groups for all 587 census block groups. The disparity index is set up to compare proportions of demographic groups to proportion of tree canopy for the entire study area. The actual value represents the difference in percent tree canopy and the percent demographic group. The expected result from these calculations is that the output values fall between (-1,1), and while most values fall in that range, some values are greater than 1 or less than -1. This outcome is due to block groups that have a disproportionately high population of a demographic compared to the rest of the city, and the same goes for block groups with a disproportionately high percent tree canopy to the overall distribution of tree canopy in the city.

Below is a list of what the values in the range of (-1,1) represent. Since all the demographic groups are indexed to Percent Tree Canopy, each resulting index value can be interpreted in relation to tree canopy.

Values closer to -1 = surplus of trees

Values closer to 1 = disparity of trees

> 0 = disparity of trees

< 0 = surplus of trees

0 = perfect equity

The word disparity implies deficit or lack, so a positive index value means there is a disparity of trees (higher percent demographic than percent tree canopy per block group). Reversely, a negative index value implies a negative disparity, indicating a higher proportion of trees to proportion of a demographic group (higher percent tree canopy than demographic per block group) relative to the entire city.

While this analysis is a useful tool to compare which block groups have more inequality between demographic groups and tree canopy, there are some drawbacks to this method. Only a few demographic groups were selected out of dozens of possible demographic groups. Further, the selected groups are not mutually exclusive; there is intersectionality between groups which is not directly represented in this study. People identify with many demographic groups- for example, someone who is Hispanic, below the poverty level, and takes the bus to work -and this study is not meant to negate that fact. For the sake of this research, we are taking a close look at groups on an individual basis, but a further iteration of this project could attempt a more intersectional, multivariate demographic analysis. Lastly, the term disparity as paired with the name of the index refers to differences and inequalities in tree canopy. Disparity has a complex meaning and this study does not attempt to prove, disprove, or claim that disparity exists, it is only an observational study of tree canopy inequality and demographic distributions.

RESULTS & ANALYSIS

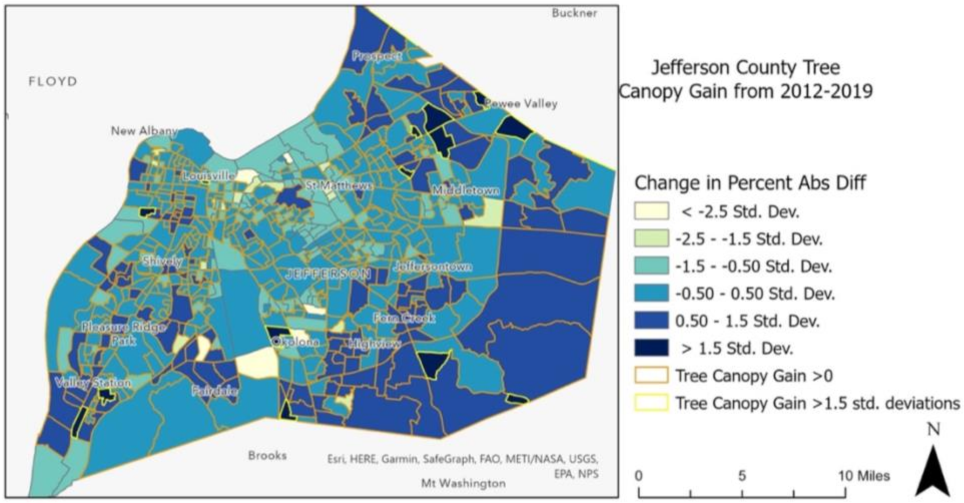
This analysis included three components, looking at tree canopy change over time, a bivariate comparison between demographic groups and tree canopy, and the main component, which is the disparity index. Each portion of analysis has associated maps that are valuable to identify block groups that have higher tree canopy disparity than others looking at a city-wide scale. Depending on the priorities of tree planting organizations or city planners in Louisville, it may be more valuable to assess the inequalities in tree canopy change over time or to take a more critical look at tree canopy disparity related to demographic groups. In all three components of analysis, we see inequality across Louisville in tree canopy gains and losses, or areas that have shade inequity, and therefore residents who will experience the negative effects of the urban heat island.

Tree Canopy Change

Absolute relative percent tree canopy change compares the block group to itself in change over time from 2012 to 2019. The highest and lowest values indicate the block groups that had the most tree canopy growth or loss in the seven-year period. There are many ways to represent the data with ArcGIS symbology, but for this map, change over time is represented in standard deviations. Standard deviation symbology holds an equal class width (0-0.5 std. dev, 0.5-1 std. dev, etc.,) but a varying frequency of observations, or block groups, per class. The benefit to using this type of symbology is that it is easier to visually identify the block groups with the most gains and losses, in standard deviations away from the mean.

Tree Canopy Growth:

Figure 3: Block groups with tree canopy growth



Louisville saw a net gain of 1% tree canopy from 2012-2019, with 407/ 587 block groups (outlined in orange on figure 3) experiencing a positive net gain. The 18 block groups that experienced the most growth (outlined in yellow on figure 3) had a percent change that is greater than 1.5 standard deviations from the average tree canopy change. The average percent tree canopy change for those block groups is 5.5% growth in tree canopy, with a range in values from 3.6% to 13.2%. While the block groups with the most growth are not spatially clustered in one area in the county, the majority are located far away from the downtown, in the suburbs and rural areas. This map signifies that the urban forest has seen the most growth in suburban neighborhoods as well semi-urban neighborhoods outside of the downtown area.

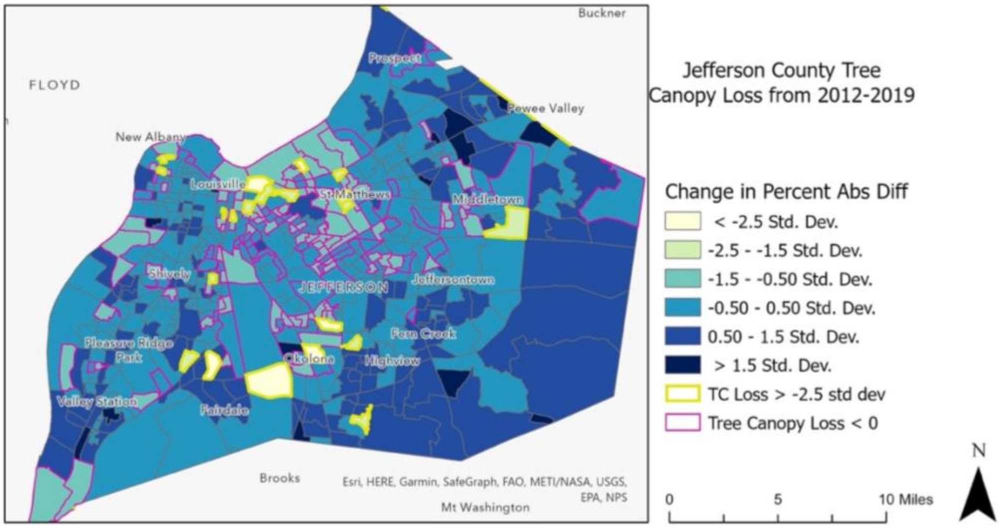


Figure 4. Block groups with tree canopy loss

Tree Canopy Loss: The map to the left symbolizes tree canopy change and 179/ 587 block groups experienced a net loss in tree canopy. Block groups outlined in pink represent all the block groups that have lost tree canopy, and block groups in outlined yellow represent the block groups with the most loss, those that had a percent change greater than -2.5 standard deviations away from the average change. The average tree canopy change for those 26 block groups is -4.6%, with a range in values from -2.5% to -14.8%. There is a cluster of block groups in the downtown area, as well as several in the mid-South end of Jefferson County that experienced the most losses. This map indicates that the downtown Louisville area is experiencing some rapid loss in tree canopy in addition to a few neighborhoods through the south and east regions of Louisville.

Demographics and TC Change

Below is a chart of summary statistics for the block groups with the most gains and losses in tree canopy. Summarized values are percentages of the block group population, not a proportion of the city population. Though each end group of the most gains and most losses are not perfectly equal, nor are the same in standard deviations away from the mean, the choice to look at each end of the dataset was from the way the data was distributed. The group of the most gains (18 block groups) and the most losses (26 block groups) are roughly equal, but also represent the tail ends of the entire tree canopy change data set, which is helpful for centering our attention on the biggest changes.

Variables	Block Groups with most canopy **gains** (18), >1.5 standard deviations from mean tree canopy change	Block Groups with most canopy **losses** (26), >-2.5 standard deviations from mean tree canopy change
Average Tree Canopy	38.3%	36.4%
Average Relative % Change	5.5%	-4.6%
Median HH Income	$60,710	$46,773
Average % below poverty	11%	15.2%
Average % White	71.41%	74.6%
Average % Black	19.5%	17.9%
Average % Hispanic	5.1%	8%
Average % younger than 5	5.3%	4.3%
Average % older than 65	18.8%	16.2%
Average % bus to work	2.2%	3.9%
Average % walk to work	2.1%	1.8%

Table 2. Demographic Comparison for block groups that experienced the most gains (18) and most losses (26). The demographics values in this comparison are reflective of the demographic makeup of the block groups alone, not a proportion of the city's population.

Tree Canopy: The results from the tree canopy change analysis offer interesting insight to the summarized demographic makeup of the block groups with highest gains and losses. The average tree canopy of the block groups with the most growth is almost parallel to the average tree canopy throughout Louisville. To be expected, the average tree canopy for the block groups with the most losses is slightly lower, at 36.4%. These figures are surprising, because it indicates that while many block groups lost 4.6% canopy on average, those block groups were not necessarily lacking tree cover in 2012. This pattern could indicate that there are forces in the public or private land ownership sphere that are possibly cutting down trees for old age or economic development. Considering there are 179 block groups that lost some degree of tree cover, there is cause to consider uneven gains throughout the city. Neighborhoods that have lost tree canopy should not be neglected for future planting initiatives, even though the city saw a net gain from 2012-2019.

Meeting the goal of 45% tree canopy by 2050, a universal gain in canopy will help the city to meet the goal sooner than uneven gains and losses. All things considered, about 70% of block groups in Louisville saw growth in tree canopy, which is promising.

Income & Poverty: Looking at the summaries for median household income and poverty level, the average median income for block groups that have lost tree canopy is $13,937 less than block groups gaining canopy, which we might expect given the current trends between increasing income and tree canopy. Similarly, the poverty level is 4.2% higher for the group with the most losses than the group with the most gains, further indicating that there might be a correlation between neighborhoods that are gaining in tree canopy and gaining in wealth. We cannot extrapolate from this study, but future research might study whether there is a trend between increasing tree cover and increasing wealth. A closer investigation of demographic averages given the tree canopy gains and losses would be an interesting subject for temporal analyses.

Race and ethnicity: The race and ethnicity demographic variables offer some interesting insight where tree canopy is losing or growing, and the results are somewhat contradictory to what we might predict. The average percent White demographic is higher for the block groups with the most losses, and the average percent Black demographic is higher in the block groups with the most gains. Though race and ethnicity are comprised of many different demographic groups, it is interesting to note that Louisville may be a city where the trend of low tree canopy in predominantly Black neighborhoods is changing. Many neighborhoods in West Louisville, an area that has more people of color compared to Louisville as a whole, have experienced growth in tree canopy thanks to the work of tree planting organization, Trees Louisville, to reduce inequity in canopy cover. As for the difference in the White demographic we see comparing gains to losses, it is possible that the downtown area is predominantly white, and that the rural areas that lost tree canopy are also predominantly white. The comparison of percent Hispanic indicates that organizations might prioritize tree planting efforts in predominantly Hispanic communities.

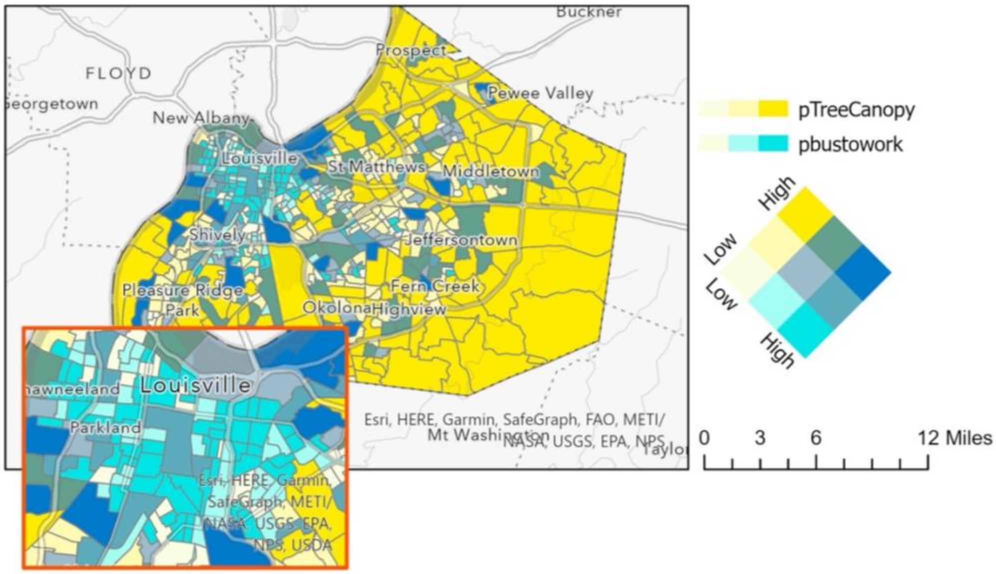
Age: The comparison of age (younger than 5 and older than 65) shows what we might expect that there are lower percentages of those two groups in the block groups that had the most loss in tree canopy.

Commute to work: The bus to work demographic shows a greater percentage in block groups that experienced the most losses. This result is concerning for people who will be more exposed to extreme heat on the hottest days than people driving in a car. Looking at the major losses in the downtown area, these statistics likely represent that change in tree canopy. The difference in percent walk to work for the most gains and losses is slim, but overall, people who walk or bus to work should be considered when planning tree planting in high density areas.

Bivariate Comparison of Demographics and Tree Canopy

Bivariate maps are useful to visualize a spatial distribution of two variable groups at the census block group level. Comparing the distribution of percent tree canopy to the distribution of percent demographic group offers a preliminary view to notice inequalities in demographic trends and clusters comparing the two variables. The bivariate quadrant symbology uses colors to indicate the relative comparison of tree canopy, with the color scale on a low-- high range. The values for percent demographic and percent tree canopy are the same from the original calculations in the methods section. The more intense yellow and aqua blue colors represent high values, the leftmost light yellow/blue square represents the lowest values of percent tree canopy and percent bus to work. The values for tree canopy and bus to work in the two leftmost diagonal columns (yellow and aqua) indicate how the values relate to the rest of the quadrant.

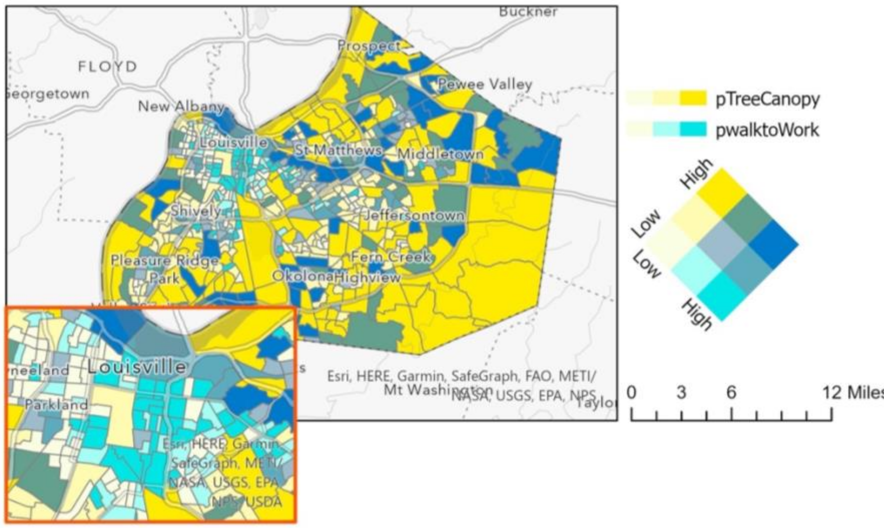
Figure 5. Bivariate comparison of tree canopy to people who ride the bus to work



The block groups in bright aqua indicate a high percent of people who ride the bus to work and a low tree canopy. Conversely, the bright yellow block groups represent high tree canopy and low percent of people who bus to work. The block groups in dark blue symbolize both a high tree canopy and a high percent of people who bus to work. Finally, the block groups in gray represent relative equality between percent tree canopy and percent people who ride the bus to work. While the whole quadrant tells a story, the aqua blue block groups would be of the most interest to organizations and planners to reduce shade inequality.

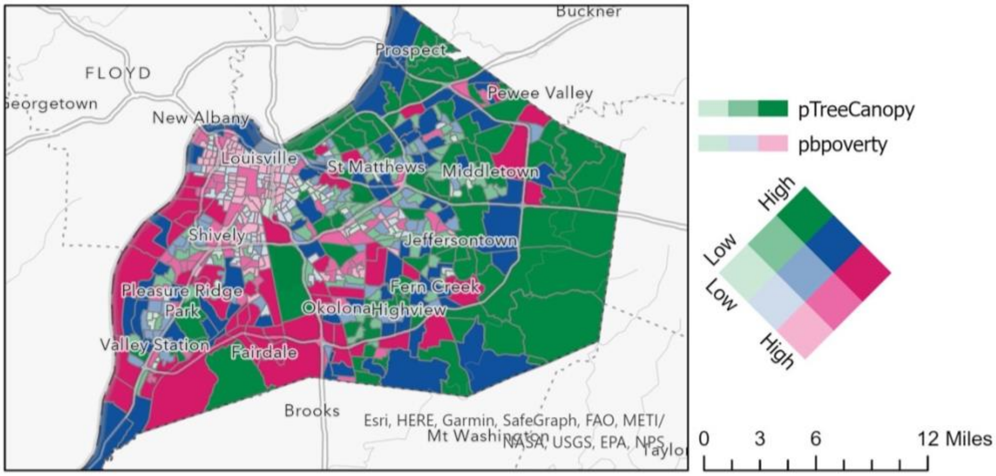
Most of bright aqua blue block groups are centered in the downtown area, which makes sense given there are a higher proportion of bus routes in the downtown area, as well as people who live close enough to their job to take the bus to work. While there is no generalization to be made on the identity of people who ride the bus to work (race, income, gender, age, etc.), we can assume that people who ride the bus to work may be more vulnerable to heat exposure while walking to the bus stop and waiting for the bus, whereas people who drive vehicles directly from their home to workplace are protected from extreme heat exposure for longer. People who take the bus to work may do so because they either cannot afford a car or choose to ride the bus instead of driving a car, thus income or preference may predict who rides the bus to work.

Figure 6. Bivariate comparison of tree canopy to people who walk to work



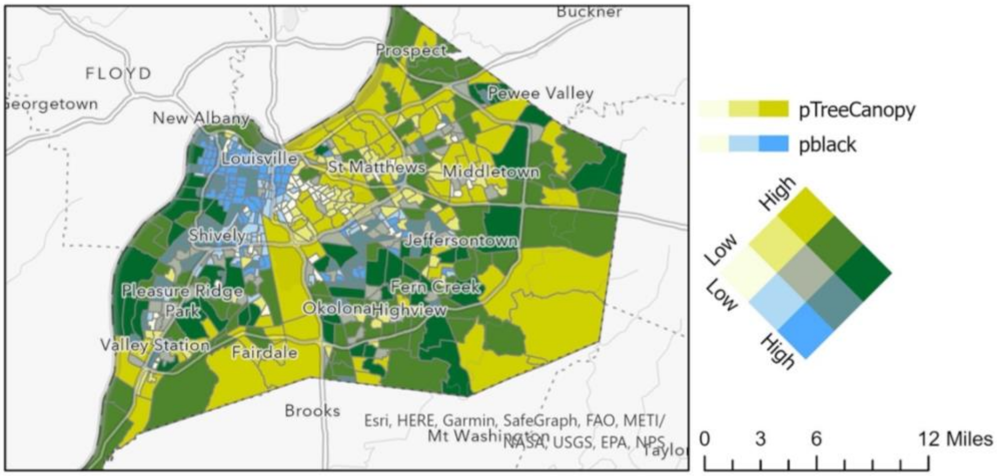
The color quadrant represents the pattern of values for this bivariate map of percent tree canopy and percent of people who walk to work. Similarly, people who walk to work have the most exposure to extreme heat on hot days, thus the great importance of planting more trees in metro neighborhoods, downtown areas, and in the right of way. Without speculating on the demographics of people who walk to work, income level, proximity to workplace, or preference may play an important role in determining whether someone walks to work or drives. Regardless of demographic identity, people who walk to work or ride the bus to work experience greater exposure to heat on hot days and deserve to be equally protected with shade tree canopy.

Figure 7. Bivariate comparison of tree canopy people who are below the poverty level



Looking at demographic groups that have been historically marginalized and therefore are of interest in achieving shade equity, bivariate maps for tree canopy and the population below the poverty level as well as the Black population both show a cluster of light pink (poverty) or blue (Black) groups with relative disparity compared to the entire city. Again, these areas might be of the most interest to reduce shade inequality, as they have the highest values of percent of people living below the poverty level and percent tree canopy. For the map below, the highest percent of people who identify as Black and percent tree canopy. These maps can give us some initial insight where there might be cause for further research, and can help to determine where to take a closer look to investigate disparity. The distribution of these two maps appear to be similar from a meta-view, with a cluster of block groups in West Louisville, neighborhoods west of the downtown area.

Figure 8. Bivariate comparison of tree canopy to people who identify as Black



The full collection of bivariate maps can be found in Appendix A.

Shade Inequality Maps

The maps representing disparity index values represent a spatial distribution of tree canopy inequality. Each map stands alone, only showing the disparities in tree canopy for each demographic group. The original shade equity model states that output index values should range from -1 to 1 with 0 indicating perfect equality between proportions of tree canopy and demographic population. However, the data from this analysis have values that exceed the range on both positive and negative ends. The more negative values indicate neighborhoods where there are disproportionately high percentages tree canopy to population and the most positive index values represent the inverse.

The maps can be symbolized with the raw data, in ArcGIS symbology known as natural breaks, or they can be symbolized in standard deviations, which highlights the block groups with the least and most tree canopy disparity. While any positive disparity value represents some level of relative tree canopy inequality in a block group, and that inequality should not be overlooked, identifying the actual neighborhoods with the most tree canopy inequalities can be one entryway to prioritize tree planting efforts in the city, given the assumption that organizations have a limited quantity of trees to allocate. Considering that the demographics in this study were selected on the premise that they are historically marginalized groups or potentially vulnerable to extreme heat, the neighborhoods symbolized in dark pink on the maps may likely be experiencing shade inequity, compared to other neighborhoods in the city.

As stated earlier in this paper, each disparity map is representative of the population distribution of all the demographic groups, but we can look at the maps to notice relative distributions, spread and clusters of inequalities.

Looking at the entire city increases the possibilities of outliers and errors in the data. The South/ Southeast border of Louisville which is consistently dark shades of green or blue on all the maps in this research are mostly parks, natural reserves, protect forests, and golf courses. For the sake of these maps and analyses, those data points were not omitted because they represent a significant proportion of tree canopy that is valued by Louisville residents. Some of those large, dark green areas include Jefferson Memorial Forest, Parklands of Floyds Fork, Fairmount Falls Parks, Fern Creek Sportsman's Club, and others.

Figure 9. Disparity index distribution of tree canopy and people who identify as Black

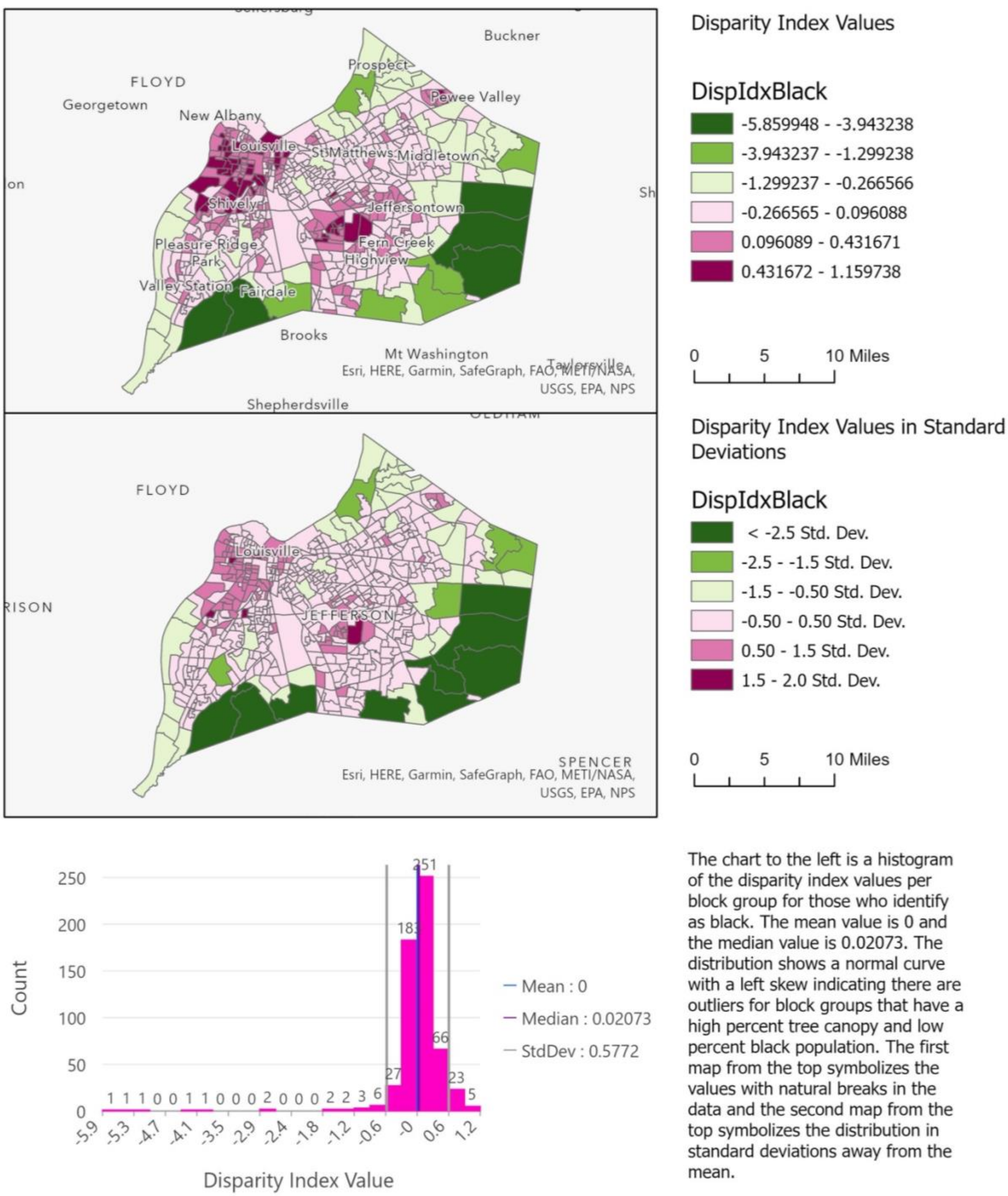
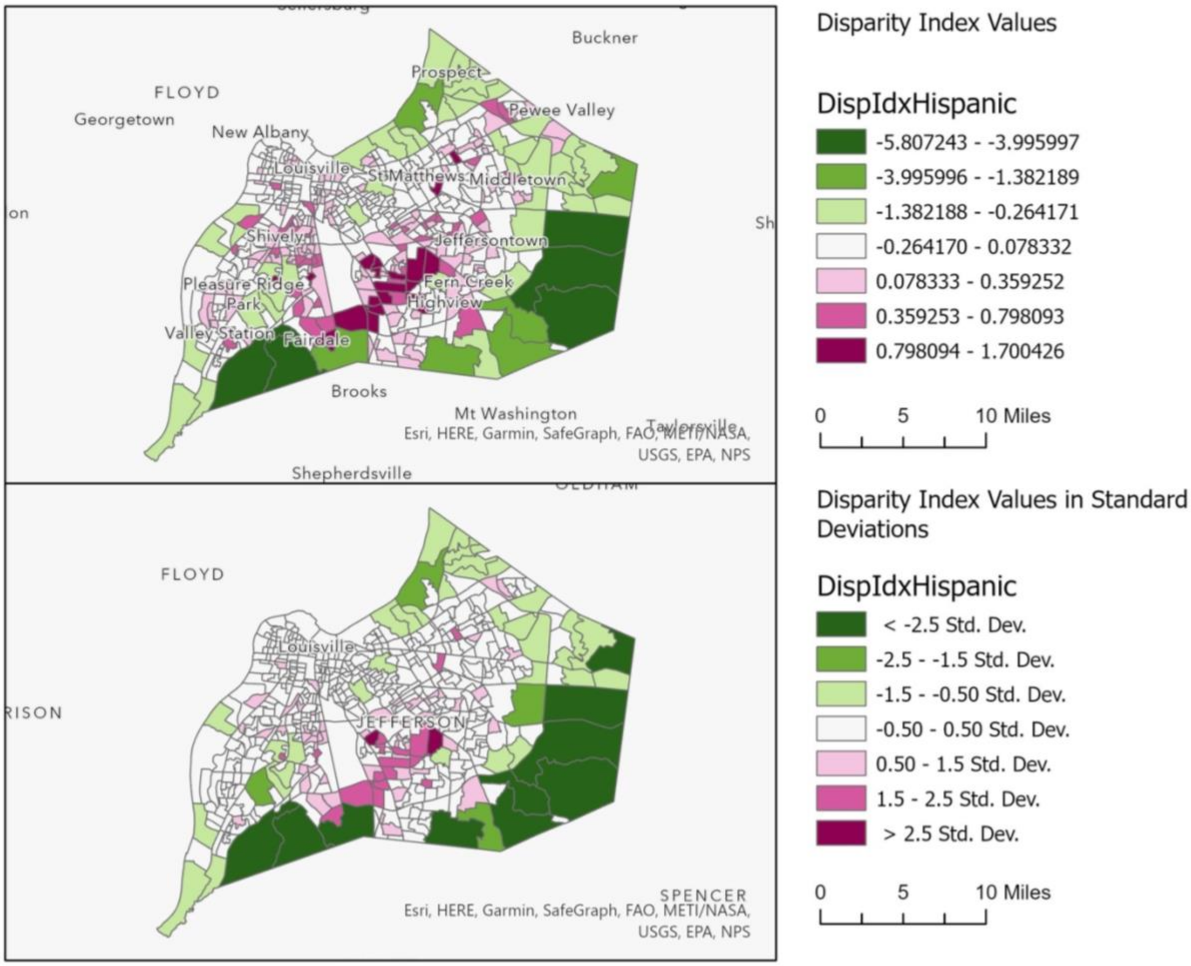
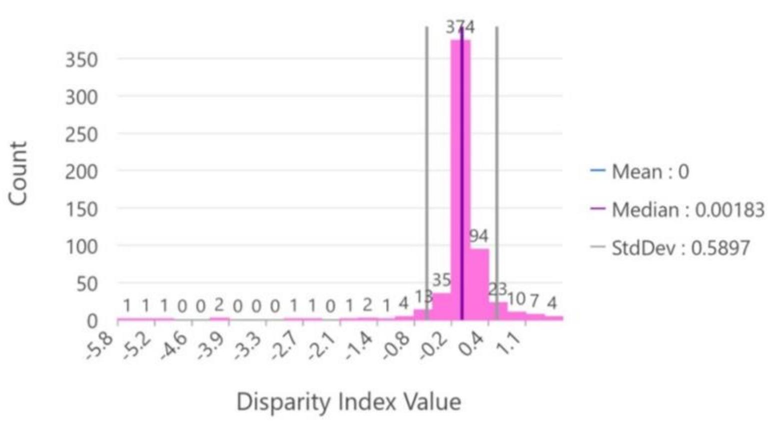


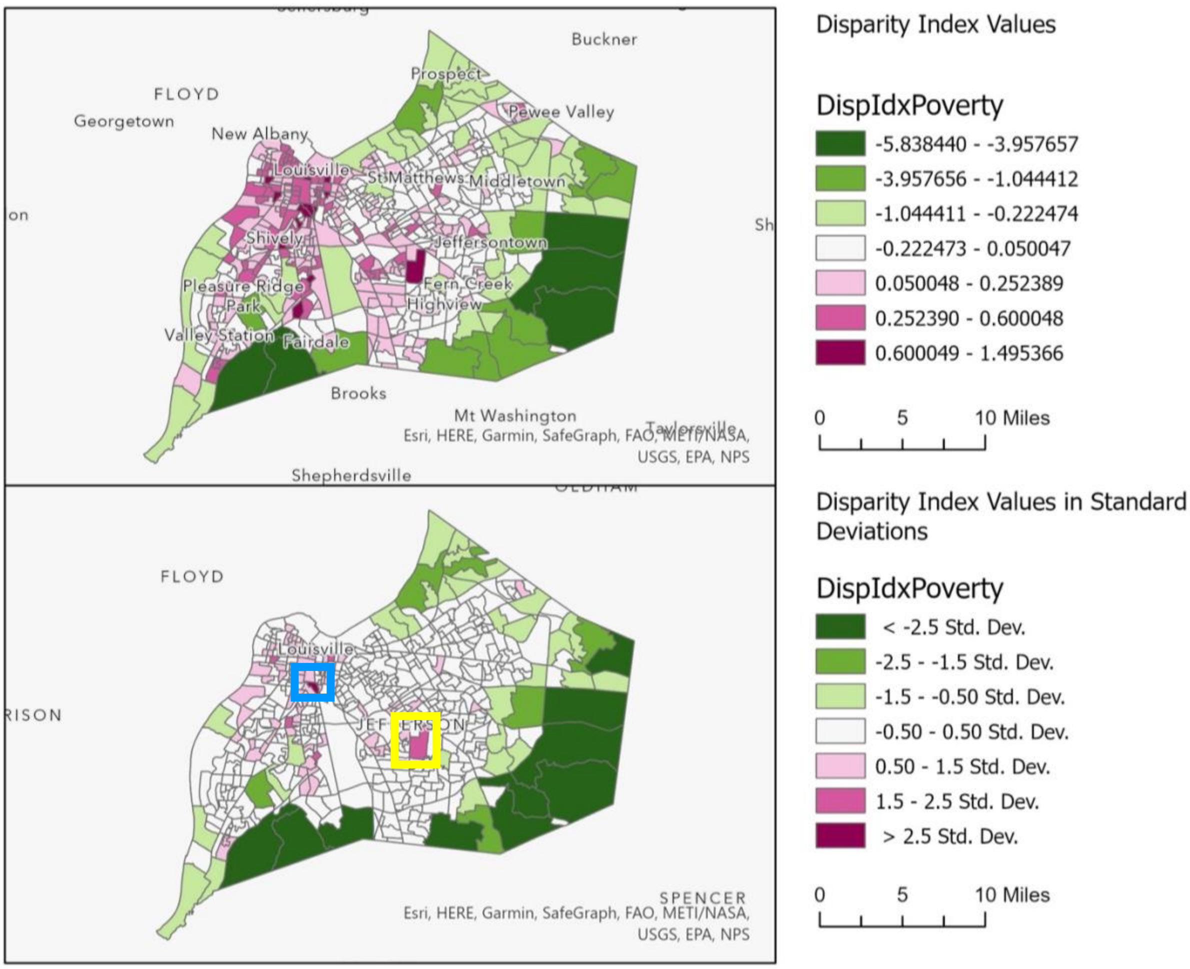
Figure 10. Disparity index distribution for tree canopy and people who identify as Hispanic





The chart to the left is histogram of the disparity index values for each block group for people who identify as Hispanic. The mean value is 0 with a small, positive median value of 0.0018. The chart shows a negative right skew indicating there are some outlying block groups with a disproportionately large proportion of tree canopy to the Hispanic population. The first map from the top symbolizes the disparity values with natural breaks in the data, and the second map from the top represents the values in standard deviations, indicating the block groups with the most tree canopy inequality in dark pink.

Figure 11. Disparity index distribution between tree canopy and people who live under the poverty level. The block group outlined in blue is in the Taylor Berry Neighborhood, and the block group outlined in yellow is in the Newburg neighborhood.



The three maps above show unique relationships between demographics and tree canopy, and each show clusters of where there is inequality between percent tree canopy and percent Black, percent Hispanic, and the percent of people living below the poverty level. The maps of age (younger than 5 and above 65) showed a more uniform distribution around Louisville, and the maps for the commute to work were relatively similar. The full collection of disparity index maps can be found in Appendix B. I include the three maps above because the findings present interesting possible reasons. For each map (Black, Hispanic, and below poverty), the darkest pink block groups have high proportions of the respective demographic group and low proportions of tree canopy, compared to the existing demographic populations and tree canopy cover of the whole city.

Two Neighborhoods with a High Disparity Index

Many existing studies have shown that wealthier neighborhoods have higher tree canopy, and since people living below the poverty level are often marginalized in society for a host of reasons, neighborhoods with high poverty rates and low tree canopy perpetuate existing inequalities in access to green space. In a brief analysis of the disparity indices for population below poverty, two different block groups have very high disparity indices. The block group outlined in blue, which has the highest tree canopy disparity on the map (value of 1.49), is in the Taylor Berry neighborhood, just west of the University of Louisville. There is 16% tree canopy, but 66% of residents live below the poverty level, with a median household income of $23,450. 30% of residents are Black, 5% are Hispanic, and 12% walk to work, which is high compared to the Louisville average.

Another block group, outlined in yellow, is in Newburg, a suburban neighborhood with only 9% tree canopy and a disparity index of 1.39. Of all the residents in that block group, 50% are under the poverty level and the median household income is $28,184. 53% of residents are Black, 13% are Hispanic, and there is a high percentage of children younger than 5, at 11%. The statistics provided are only data included in the scope of this research, but qualitative data would contribute much more to understand both neighborhoods. However, a brief demographic summary of those two neighborhoods reveals a few insights, one, that residents of those neighborhoods may have less access to shade on hot days, making them more vulnerable to negative effects of extreme heat. There are many other ecosystem services that are lost from a low tree canopy. Another insight is based on the literature about green gentrification, that tree planting in low-income neighborhoods can be complicated and possibly lead to gentrification or the relocation of residents. The complex dynamics of shaping an equitable landscape require careful considerations from planners, organizations, and stakeholders to ensure needs are met. Tree canopy inequality is a clear issue to visualize, but more in-depth qualitative research, historical land use patterns, and engaged planning are all important components to combine perspectives in the ongoing work towards equity.

CONCLUSION

Cities continue to get hotter and become more vulnerable to extreme climate events. More impervious surfaces and high population density leads to less green space, which renders the urban landscape less absorbent of heat waves and poses environmental hazards to urban residents. Louisville is planning to foster healthy and resilient communities, emphasizing equity as a key pillar in climate solutions. Though it is so important to understand the complex problems at play in urban landscape, the work intends to contribute to the body of work on solutions. Organizations such as Trees Louisville and Louisville Grows accomplished great strides to regrow the urban forest after the 2015 assessment reported a declining trend in canopy. Their efforts, along with urban planners and researchers, contributed to reversing the trend, and are beacon of hope to the urban ecosystem.

Working in an environmental justice lens, this research investigated tree canopy inequality and disparity among specific demographic groups. The field of Environmental Justice recognizes that not all groups of people have equal access to environmental amenities, and thus those groups that have been marginalized or are vulnerable to environmental harms should be prioritized as cities build resilience through green infrastructure. Access to green space has proven to be inequitable in urban areas, and research on green gentrification and regreening urban landscapes illuminates the systems that create access barriers to green space. Since green infrastructure can raise property and neighborhood values, tree planting and re-greening efforts should proceed with the awareness of potential repercussions.

I hope this research will contribute to the growing body of tree canopy research and urban environmental justice literature, supporting the work of organizations, planners, and policy makers. This work uses quantitative methods to identify potential tree canopy disparities, while recognizing the importance of pairing quantitative approaches with qualitative research to include different perspectives on and approaches to equity. To achieve shade equity, we must consider the wants and needs of stakeholders who will be impacted by tree implementation through a participatory planning and engagement process.

Limits to the model:

The disparity index model was only one approach to identifying inequity, and the analysis proved itself to be useful and transferable between cities, requiring the knowledge of ArcGIS software and access to local data. The findings that I have presented suggest that within the distribution of several demographic groups, there is tree canopy inequality throughout the city, which could exist as a result of race, income, age, or as prior research suggests, historical land zoning policies. While the results from this study do not prove disparity, the maps offer a citywide view of the most recent urban forest data coupled with demographic distributions.

One limitation to the method of a single variate disparity index is that intersectionality is not fully addressed. There are many possibilities for future research, including spatial analyses to overlay multiple combinations of demographic groups for a quantitative identification of the neighborhoods with shade inequity. With intersectional environmental justice, we must understand that urban social-ecological systems have complex dynamics and histories, and people have complex identities, thus a single variate demographic analysis fails to include the nuanced realities of the real-world. There are many opportunities for future academic studies, including qualitative research or more quantitative research to test for the statistical significance of sociodemographic groups as predictors of tree canopy in Louisville.

Further questions:

The method and overall research spurred more questions to answer, such as, what is equity? What is disparity? How far can quantitative spatial data work to prove inequity, without testimonials and case studies from local residents and stakeholders? What are the important factors to achieve equity, and at what scale? Through reading the literature on the complex systems that drive tree canopy inequity, as well as doing analysis with spatial data, it is clear that equity can be approached and studied in many different ways. The literature suggests that due to the complex dynamic between green infrastructure implementation, the systems of economic land valuation, and gentrification, shade equity may or may not be achieved in certain communities by planting trees. Other aspects and values of community development might be more important to a community at a cultural or personal scale. and those values should be accounted for. Additionally, communities should always be included and treated as stakeholders in the planning and planting process to determine community values and goals, as well as be informed of the possible economic impacts of trees on the land value.

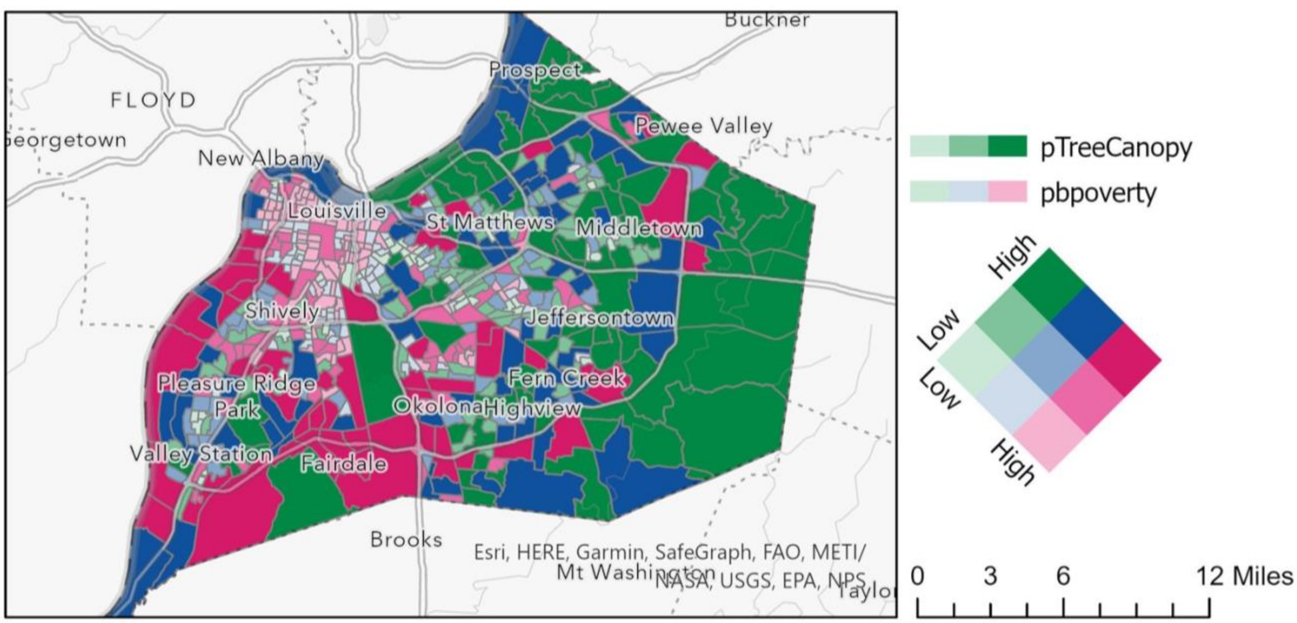
Ultimately, intervening with the cycle of green gentrification that would stop perpetuating inequitable access to green space, calls for deeper, systemic change that is rooted in most capitalist economic systems. Moving away from an economic valuation of ecosystem services would be one piece of change to make, along with community or municipality authority over what specific components impact land value. Keeping equity in mind aids in the process of deconstructing the systems that perpetuate inequity.

In an equitable society, sociodemographic identity should not impact access to essential ecosystem services, health benefits, and protection from existing tree canopy and green space-benefits that we can no longer take for granted in the era of climate change. Although adding green space and pervious surfaces is a critical design and planning process now and, in the future, trees do not have universal value, nor are the benefits universally understood or accepted by everyone. Continuing to identify disparities in green space and to foster equity through community engagement, planning, and implementation processes is essential for sustainable and livable cities.

Appendices

Appendix A: Bivariate maps of tree canopy and demographics

Demographic category: **Income**
Figure 1. Bivariate comparison of tree canopy and people below the poverty level



Demographic category: **Race & Ethnicity**

Figure 2. Bivariate comparison of tree canopy and people who identify as Black

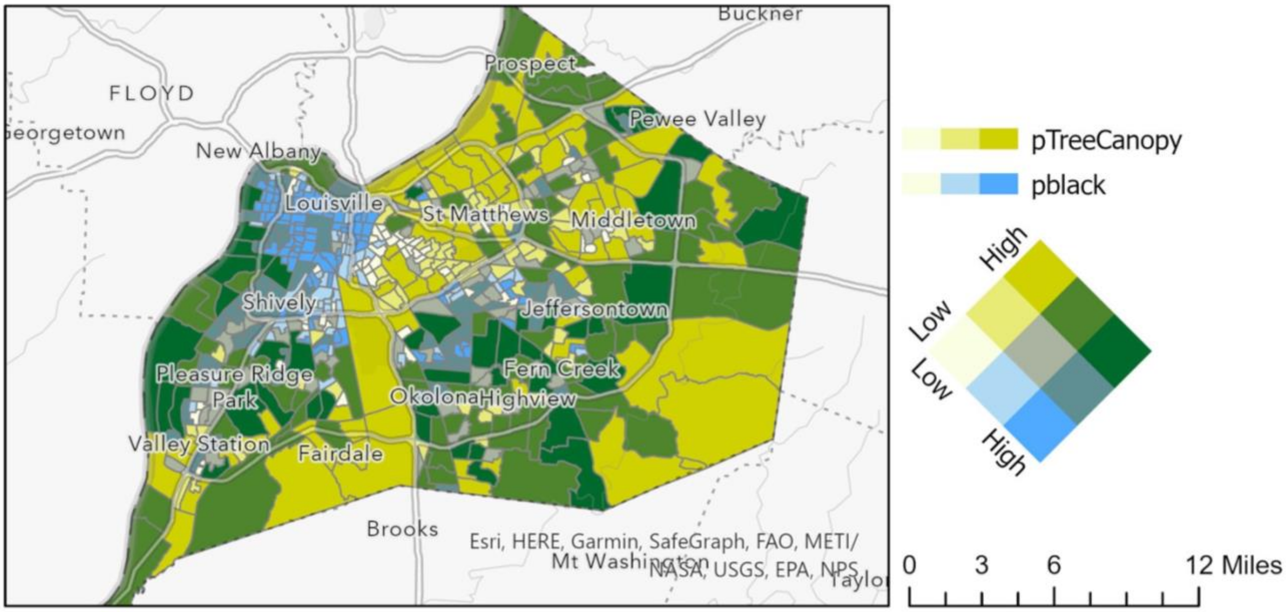
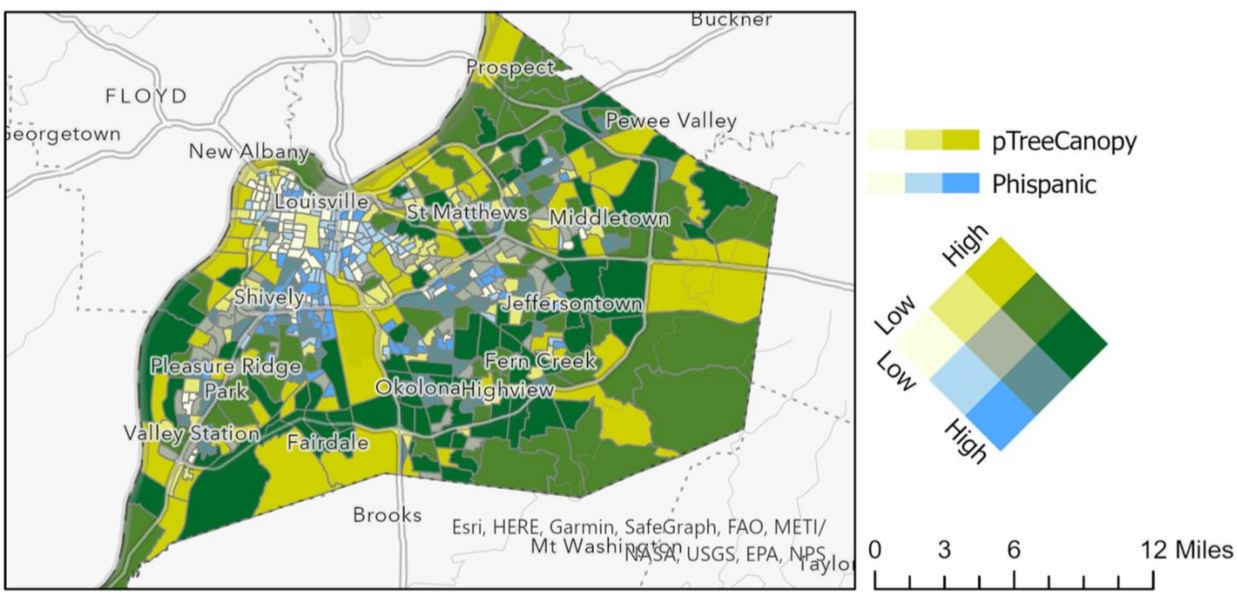


Figure 3. Bivariate comparison of tree canopy and people who identify as Hispanic



Demographic category: **Age**

Figure 4. Bivariate comparison of tree canopy and people who are younger than 5

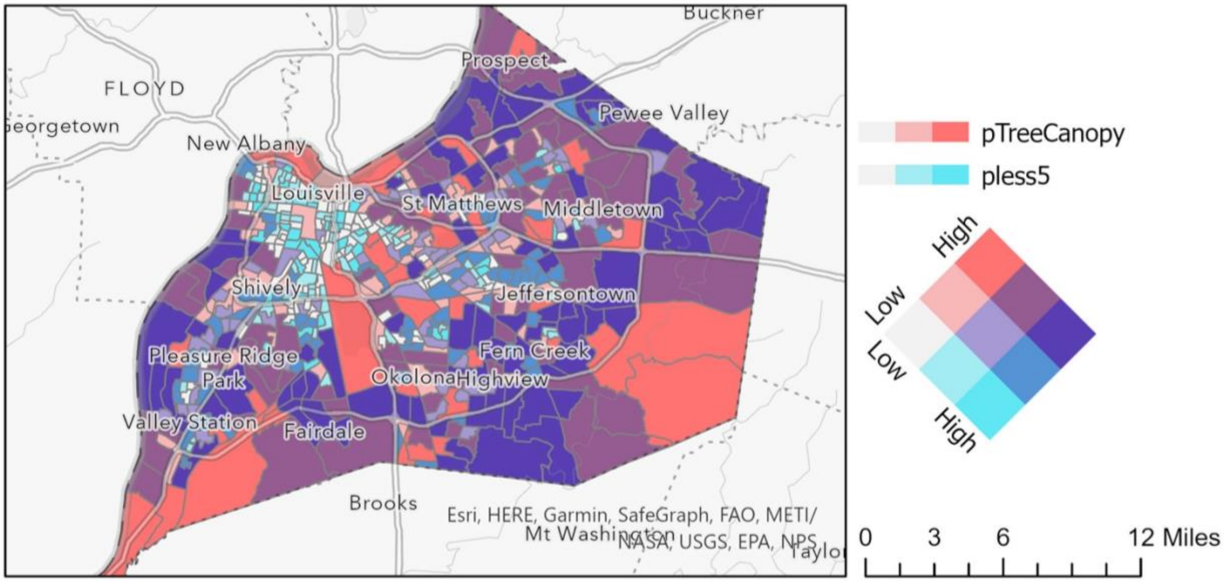
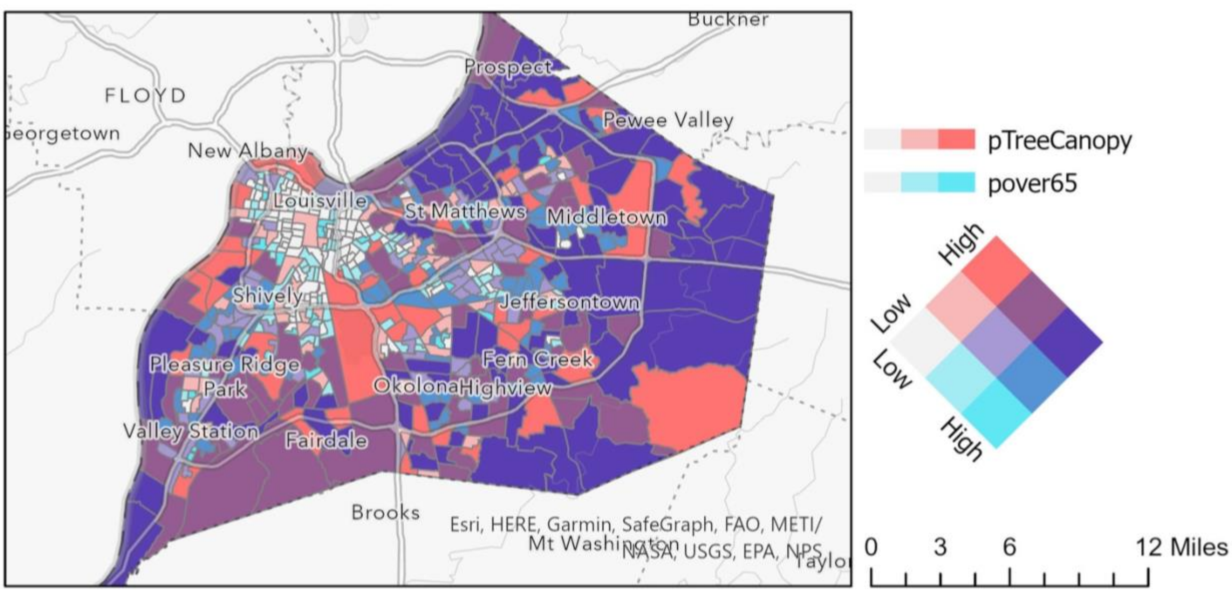


Figure 5. Bivariate comparison of tree canopy and people who are older than 65



Demographic category: **commute to work**

Figure 6. Bivariate comparison of tree canopy and people ride the bus to work

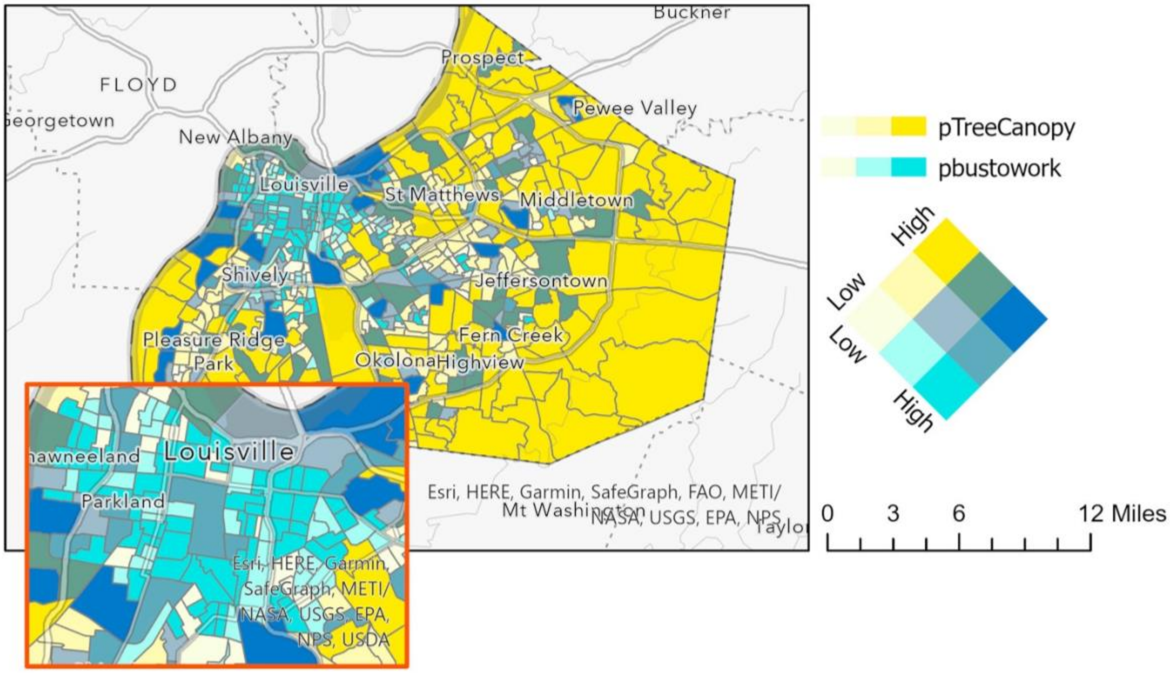
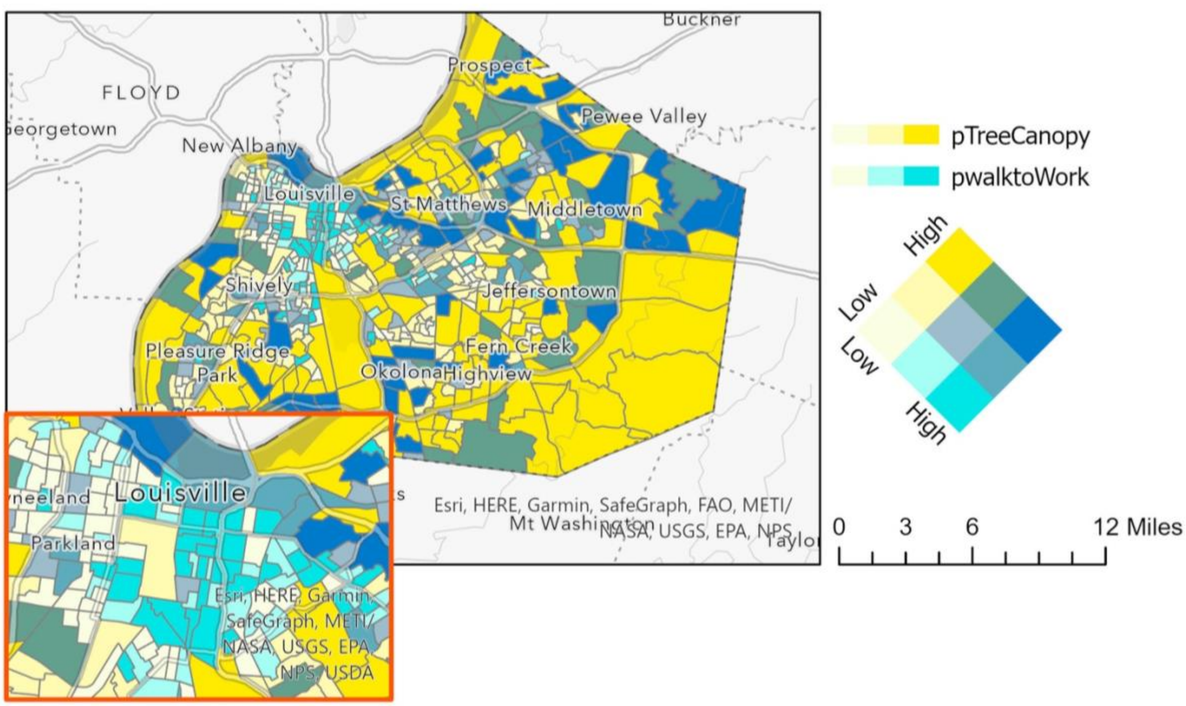


Figure 7. Bivariate comparison of tree canopy and people who walk to work



Appendix B:
Figure 1. Disparity Index Map for Tree Canopy and People Below Poverty

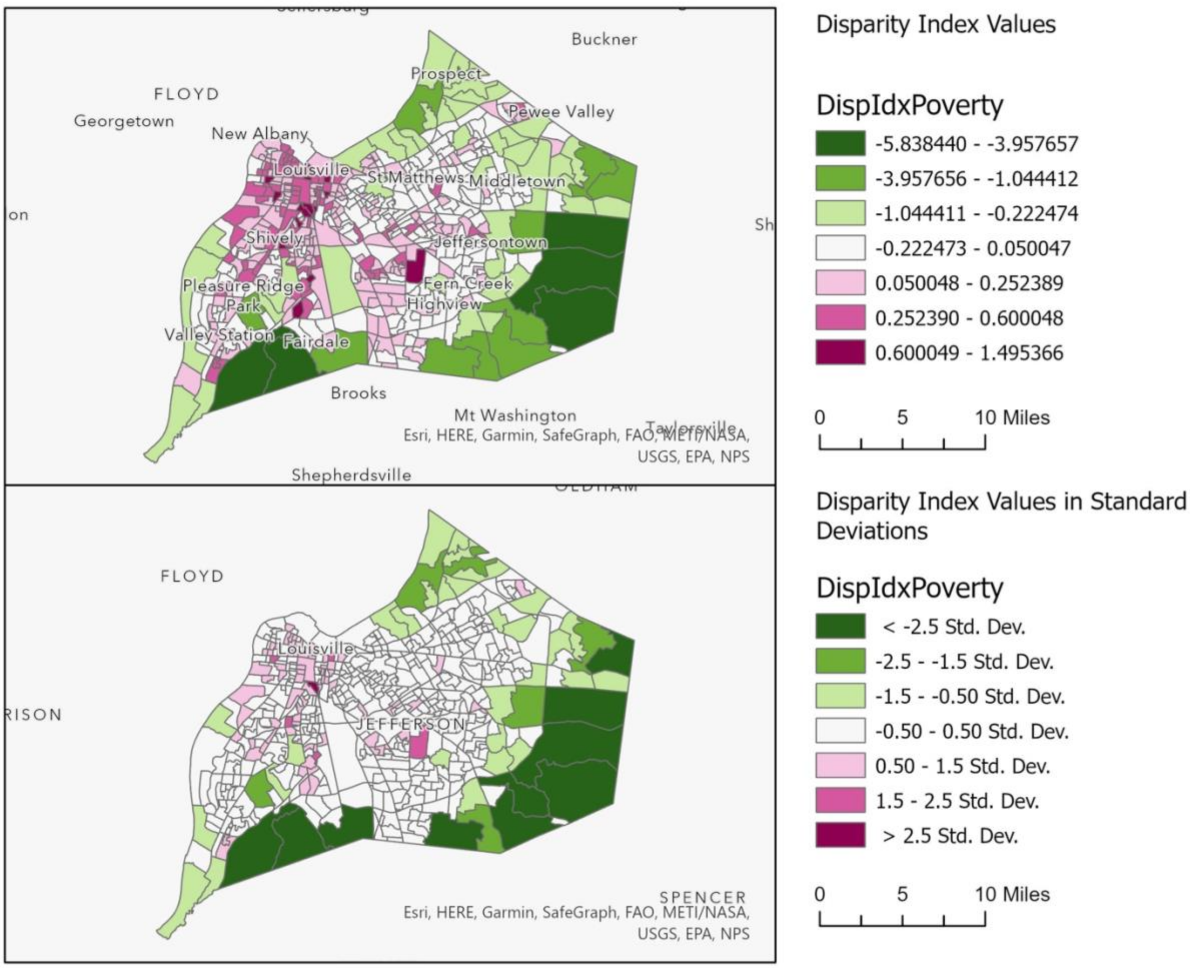
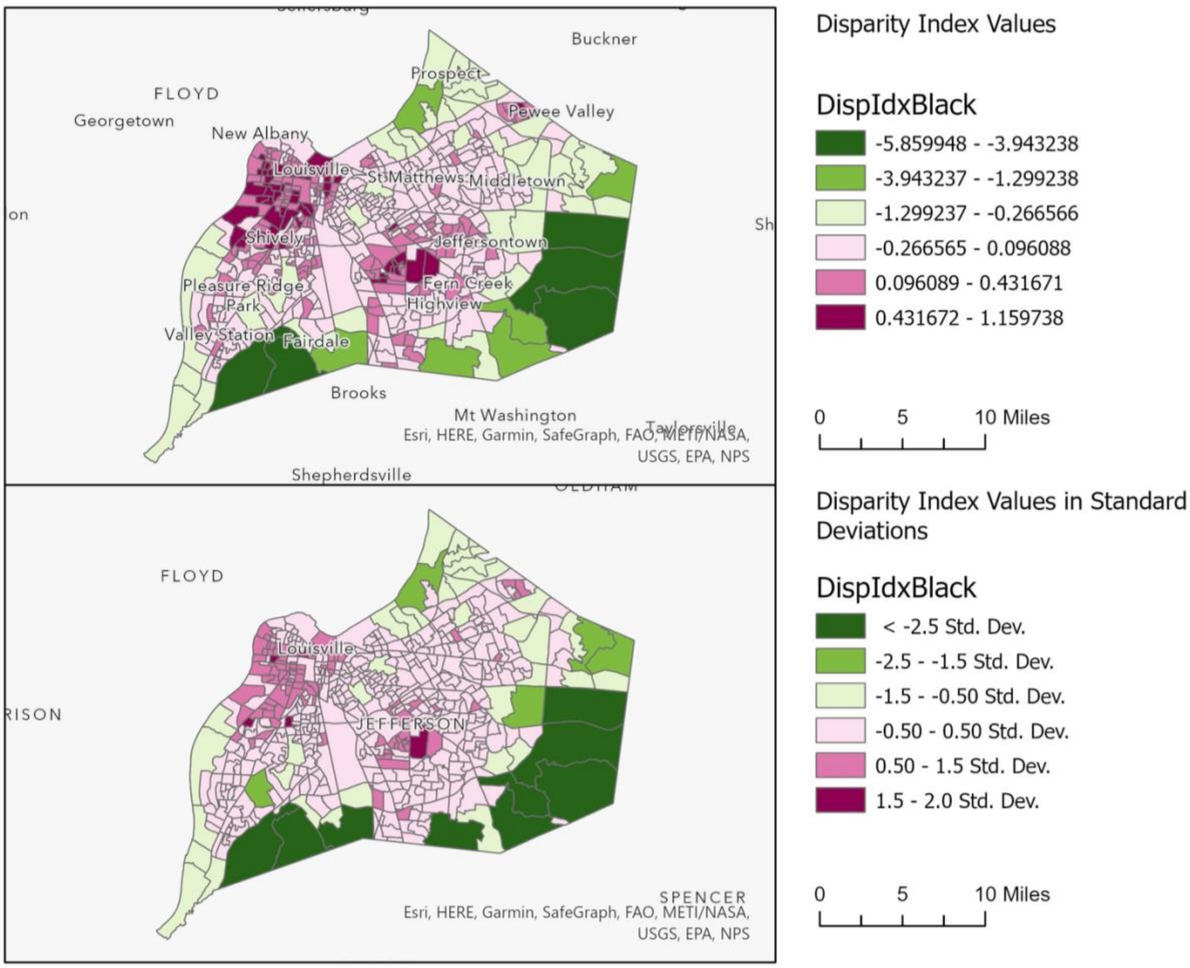
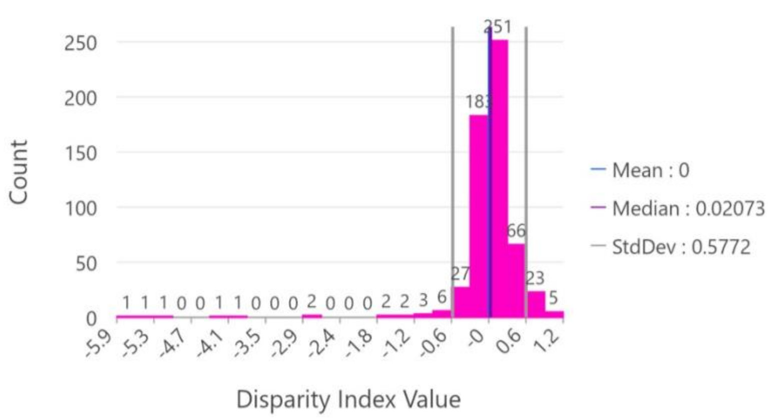


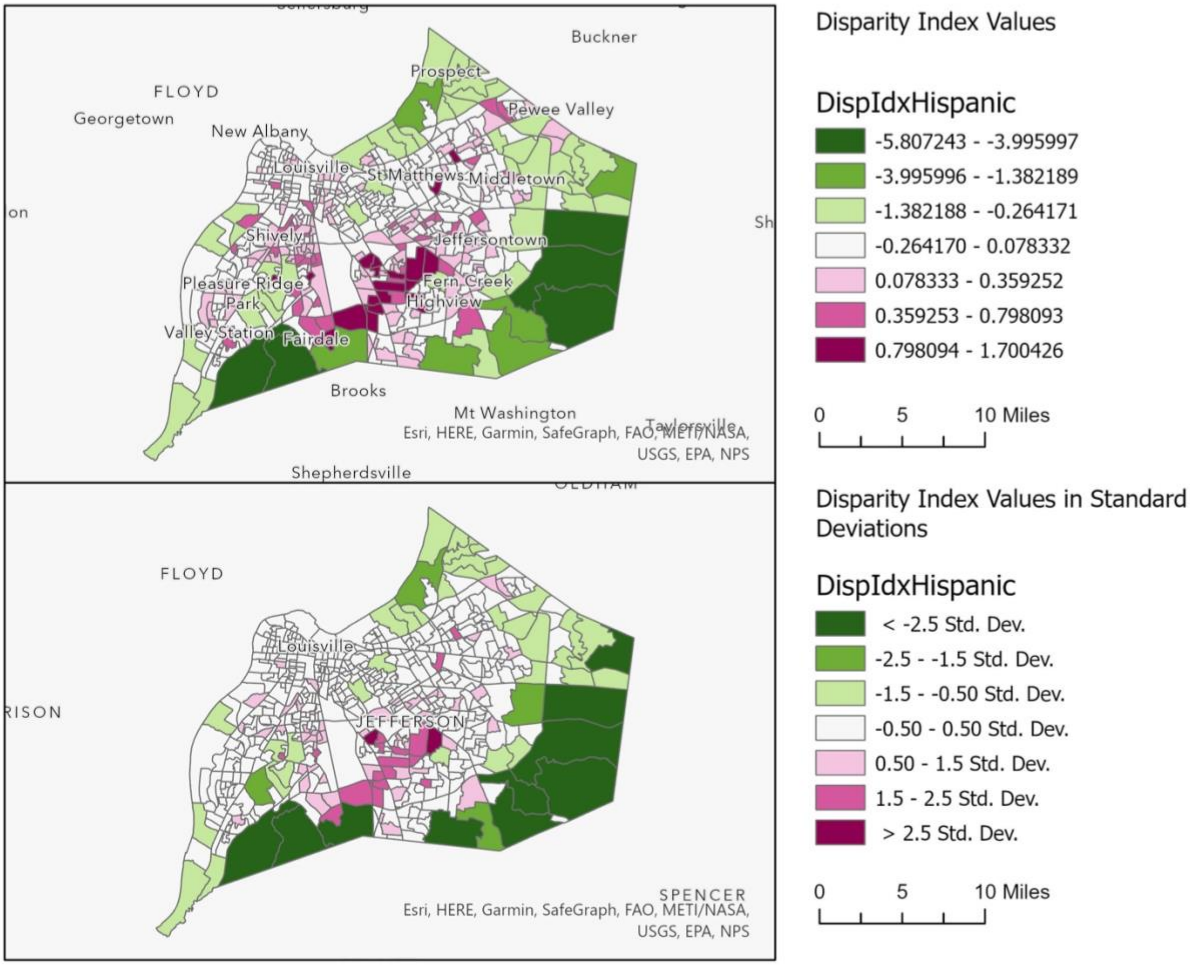
Figure 2. Disparity Index Map for Tree Canopy and People Who Identify as Black

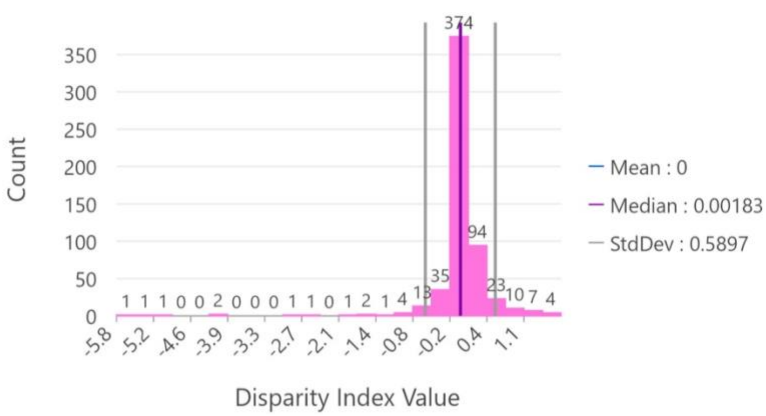




The chart to the left is a histogram of the disparity index values per block group for those who identify as black. The mean value is 0 and the median value is 0.02073. The distribution shows a normal curve with a left skew indicating there are outliers for block groups that have a high percent tree canopy and low percent black population. The first map from the top symbolizes the values with natural breaks in the data and the second map from the top symbolizes the distribution in standard deviations away from the mean.

Figure 3. Disparity Index Map for Tree Canopy and People Who Identify as Hispanic





The chart to the left is histogram of the disparity index values for each block group for people who identify as Hispanic. The mean value is 0 with a small, positive median value of 0.0018. The chart shows a negative right skew indicating there are some outlying block groups with a disproportionately large proportion of tree canopy to the Hispanic population. The first map from the top symbolizes the disparity values with natural breaks in the data, and the second map from the top represents the values in standard deviations, indicating the block groups with the most tree canopy inequality in dark pink.

Figure 4. Disparity Index Map for Tree Canopy and Children Younger than 5

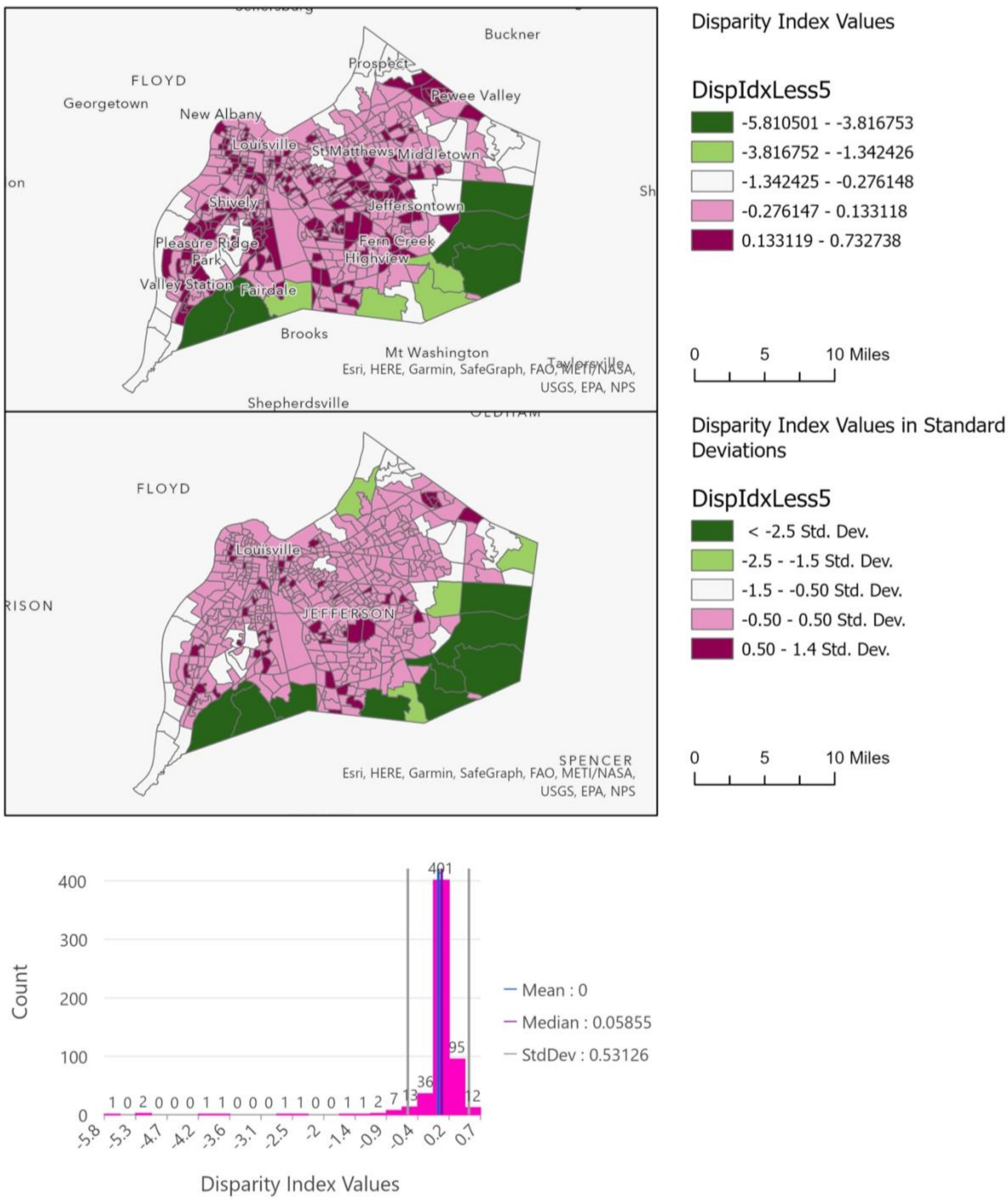


Figure 4. Disparity Index Map for Tree Canopy and People Older than 65

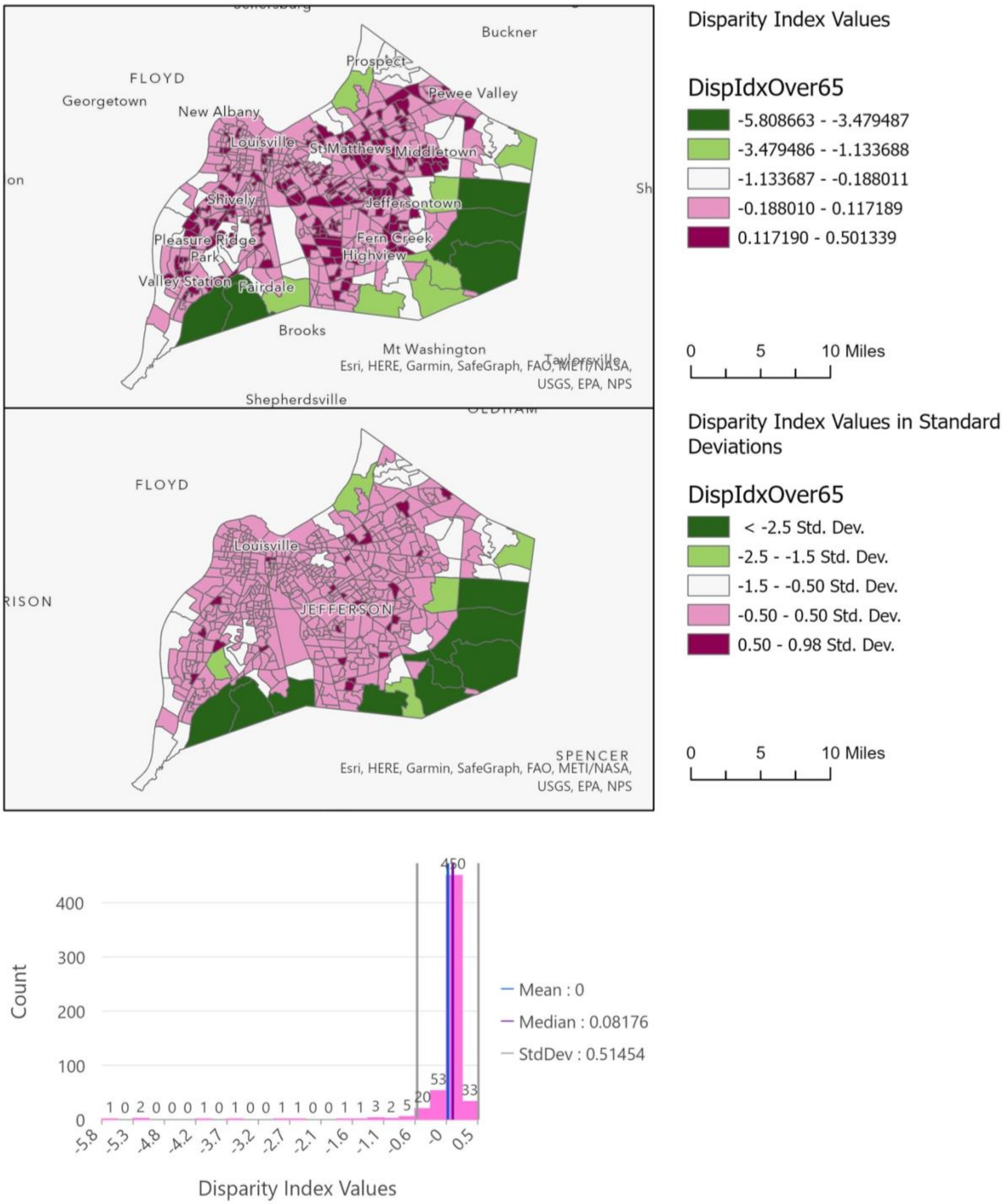


Figure 6. Disparity Index Map for Tree Canopy and People Who Ride the Bus to Work

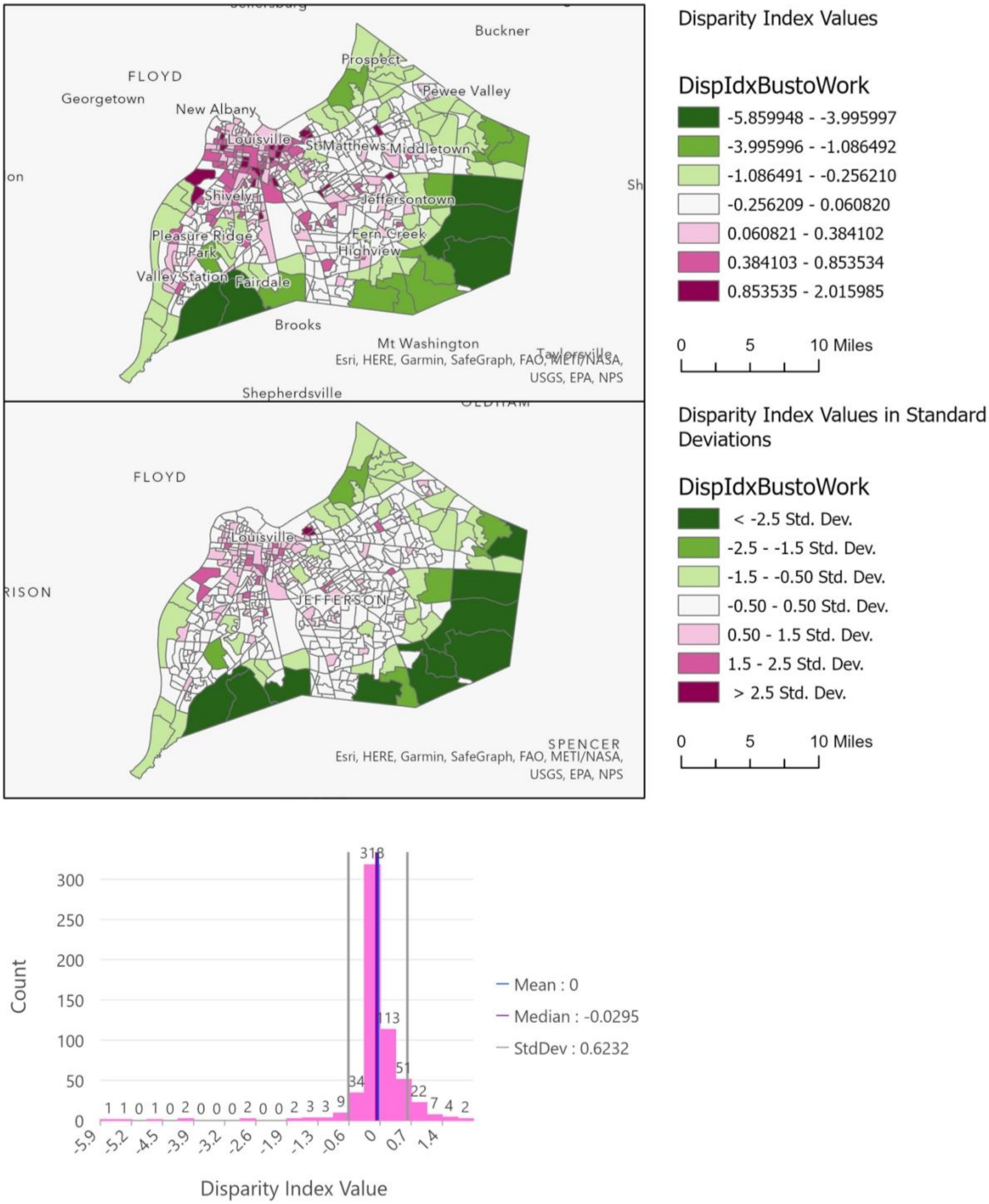
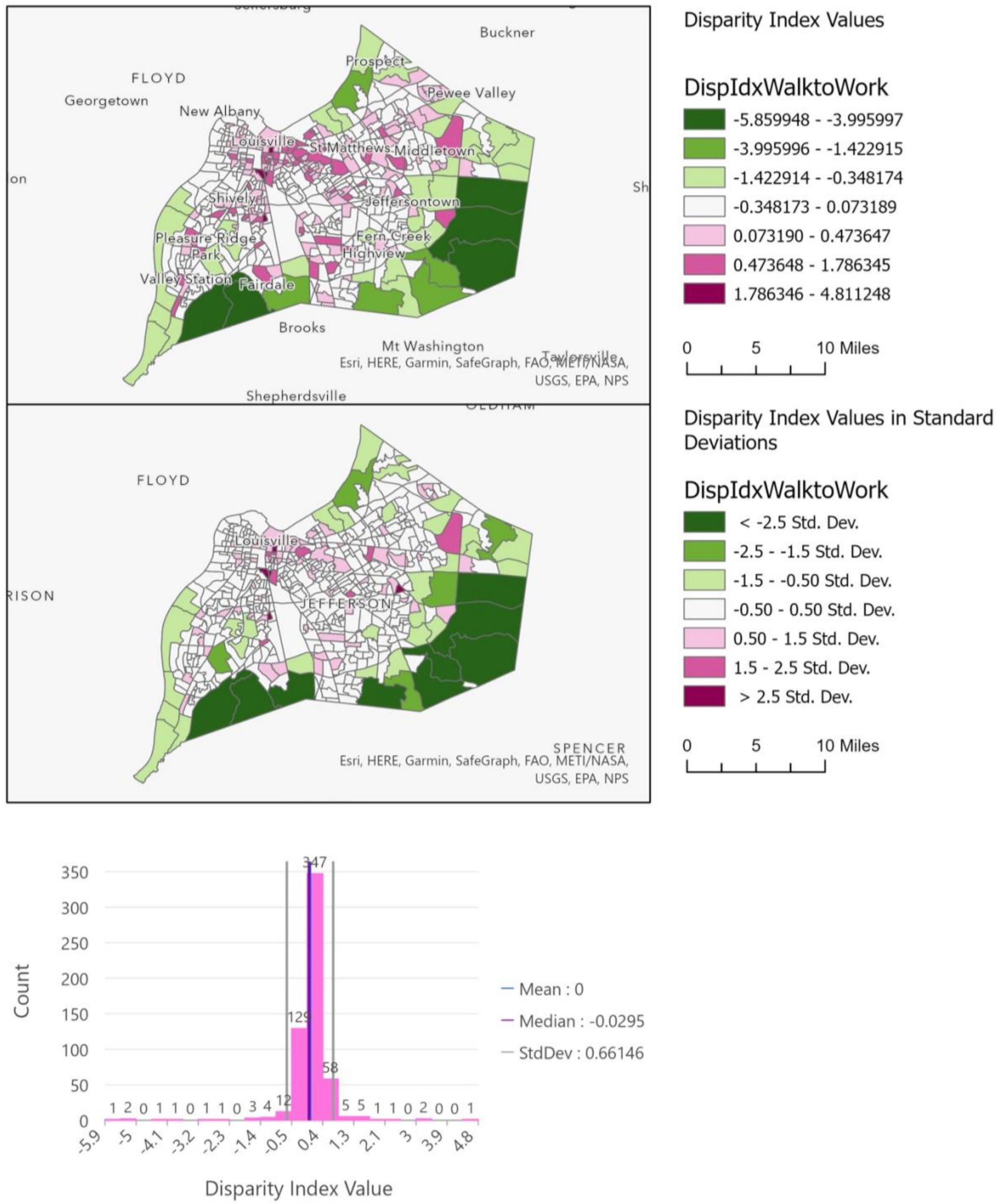


Figure 7. Disparity Index Map for Tree Canopy and People Who Walk to Work



[Appendix C](#): ArcGIS Story Map: Shade Equity in Louisville

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