City of La Crosse
Green Space Expansion

Prepared for

The City of La Crosse

By

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Table of Contents

Foreword

Students at the La Follette School of Public Affairs at the University of Wisconsin–Madison prepared this report for the City of La Crosse, Wisconsin, as part of the La Follette School's capstone program. The capstone program's goal is to provide graduate students the opportunity to improve their policy analysis skills while providing valuable service to governments and community organizations across Wisconsin and around the world.

The La Follette School offers a two-year graduate program leading to a Master in Public Affairs (MPA) or a Master in International Public Affairs (MIPA) degree. Students study policy analysis and public management, and they spend the first year and a half of the program taking courses in which they develop the expertise needed to analyze public policies, including skills in statistics, economics, and policy analysis. The authors of this report are all in the final semester of their degree program and are enrolled in the Workshop in Public Affairs course. Although acquiring a set of policy analysis skills is important, there is no substitute for doing policy analysis as a means of experiential learning. The Workshop in Public Affairs gives graduate students that capstone opportunity as they produce a report for a real-world client about a question of importance to the organization.

I thank Natalie Chin with Wisconsin SeaGrant for helping to coordinate the team's efforts with La Crosse. La Crosse staff and leadership have been generous with their time and support of the students' work: I am grateful. Taken together, the students have contributed hundreds of hours to the project and in the process sharpened their analytical skills, learned about urban heat mitigation, and developed a new appreciation of La Crosse, jewel of the Coulee Region. The La Follette School hopes that the collaboration and this report prove valuable.

Forward.

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The views, opinions, and recommendations in this report represent those of the authors alone and do not reflect the findings, recommendations, or policies of the University of Wisconsin–Madison, the La Follette School, or the City of La Crosse.

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Abbreviations

DI	Dissimilarity Index
EPA	Environmental Protection Agency
NOAA	National Oceanic and Atmospheric Administration
OLS	Ordinary Least Squares
UHI	Urban Heat Islands

Executive Summary

This report studies the heat island effect in the City of La Crosse with attention to resident health, economic conditions, and environmental justice. Through a meta-analysis of current literature and interviews with experts, this report seeks to address the heat island effect and its impacts on the La Crosse community, then evaluate policy options to mitigate heat effects through the expansion of green spaces. Specifically, this report examines:

1. The definition and causes of urban heat islands;
2. The health and economic effects of heat islands on residents;
3. The racial and socioeconomic distribution of heat islands within La Crosse, with a particular focus on environmental justice and equity; and
4. The costs and consequences of intra-urban heat islands and disparities in access to green spaces.

Our analysis found that the City's tree canopy and impervious surfaces are inequitably distributed throughout the City. Through a detailed analysis of census tracts, we identified three that La Crosse should prioritize when considering our recommendations: Census Tracts 8, 10, and 11.01. We chose these tracts because of their low percentage of tree canopy, high percentage of impervious surfaces, and high average summer temperatures.

Based on our analysis, we recommend that the City:

1. Employ urban tree canopy expansion and pocket park creation to mitigate the urban heat island effect;
2. Target green space expansion to areas with vulnerable populations and areas lacking access to green space, specifically focusing on our recommended Census Tracts 8, 10, and 11.01; and
3. Study the feasibility of green roof construction on municipal buildings.

Introduction

This study investigates how the City of La Crosse can increase green space to improve the City's resilience against future extreme heat events, particularly in areas disproportionately impacted by urban heat.

The National Oceanic and Atmospheric Administration (NOAA) projects that by the year 2100 La Crosse will experience 50 additional days per year when the temperature exceeds 95 °F (paleBLUEdot 2022). The City will be, on average, 6 to 12 °F hotter than it is today. Extreme heat events have become increasingly common over the last several decades. According to the Environmental Protection Agency (EPA), the frequency, duration, and intensity of heat waves have increased substantially since 1961 (n.d.). In July 1995, a historic heat wave in Wisconsin caused 141 heat-related deaths; during that heat wave, La Crosse experienced a record-high temperature of 108 °F that has yet to be broken (National Weather Service n.d.).

Urban environments are particularly vulnerable to extreme heat due to the urban heat island (UHI) effect, a phenomenon where urban areas are significantly warmer than the surrounding area due to manufactured structures that absorb more heat than natural landscapes (EPA n.d.). In La Crosse, the UHI effect contributes to summer temperatures of up to 10 °F hotter than the surrounding area (paleBLUEdot 2022). Crucially, the brunt of the UHI effect is not evenly distributed among La Crosse residents. As we will see, low-income neighborhoods and communities of color are more likely to have infrastructure exacerbating the UHI effect.

To help address this challenge in La Crosse, we analyze three options for expanding green space in the City: tree canopy expansion, pocket parks, and green roofs. We evaluate each option's efficacy in mitigating the UHI effect, promoting equitable access to green spaces, logistical feasibility, and add-on benefits unrelated to heat, such as stormwater drainage and increased property values. Ultimately, we recommend that the City prioritize tree canopy expansion in the areas with the least green space and most impervious surfaces while also investigating the feasibility of pocket parks and green roofs. We also outline considerations for implementation as the City moves forward with a pilot project.

Background: Urban Heat Islands

Definition and causes

UHIs are a common weather phenomenon when air and surface temperatures in urban areas are warmer than in outer rural areas. Urban areas tend to have higher concentrations of buildings, concrete, and other infrastructure that absorb rather than reflect and re-emit the sun's heat. The phenomenon has been well studied over the past 200 years since researcher Luke Howard recorded temperature measurements in London that identified the effect and most of its causes (Howard 1833). Compared to rural areas, UHI can have an effect of higher daytime temperatures of 1 to 7 °F and higher nighttime temperatures of 2 to 5 °F (EPA 2023).

Urban areas experience heat islands more than rural areas since less vegetation and open land space dominate the landscape. Green spaces, such as tree canopy and parks, can help reduce air temperatures through evapotranspiration, which occurs when plants release water to cool the surrounding warmer air. As cities develop, there is an increase in impervious surfaces, such as parking lots and pavement, and a decrease in vegetation to cool the air. The higher prevalence of albedo materials—non-reflective and water-resistant materials, used for buildings and roofs—contributes to the UHI effect (EPA 2012). Since there is a lower density of trees in urban areas, this increases land surface and air temperatures by reducing shading and evapotranspiration that could shift temperatures (Stone et al. 2001). Residents in urban areas depend more on cooling amenities, such as air conditioners, which adversely impact cities' rising temperatures by releasing heat exhaust and particulate matter into the atmosphere (Kondo 2021).

Health and economic effects

UHIs affect the quality and comfort of life for urban residents, with more heat waves in urban areas increasing acute and chronic exposure to heat and air pollutants. Cities with increased temperatures have reported a higher frequency of heat illnesses such as heat stroke, heat exhaustion, heat syncope, and heat cramps (Kovats et al. 2008). In some cases, when temperatures exceed 103 °F, heat can lead to multiple organ dysfunction (Ibid). The redistribution of blood to the skin during heat waves increases cardiac demand requiring the heart to pump harder, thus leading to potential cardiac arrest and death (Crandall et al. 2010). UHIs can also indirectly affect urban residents by lowering life satisfaction from heat stress, sleep deprivation, less daily travel, and more sedentary lifestyles (Arifwidodo et al. 2019). Air pollutants, which more commonly occur in UHIs, are also associated with anxiety, depression, poor cognitive development in children, dementia, and psychosis (Bakolis 2020).

Another adverse impact of UHIs is the increase in energy costs due to an increase in energy consumption from deteriorating human comfort and increased air pollution. Urban areas consume more energy than rural areas because of more energy-intensive activities such as urban transportation, cooling of buildings, and higher density of industrial activities (Gago 2013). Energy consumption is highest during the summertime, when homes and commercial buildings run cooling systems and appliances. The demand for electric air conditioning increases by 1 to 9 percent for every 2 °F increase in temperature (Santamouris 2020). This increase in demand contributes to higher energy bills for residents. Increasing air conditioning with higher temperatures also elevates the output of harmful pollutants and greenhouse gases such as nitrogen oxides, mercury, sulfur dioxide, and black carbon (EPA 2023).

Today, roughly 55 percent of the world lives in urban areas, a total projected to reach 68 percent by 2050 (United Nations 2019). This expansion is estimated to increase urban spaces, by 78 to 171 percent by 2050 (Vujovic et al. 2021). Future generations may face more environmental burdens as more people move into urban communities and as global temperatures rise. The UHI effect amplifies higher temperatures in urban environments and is the highest weather-related killer in the U.S., with around 1,500 attributed deaths annually (Hsu et al. 2021). Data on heat-related deaths indicate that most occur during heat waves, which are becoming more frequent and severe. The average length of heat wave seasons in the 1960s across 50 major U.S. cities was 25 days and has increased to approximately 70 days in the 2020s (U.S. Global Change Research Program 2021). The average number of days annually for counties exposed to at least one "dangerous day," or a heat index of 100 °F or higher, is expected to increase from 24 days in 2023 to 37 in 2053 (First Street Foundation 2022).

Environmental Justice and Equity

Racial and income inequalities within La Crosse

The distribution of exposure and intensity of UHIs creates significant inequities for various vulnerable populations. The uneven urban landscapes at the neighborhood level create intra-UHIs, which are home to more people of color and low income (EPA 2022). La Crosse currently is predominately White and non-Hispanic, with an 88.7 percent population, at one point being the fifth most White metropolitan area in the nation in 1980, when the Census Bureau recorded a 99 percent White population (Pofaul 1980). Using the Dissimilarity Index (DI), which indicates the degree to which two groups living in a region are similarly geographically distributed, from 1990 to 2010, segregation decreased by about 50 percent for each racial demographic (La Crosse 2019). Nevertheless, from the early 20th century to the implementation of the Fair Housing Act of 1968, La Crosse was characterized as a "sundown town" where mistreatment toward Black and other minority populations did not necessarily come through acts of violence but rather through "freeze-outs," when no formal policy was implemented to keep the area predominantly White (Loewen 2015). This informal policy included derogatory language in newspapers and names for parks and landmarks, refusal of service in stores, and a local Ku Klux Klan organization (Ibid).

La Crosse has inequities with homeownership with regard to race, which stems from demographic trends and historical periods as a sundown town (DeRocher 2016). In La Crosse, homeownership for White households is slightly over 50 percent, while Black household ownership remains under 5 percent (La Crosse 2019). Disparities in homeownership cause Black and other minority populations to rely more on renting. Previous research shows that those living in apartments have poorer health outcomes than their peers who live in houses, and access to open green space coincides with psychological distress (Feng et al. 2022). A study examining access to green space in 12 urban areas in the U.S. found that there is significantly less street greenery in areas with more significant proportions of residents of color but more walkability to small-to-large-sized parks in these areas (Choi et al. 2020). Another study that analyzed more than 59,000 U.S. urban census tracts between 2001 and 2011 found that neighborhoods with higher minority proportions had less greenness than White neighborhoods and even decreased in green spaces over time (Casey et al. 2017).

Costs and consequences of intra-urban heat islands

Historical patterns in urban planning show that green space is more limited in low-income and higher-minority neighborhoods (Wilson 2020). This lack of green space results in higher temperatures, as higher concentrations of pavement and buildings absorb and retain heat. Lower-income households also tend to reside in less energy-efficient homes, which creates a higher dependence on central air conditioning that contributes to air pollution and higher costs for energy usage. UHIs in previous research show that cooling costs in urban areas can increase by a median of 19 percent, and intra-urban variation costs increase from 10 to 120 percent, with the higher increases in lower-income neighborhoods (Li et al. 2019). In the U.S., 30 percent of households claim to have difficulties paying energy bills or concerns about the costs of keeping their houses cool (EPA 2022). Rising temperatures in these neighborhoods may create greater gaps and adversely affect UHIs without green space interventions.

Variation in UHI effects with intra-UHIs shows different health outcomes for neighborhood residents. One study provides evidence that the poorest neighborhoods in 72 percent of 25 cities worldwide experienced more negative health outcomes due to summer rising heat temperatures (Chakraborty et al. 2019). From a public health perspective, experts are concerned for vulnerable populations and how intra-UHI neighborhoods experience higher rates of heat stroke, dehydration, and exacerbation of existing medical conditions like cardiovascular and cerebrovascular disease, diabetes, chronic obstructive pulmonary disease, pneumonia and asthma, and increased mortality (Heaviside et al. 2017).

An important factor to consider in expanding access to urban green space and addressing environmental justice is how demographics are unequally exposed to UHIs and how sensitive they are to adverse outcomes. Between 2004 and 2018, elderly populations 65 years and older had relatively high sensitivity to UHIs, accounting for 39 percent of total heat-related deaths. However, research also shows a significant negative correlation in their exposure to UHIs, as older populations tend to live in areas with more urban green space and gardens (Hsu et al. 2021; Voelkel et al. 2018). Older populations may also be more susceptible due to being less mobile, isolated, and living on reduced incomes (Gamble et al. 2013). Smaller and younger children are also vulnerable due to their extensive time outdoors and rapid breathing rates, which increases the likelihood of asthma attacks or lung diseases during heat waves (Gamble et al. 2016). People who spend their time working outdoors are also more prone to heat exhaustion and heat stroke if work tasks involve heavy exertion (Ibid).

Ecological gentrification

Access to green spaces for vulnerable populations is a problem for many urban communities. Paradoxically, increasing urban green spaces could increase property values and displace the residents that the expanded green spaces were intended to help. Low-income communities of color often have poor access to maintained parks and other open spaces, creating an opportunity to adapt obsolete infrastructure such as brownfields and underutilized urban streets. While urban forestry and parks can create healthier neighborhoods and make them more appealing, ultimately increasing the supply of green space, this creates a higher demand for investments and willingness to move into these areas, which drives up housing prices (Wolch et al. 2014). A famous example that illustrates ecological gentrification is New York City’s High Line park, which officials considered obsolete and set for demolition in the 1980s. Opposition from activists to have the project redesigned as a greenway was successful, and the project was transformed into a walkable green space in 2009. According to the New York Economic Development Corporation, property values around the High Line between the start of construction and completion of the project increased by 103 percent, and $2 billion was invested in property development despite the Great Recession (Brisman 2012).

Another example of green space investments creating higher housing costs is the City of Chicago’s 606 Park, a 2.7-mile linear park with active transportation converted from an obsolete railway. An interesting aspect of this project is that the park connected diverse neighborhoods through connecting trailheads, which are split between the “606 East " and “606 West.” The 606 East is predominantly non-Hispanic White, with a median household income of $116,000 and a poverty rate of 4.8 percent; the 606 West is predominantly a minority neighborhood, with a median household income of around $50,000 and a poverty rate of 25.5 percent (Smith et al. 2016). From the park's groundbreaking in 2013 to its completion in 2016, average housing prices in the 606 West, East, and in Chicago writ large increased by 48.2 percent, 13.8 percent, and 23.4 percent, respectively (Ibid). Creating large-scale green projects had direct and regressive impacts on lower-income households, resulting in larger premium payments for their properties.

To prevent ecological gentrification and displacing populations a city intends to benefit, green space needs to be balanced appropriately in vulnerable neighborhoods. More specifically, studies on the “just green enough” strategy can create insight into methods to minimize gentrification by creating green projects on a smaller scale in scattered sites (Wolch et al. 2014). Additional research on this strategy found clear evidence in 10 major U.S. cities from 2008 to 2016 that new greenway parks with active transportation fostered gentrification more than other parks, and parks located downtown were more likely to create gentrification than parks in the outskirts (Rigolon et al. 2020). Strategies for green space intervention require “projects that are explicitly shaped by community concerns, needs, and desires, rather than either conventional urban design formulae or ecological restoration approaches” (Wolch et al. 2014).

La Crosse and Heat Islands

La Crosse and its 23.8 square miles are located alongside the Mississippi River to the west and hilly bluffs to the east (U.S. Census 2020). La Crosse sits in the Driftless Region, which represents 24,000 square miles along the Mississippi River in mostly Southeastern Wisconsin, where land formed from the most recent Ice Age around 10,000 years ago (Melchior 2019). The area gets its name from the absence of glacial drift, where much of the uneven and hilly topography lacks silt, gravel, and rock deposits that glaciers would have left behind had the drifts passed through. La Crosse is sometimes considered the “Coulee Region,” from the French term “coulée,” which describes landforms with high ridges and low valleys (Hoefer 1985).

La Crosse is also the region’s urban hub, making the area vulnerable to UHI effects. From 1980 to 2018, the City’s average annual temperatures have increased by 1.62 °F and are predicted to increase to 6 to 12 °F by 2100 (Climate Explorer 2023). Future modeling predicts that this will require the usage of air conditioners to increase by 178 percent and days with temperatures above 95 °F to increase by 50 annually (Ibid). According to the City’s most recent Climate Action Plan, La Crosse is 1.8 °F warmer than surrounding municipalities, and the average tree canopy coverage per census tract is 30 percent (Climate Action Plan 2022). The necessity for intervention among residents with UHI Effect is shown in the latest Climate Action Survey, where 92 percent of city residents were either moderately, very, or extremely concerned about climate change (Ibid).

Since 2000, the City has increased in population by only 0.66 percent, or 352 people, which may be attributed to recent urban sprawl, as surrounding municipalities such as Holmen and Onalaska increased 86.45 percent and 29.9 percent respectively (Wisconsin Department of Administration 2023). The White population of La Crosse in 2022 will be 89.6 percent, compared to Wisconsin’s 86.6 percent, which could make La Crosse more vulnerable to access to green space for minority populations as previous studies suggest (U.S. Census 2023). The city already leads as an example for environmental-friendly mitigation, as previously passed local legislation has the City transitioning to carbon neutrality and 100 percent renewable energy by 2050 (La Crosse 2018).

Heat Island Mitigation

The published research literature regarding causes of UHI and effects has increased exponentially over the past three decades. Approximately 30 UHI studies were conducted yearly in the 1990s, which has risen to over 300 per year by 2015 (Huang and Lu 2017). Of these UHI studies, studies on UHI mitigation strategies are gaining popularity and receiving more scientific attention (Huang and Lu 2017). Within the literature, mitigation strategies usually fall into one of two categories: increasing urban albedo through roofing and paving strategies and increasing evapotranspiration through the reduction of impervious surfaces and increases of urban vegetation (Sailor 2006). The research found that urban vegetation and high-albedo surfaces can reduce the energy consumption of buildings they surround and that, if expanded city-wide, can offset or reverse UHI effects in that city (Akbari, Pomerantz, and Taha 2001). Meteorological simulations suggest that urban albedo and vegetation increases can drop a city's air temperature between 3.6 and 7.2 ºF, depending on the extreme increases and other contextual factors (Taha 1997). While these findings are widely accepted and cited as foundational UHI mitigation literature and subsequent studies analyze more nuanced mitigation strategies in various climate and city contexts.

Increasing evapotranspiration

A meta-analysis of UHI studies found that increasing evapotranspiration in cities through added urban vegetation and agriculture can reduce urban temperatures by 0.43 to 7.2 ºF (Qiu et al. 2013). The meta-analysis identified tree canopy, grass, shrubs, bushes plots, green roofs, and water bodies as the primary forms of increasing evapotranspiration. Trees and green roofs were the strategies that had the most positive impacts, with trees being widely more effective than other types of urban vegetation, such as grass, flowers, shrubs, and bushes (Qiu et al. 2013). More vegetation means more water evaporates into the air when sunlight reaches the plants. This evaporation leads to the cooling of the surrounding ambient heat (EPA n.d.). Furthermore, urban forestry that replaces impervious surfaces results in less water runoff, as rainfall can make it into groundwater reservoirs and supply vegetation with more water that can be evaporated, which further cools the surrounding air (Gill et al. 2007). The following strategies have been identified as the primary tools to increase evapotranspiration, and large swaths of literature analyze each strategy's impacts on UHI mitigation.

Urban vegetation

Planting trees in urban centers has repeatedly been shown to decrease the UHI effect in cities. Planting trees in cities not only has the potential to decrease surrounding air temperatures by up to 7.2 ºF, but it can decrease the surface temperatures of buildings and pavement by 19.8 to 45 ºF and, as a result, decrease annual energy and AC usage by 30 percent (Hashem Akbari et al. 1997). The EPA lists five primary benefits beyond evapotranspiration that trees and urban vegetation bring to cities: 1) a reduction in energy and AC use through the shade provided towards buildings; 2) an improvement in air quality and lower greenhouse gas emissions through storing and sequestering carbon dioxide; 3) the enhancement of stormwater management and water quality by absorbing and filtering rainwater; 4) a reduction of pavement maintenance through an increase in shade, slowing pavement deterioration; and 5) an improvement in the quality of life through increases in aesthetic value, wildlife habitats, and noise reduction (EPA 2022).

Trees also mitigate UHI effects, but many contextual factors condition the heat mitigation effects of trees. Tree species, planting locations, planting density, and tree maintenance all factor into the overall impact of urban tree planting on UHI mitigation. A lack of tree maintenance and the outright removal of urban trees can severely impact UHI effects. Studies have found that poor maintenance of trees can decrease the likelihood that they reach maturity and maximize tree canopy, leading to greater maintenance costs down the road and a reduction of energy savings of nearby buildings (Vogt, Hauer, and Fischer 2015). A simulation study that modeled temperatures and urban green space in Manchester, England, found that a 10 percent reduction of green space coverage correlated with 12.6 or 14.76 ºF temperature increases in a city by 2080; however, simulations aren't always the most reliable. (Gill et al. 2007). The location of tree planting also has considerable impacts. A modeling study done in Hong Kong expanded on previous literature about the downwind cooling effects of urban trees. The strategic placement of trees on city streets that are wind corridors, or streets that often experience high wind, increases the downwind spread of cool temperatures (Tan, Lau, and Ng 2016).

The location of urban trees can determine the surface temperature below the canopy and the average temperature surrounding the trees. A meta-analysis found that the evapotranspiration of trees planted on grass plots is ten times higher than trees planted in carved-out pavement sections (Rahman et al. 2020). The study also found that a tree's impact on surface temperature reduction is greater on asphalt—with a 10.8 ºF decrease—than on grass, which results in a 5.4 ºF decrease. Parks can also host trees, and literature surrounding the effectiveness of parks found that their cooling effects varied depending on park shape, size, species of vegetation, and tree canopy size (Feyisa, Dons, and Meilby 2014). Studies found that an increase in tree canopy and density in parks directly decreased temperatures (Feyisa, Dons, and Meilby 2014). Furthermore, the shade effect of trees in parks is much more impactful on UHI effects than that of other shade-providing infrastructure (Shashua-Bar, Pearlmutter, and Erell 2009).

The size and shape of urban forestry and vegetation plots directly impact the cooling effects they provide. Studies have found that more spatially distributed and elongated parks had greater cooling distances than compact circular parks (Feyisa, Dons, and Meilby 2014). However, studies have also shown that the majority of cooling effects resulting from parks are localized and felt the most within the park and that if there are buildings, roads, or impervious surfaces directly adjacent to the park, the temperatures return to those close to the original UHI effect (S.-H. Lee et al. 2009). Regardless, some cities are beginning to adopt "pocket parks" to increase green space and decrease UHI effects. Pocket parks are small plots of land that host green space, vegetation, artwork, and other amenities, usually around one-fourth of an acre large (National Recreation and Park Association). Between 1961 and 1967, Philadelphia created 60 pocket parks varying in size, building material, and amenities by reconstructing vacant or abandoned lots in low-income areas (Blake 2013). A study in Hong Kong found that pocket parks can have marginal cooling effects at the micro-level, but only when they are composed of vegetation or tree canopy versus impervious surfaces and structures (Lin et al. 2017).

The species of tree also has an impact on the extent of UHI mitigation. Increasing tree canopy alone does not mitigate UHI effects. Properly selecting the most appropriate tree species is the first order of business (Ballinas and Barradas 2016). Trees with darker or larger leaves, larger sizes, and faster growth rates were found to increase cooling effects (Rahman et al. 2020). While the species matters, selection should only occur within the pool of trees native to the location to ensure the proper maintenance of the tree and the feasibility of planting.

Green roof construction is another increasingly popular method to increase urban vegetation and evapotranspiration. Green roofs usually fall into one of two categories: extensive green roofs and intensive green roofs. The former consists of a thinner layer of soil and drought-tolerant low and hardy vegetation planted over the whole roof (J. Lee, Kim, and Lee 2013). The latter is usually heavily landscaped with deeper soil layers strong enough to support trees and shrubs, sometimes with an additional layer that stores rainwater (J. Lee, Kim, and Lee 2013). The EPA identifies green roofs as a legitimate UHI mitigation strategy because of their contributions to decreasing energy usage within the buildings they occupy and the evapotranspiration they can provide (EPA 2008). Studies modeling the effects of green roofs have shown that they can reduce air temperatures in a city by up to 5º F and decrease the roof's surface temperature by up to 40º F (Santamouris 2014). Another study model showed that surface and air temperatures decrease almost linearly when an area's green roof fraction increases (Li, Bou-Zeid, and Oppenheimer 2014).

Green roof installation has increased across the country exponentially over time at varying levels of intensity and success. Surveys by industry stakeholders in 2019 found that there has been a reported 5 to

15 percent overall industry growth of green roofs since 2013, with 763 projects across 35 U.S. states and three Canadian provinces installing more than 3.1 million square feet of green roofing (Green Roof for Healthy Cities 2019). Chicago alone has more than 500 green roofs amounting to more than 5.5 million square feet of coverage, and some have existed since the 1960s. Thirteen of Chicago's green roofs act as rooftop farms, generating 8,000 pounds of produce annually. Chicago has also reported an annual saving of $3,600 in energy costs at its City Hall due to green roof installation (EPA 2008). A modeling study in Chicago found that while green roof expansion was generally good in UHI mitigation, unintended consequences could occur. Namely, the increase in moisture resulting from green roof expansion can offset the reduction in temperature through evapotranspiration. The authors of the study discussed that an optimal strategy for UHI mitigation is a strategic combination of green roofs and "cool roofs," or light-colored/reflective roof surfaces that increase albedo (Smith and Roebber 2011).

Policy Options

The present study considers three potential approaches to increasing green space in La Crosse: tree canopy expansion, pocket parks, and green roofs.

Tree canopy expansion

Expanding the tree canopy in La Crosse would provide a cooling effect to the immediate coverage area while providing shade and cooling to residents. As an initial pilot program, canopy expansion would likely constitute a program to plant and maintain new trees along city streets, parking lots, and other city-owned lands. For optimum impact under limited budgets, the City should plant these new trees in areas with high urban heat indices and where vulnerable populations could benefit. Based on the City's Climate Action Plan, the goal would be to expand tree canopy coverage from 30 percent to 32.5 percent by 2030 (paleBLUEdot 2022).

Pocket parks

Adding a series of "pocket parks" is a viable option to increase green space within La Crosse to reduce the effects of heat islands. The City should scatter these smaller plots of outdoor recreational and green space throughout the City in locations with high heat indices and low accessibility to current recreational green spaces to help mitigate the effects of heat islands in denser areas (Lin et al. 2017) while also being accessible to the public. The City should also prioritize areas lacking current green space—mainly residential and commercial areas—to help distribute recreational space equitably.

Green roofs

A third option for expanding green spaces is incentivizing and implementing green roofs on both public and privately-owned buildings. Roofs covered in vegetation and acting as a growth medium throughout is an emerging method of achieving heat resiliency (U.S. EPA 2014), as new or existing land would not require conversion to green space while achieving some mitigation of heat. With this option, the City should prioritize buildings in areas with high urban heat indices to maximize the effectiveness of green roofs.

Maintenance of green roofs are valid concerns for aesthetic and infrastructural reasons. Depending on the nature of the buildings, the City would have to either maintain the roofs themselves if City-owned or incorporate maintenance costs into their incentivization plan if privately owned. If the City were to implement a green roofing program, city-owned buildings could take the lead and provide an example of converting regular roofs to green roofs. This lead-by-example method could help motivate and incentivize privately-owned buildings to follow suit (Koski and Lee 2014).

Evaluative Criteria

Four significant goals are relevant to increasing green space in La Crosse: feasibility, heat mitigation, equity, and positive externalities. Our analysis ranks each criterion under one policy option as high, medium, or low. A low-scoring policy will have to overcome significant barriers. A medium ranking means a policy can overcome obstacles, but policy entrepreneurs need sustained effort. When a policy sufficiently meets the requirements in that column, it scores high. An ideal policy would increase green space in a heat-vulnerable area, be politically feasible, mitigate heat, increase equity, and maximize positive externalities.

The feasibility criterion consists of monetary cost and implementation practicability. Monetary cost accounts for both short- and long-term costs. For example, a tree canopy solution will require up-front planting costs and yearly maintenance. Our policy options have an up-front cost and a variation of maintenance costs. Secondly, we evaluate the practicability of implementation, which includes agency capacities to implement the project, potential administrative barriers, and how much La Crosse would have to engage with the community for the project to be successful. For example, amending zoning laws to create pocket parks would have a higher administrative burden. Another example would be if La Crosse decides to increase the tree canopy of privately-owned land, it would have to invest in community outreach. While each policy option's feasibility implementation varies, all have a variable essential to consider before making our final recommendation.

The heat mitigation criterion considers how each policy option could reduce the exposure to the UHI effect. The ideal policy would be able to reduce the UHI effect by a measure of degrees Fahrenheit. However, due to the nuance of heat mitigation, there is no consistent estimate of how a policy would reduce heat mitigation. Existing research indicates that heat mitigation depends on the project: the size, shape, species of vegetation, and tree canopy size (Feyisa, Dons, and Meilby 2014). Furthermore, the two policies likely have the same heat mitigation effect in the aggregate. For example, one tree does not have a significant heat mitigation effect; however, the marginal effect of many trees across the City may add up to the same heat mitigation effect as a pocket park. While heat mitigation is important to the City of La Crosse, this criterion was the most difficult to measure and score in our analysis.

The following criterion is that the project increases equity. We define equity as the project's impact on increasing green space in marginalized communities within the City of La Crosse. Marginalized communities include impacts on homeless populations, people of lower socioeconomic status, and people of color. Our analysis uses a Gini coefficient, a tool that measures the inequality of distribution over a variable of interest on a scale from zero to one (U.S. Census Bureau). The variable of interest for our analysis was tree canopy and green space. Zero means perfect urban tree canopy dispersion across the City, and one means perfect urban tree canopy inequity (Ellis et al., 2020). To determine equality, each census tract counts as one unit, weighted by population density. A Gini coefficient allows us to consider policy options and how they could enable La Crosse to increase green space equitably.

The final criterion was positive externalities, which is any additional benefit to the City beyond the other measures the policy solution will provide. For example, parks help with heat mitigation and serve as playgrounds and centers of the community. For our analysis, we first measured if any other positive externality to the community would exist. Our analysis considers effectiveness as how many residents the positive externality could serve. For example, creating a park would increase green space for more residents than planting trees within one neighborhood. While this analysis is subjective, it was essential to consider how our recommendation would impact the community.

Data Analysis

To understand the current distribution of tree canopy and green space in the City of La Crosse, we conducted several forms of data analysis. We analyzed tree canopy, impervious surfaces, land surface temperature, and demographic characteristics at the census tract level and census block group level (Gilbert, n.d.) using U.S. Census Bureau American Community Survey (ACS), the Multi-Resolution Land Characteristics (MRLC) consortium National Land Cover Database (NLCD), the United States Department of Agriculture Forest Service (USDAFS) iTree Landscape database, and the National Aeronautics and Space Administration (NASA) Moderate Resolution Imaging Spectroradiometer (MODIS) Land Surface Temperature and Emissivity data from 2021. Descriptive Statistics about La Crosse can be found in Appendix B. As a note, poverty and minority are used in our analysis in accordance with the definitions set forward by the U.S. Census Bureau. For the current definition of the federal poverty limit, the Census Bureau's poverty measurement methodology, and the Census Bureau's race measurement methodology, please see Appendix D. To investigate the relationship between tree canopy, impervious surfaces, land surface temperature, and demographic characteristics in La Crosse, we performed multivariate ordinary least squares (OLS) regressions. This process estimates the relationship between variables, allowing us to identify and understand how different variables in our data may be related to one another.

Our analysis of tree canopy distribution in La Crosse found that the percentage of minority population in a census tract and percentage of people living under the federal poverty limit in a census tract had a statistically significant negative effect on the amount of tree canopy in that census tract. These findings imply that as the percentage of both minority population and lower income population in a census block group increases, tree canopy in that census block group decreases in La Crosse. Please see Appendix C for the full regression tables and graphs.

Our analysis of the distribution of impervious surfaces found mixed results. A simple regression analysis showed that there was no statistically significant relationship between minority percentage, poverty level, and percent impervious surfaces in a census tract. However, a model which included an interaction term between race and income showed a statistically significant relationship between impervious surfaces and minority percentage, but not poverty percentage. When modeling this relationship further, we found that the wealthier a census tract is, the larger effect race seems to have on impervious surface percentage. We suggest further research to better understand the relationship between race, income, and impervious surfaces in a census tract. Please see Appendix B for the full regression tables and graphs.

Census tract analysis

Additionally, we looked at census tract level data to identify which tracts La Crosse should prioritize in heat island mitigation efforts. Of the 17 census tracts comprising the majority of the City, three stood out: Tracts 8, 10, and 11.01. These tracts represent the areas of La Crosse with the least percentage of tree canopy, greatest percentage of impervious surface, and the greatest summer average land surface temperature. These indicators suggest that the above Census Tracts 8, 10, and 11.01 are high-priority areas for green space expansion. See Appendix E for maps of La Crosse outlining these priority census tracts.

Census Tract 8 is near the middle of downtown. The tract ranks 17th (last) in square miles of tree canopy per person, 16th in tree canopy percentage, 15th in average summer temperature, 17th in high summer temperature, 15th in percentage of non-impervious surfaces, and 16th in square miles of non-impervious surfaces per person. Demographically, Census Tract 8 ranks 13th in total population, 2nd in population density, 2nd in median income, 9th in percentage of residents who are minorities, and 7th in percentage of the population living under the federal poverty limit.

Census Tract 10 is directly south of Census Tract 8. The tract ranks 15th in square miles of tree canopy per person, 15th in tree canopy percentage, 17th in average summer temperature, 15th in high summer temperature, 16th in percentage of non-impervious surfaces, and 15th in square miles of non-impervious surfaces per person. Demographically, Census Tract 10 ranks 11th in total population, 3rd in population density, 13th in median income, 5th in percentage of residents who are minorities, and 5th in percentage of the population living under the federal poverty limit.

Census Tract 11.01 is directly east and south of Census Tract 10. The tract ranks 14th in square miles of tree canopy per person, 17th in tree canopy percentage, 16th in average summer temperature, 16th in high summer temperature, 17th in percentage of non-impervious surfaces, and 14th in square miles of non-impervious surfaces per person. Demographically, Census Tract 10 ranks 17th in total population, 7th in population density, 10th in median income, 12th in percentage of residents who are minorities, and 9th in percentage of the population living under the federal poverty limit.

Importantly, we did not consider Census Tracts 4 (now 4.01 and 4.02) and 5 in our analysis of potential recommended tracts, due to the universities present in these tracts and high number of students living there. These factors both tended to skew our data, while also making an implementation plan more difficult.

Gini coefficient

Using the same data referenced above, our team also constructed a Gini coefficient to better understand the equitability of tree canopy and impervious surface distribution in La Crosse. Gini coefficients measure the equitability of the distribution of a resource throughout a society, with a coefficient of 0 representing a perfectly equal distribution and a coefficient of 1 representing a perfectly unequal distribution. For example, in a society of 10 people and $10, each person owning $1 would be a perfectly equal society, with a Gini coefficient of 0. One person owning all $10 would be perfectly unequal, with a Gini coefficient of 1.

We applied this methodology to tree canopy and non-impervious surfaces, measuring the distribution of these resources throughout the City. The coefficient is based on comparing the proportion of the population in a census tract to the proportion of total tree canopy/non-impervious surface in that census tract. For tree canopy distribution, we calculated La Crosse to have a Gini coefficient of **0.59.** This indicates that there is an inequitable distribution of tree canopy by census tract in La Crosse, with some census tracts having larger amounts of tree canopy than others. For distribution of non-impervious surfaces (an approximation for green space distribution), we calculated a Gini coefficient of **0.42.** This indicates that while there is still an unequal distribution of non-impervious surfaces, it is more evenly distributed throughout the population than tree canopy.

Although no city will ever have a perfectly equitable distribution of tree canopy or impervious surfaces, we recommend using these Gini coefficients to measure improvement in access to green space going forward. When taking on new projects that would create new tree canopy or non-impervious surfaces, considering the current distribution of these resources can be a key factor in deciding the location of new projects. For example, increasing the tree canopy in our 3 highlighted census tracts—8, 10, and 11.01—to the City per-tract-median of 6.52 percent results in a decrease of the tree canopy Gini coefficient to **0.55.** A decrease in the Gini coefficient represents that there is a more equitable distribution of tree canopy throughout the city, and that less canopy is concentrated in certain census tracts. Although it may be impossible to decrease the Gini to 0, the Gini still serves as a useful benchmark to measure improvement resource allocation. Performing repeated analysis of the Gini coefficient in coming years, particularly after large scale planting projects or park development, can help the City understand its resource distribution and better plan for future projects.

Policy Analysis

Using the criteria of feasibility, heat mitigation, equity, and positive externalities, we discuss how increasing tree canopy, creating pocket parks, and installing green roofs compare on evidence from studies and talking with local experts. Appendix A is a goals–alternatives matrix summarizing this analysis.

Tree canopy

Feasibility (Rating: Medium): The financial costs of expanding urban tree canopy have various contextual fiscal feasibility considerations. According to an interview with the City's Parks and Forestry Building and Grounds Manager, Dan Trussoni, buying and planting a tree costs approximately $650 plus additional annual maintenance costs that slowly increase. The maintenance costs account for pruning, trimming, irrigation, and pest and disease control. The forestry department would also need to rely on soil cells—are structures that allow trees to grow efficiently in urban environments without harming nearby infrastructure—which costs $7,500 per tree. Additional labor costs may be necessary for extended urban forests, where the City plans to create an additional arborist position. Given specific budget constraints, local leaders can use that information to determine how many trees are appropriate to buy and plant.

Areas such as downtown and college residential neighborhoods are subject to vandalism, which are unsuitable environments for tree growth. The City maintains more than 20,000 trees and has almost completed an aggressive eradication project for removing ash trees infested with emerald ash borer, with 100 ash trees remaining to be removed. The City may also encounter more difficulty coordinating with homeowners to maintain trees on private properties, as homeowners are expected to water trees. While increasing tree canopy on city-owned property is doable, the potentially high cost of soil cells and increased tree maintenance throughout the City led our analysis to rank feasibility as medium.

Heat Mitigation (Rating: Medium): Urban tree canopy has proven heat mitigation benefits, as previous research and policies from other communities show. Trees use evapotranspiration, which combines evaporation and transpiration, where water collected from plants is released to cool the surrounding air and surfaces. Previous research indicates that trees can decrease surrounding air temperatures up to 7.2 °F and decrease surface temperatures by 19.8 to 45 °F (Hashem Akbari et al. 1997). The area of planting trees affects heat mitigation as the surface temperature on asphalt decreased by 10.8 °F, compared to grass at 5.4 °F (Rahman et al. 2020). These direct impacts from reductions in heat can also have financial savings, as decreases in temperature from Akbari's research showed annual energy and air conditioning consumption decreased by 30 percent when implementing urban trees. However, the literature surrounding the effectiveness of trees reducing UHI varies on the number, size, density, and species of vegetation. Therefore, measuring the exact effects in La Crosse's context is difficult, which led us to score heat mitigation for increasing tree canopy as medium.

Equity (Rating: Medium): As lower-income and minority households often live in areas with higher pollution levels, tree canopy can sequestrate and collect greenhouse emissions if trees are targeted in these neighborhoods. The environmental justice aspect of urban tree canopy can help alleviate health disparities among different neighborhoods and mitigate intra-UHIs through cooling effects with evapotranspiration and increased shade. However, previous research shows that increasing urban canopy can increase housing and property prices, which may increase the likelihood of ecological gentrification (Donovan et al. 2021). Our group ranks this alternative's equitable impact as medium because it could help lower-income and minority households, but there could be some unintended negative consequences.

Positive Externalities (Rating: Medium-Low): Urban tree canopy provide various positive externalities that impact other parties not directly involved with planting and maintaining urban trees. First, urban canopy benefit stormwater management as trees can absorb and filter rain. La Crosse is particularly vulnerable to flooding due to combinations of contextual factors for being geographically flat between the bluffs and the Mississippi River and large snowpacks from winters that melt and increase the river depth. A study in British Columbia shows that trees can intercept between 50 and 60 percent of rainwater, which can be released safely into the air through transpiration and mitigate adverse flooding outcomes (Asadian, Weiler 2009).

Urban tree canopy also have positive externalities improving air quality through lower greenhouse gas emissions and improving quality of life. According to the Arbor Day Foundation, a mature tree will absorb more than 48 pounds of carbon dioxide from the atmosphere and release oxygen in exchange (ADF n.d). In monetary value, one ton of sequestered carbon dioxide equals $50 in avoided social costs, according to the Wisconsin Legislature (2021). If we take the 20,000 trees from La Crosse's current urban canopy, the avoided social costs equal roughly $23,800 annually. Another benefit of tree canopy is increasing community appeal and quality of life by enhancing leisure, recreation, and reduced stress (Brown 2021). While increasing tree canopy has other benefits beyond heat mitigation, pocket parks and green roofs offer significantly more positive extra benefits, which is why our analysis scored positive externalities medium-low for tree canopy.

Pocket parks

Feasibility (Rating: Medium-Low): Our analysis started with a medium ranking because maintenance costs will likely be low in the long term. Compared to tree canopy expansion across a city, a pocket park is in one location, making ongoing maintenance easier. Since pocket parks are less than one-fourth of an acre, we do not expect to increase the park maintenance burden significantly. Furthermore, if the City maintenance is unable to care for all the pocket parks, it is possible the City could partner with homeowner associations to maintain the parks for the long term.

One of the challenges with implementing pocket parks is that the City would have to acquire land to build the pocket park, which would have a high up-front cost. Depending on how much the City wants to develop the pocket park, the cost ranges from tens of thousands to half a million dollars (Office of Real Estate Services 2015; Faraci 1967). Furthermore, the City would have to consider re-zoning any land it would have to purchase and classify it as public property ("City of La Crosse Online Mapping" n.d.). Since City staff will be responsible for re-zoning purchased property, there is an opportunity cost of time. Additionally, the construction cost could be high, given that current zoning suggests that La Crosse would have to remove concrete from a parking lot or building. Therefore, the City would have to invest in restoring the soil before planting any trees. Dan Trussoni informed us that the City is looking at purchasing soil cells for trees in downtown La Crosse. While soil cells could solve soil quality in a small park, it would be expensive, as the early estimate for one soil cell is $7,500. Combining these factors, our analysis scores the feasibility of pocket parks as medium-low because of the high up-front investments.

Heat Mitigation (Rating: Medium): Since the literature surrounding the effectiveness of parks varies on the size, shape, species of vegetation, and tree canopy size, there is not a precise estimate of how much a pocket park would reduce UHI (Feyisa, Dons, and Meilby 2014). Nonetheless, studies have shown that the shade effect of trees in parks is much more impactful than other shade-providing infrastructure (Shashua-Bar, Pearlmutter, and Erell 2009). While the concentration of trees allows parks to have a more significant cooling effect than trees planted in a line, most of the cooling effects from trees are localized to the park. If buildings, roads, and impervious surfaces are adjacent to the park, UHI will likely return to the original (S.H. Lee et al. 2009). Furthermore, a study in Hong Kong found that pocket parks have a cooling effect at the micro-level, but only when comprised of vegetation and tree canopy. Given that the park would provide micro-level cooling, our analysis scored pocket parks as medium.

Equity (Rating: Medium): If the City of La Crosse adds a pocket park in an area lacking green space, the Gini coefficient moves closer to zero, indicating improved equity. Since the implementation of pocket parks will be slow due to the high fixed cost, it could take years to have an equitable distribution of green space. Therefore, our analysis ranked pocket parks right in the middle in terms of a successful policy that would improve equity.

Positive Externalities (Rating: High): Besides increasing tree canopy and heat mitigation, parks provide economic, health, environmental, and social benefits to the City and community. Some economic benefits include an increased local tax base and property values of residential areas near parks; a meta-analysis of the 25 studies reviewed 20 of them showed higher property values when a park is nearby (Crompton 2001). Furthermore, urban parks reduce stormwater runoff, which is environmentally friendly. Studies have found that a medium-sized tree, 20 to 40 ft in range, can intercept a maximum of 2,380 gallons of rainfall per year (Center for Urban Forest Research, Pacific Southwest Research Station, USDA Forest Service 2002). According to a study by the EPA, trees can reduce runoff and storm erosion by about 7 percent, reducing the need for erosion control (EPA 2008). Many studies find that parks help improve water quality, protect groundwater, and prevent flooding (EPA, 2008; Center for Urban Forest Research, Pacific Southwest Research Station, USDA Forest Service 2002; National Parks Association n.d.). Given the extensive research on how parks help absorb and filter water, the City would improve the surrounding environment and potentially save on stormwater costs.

In addition to the host of environmental benefits parks support, parks can improve human health and create a space for people to socialize. Pocket parks also promote physical activity. Cohen et al. found that physical activity in pocket parks compares favorably with existing parks (Cohen et al. 2014). Small green spaces such as pocket parks also reduce stress, improve general resident mood, and increase mindfulness and creativity (Wolf, 2017; National Parks Association n.d.). Furthermore, small parks have social importance, giving neighborhoods a space to connect. Due to the economic, health, environmental, and social benefits pocket parks could provide, our analysis scored it high in the positive externalities category.

Green roofs

Feasibility (Rating: Low): The cost, creation, and maintenance of green roofs depends on various factors. The EPA cites green roof costs as "$10 per square foot for simpler extensive roofing, and $25 per square foot for intensive roofs." (EPA 2022) Furthermore, annual maintenance was cited to cost between $0.75 and $1.50 per square foot annually (EPA 2022). The up-front costs of a green roof installation are where most of the overall costs will be incurred, and the overall benefits and savings of the green roof, via reduced energy costs, can help offset some of these costs over a green roof's lifespan.

Many factors are at play when determining whether a green roof is feasible. The material of the existing roof, its load-bearing capacity, waterproofing ability, sun/wind exposure, zoning restrictions, and flatness are some of the factors that need to be considered before installing a green roof. In cases where a roof is eligible to be converted, an incentive structure is still needed to garner the private building owners' buy-in. New York City, for example, instituted a property tax deduction of $5.23 per square foot of green roof space. Implementing green roofs on municipal buildings would be a much quicker starting point, identified as a "phase one" action that the recent La Crosse Climate Action Plan identified. Regarding the feasibility of green roofs, the immediate costs and implementation hurdles resulted in a feasibility ranking of this alternative as low.

Heat mitigation (Rating: Medium): Green roofs can lower the surface temperature of the actual roof by 30 to 40°F while decreasing city-wide ambient temperatures by up to 5 °F, according to the EPA. Green roofs decrease the percentage surface area of impervious surfaces in a city, decrease urban albedo, and increase the amount of evapotranspiration. In addition, green roofs decrease the annual energy costs of buildings, as they naturally cool the building by reducing the roof's surface temperature. The reduction of building temperature reduces AC reliance, which actively reduces emissions produced by the building, further mitigating heat.

Heat mitigation can vary by the type of green roof and especially the vegetation on it. Green roofs with tree canopy mitigate heat more than smaller grass and vegetation. Larger and denser vegetation types are associated with more intensive green roof systems, which are much less feasible to implement than extensive green roofs. Studies surrounding heat mitigation and actual temperature changes per green roof are lacking, so it is difficult to measure the exact effects in La Crosse's context. While green roofs mitigate heat in various ways, the difficulty of implementing enough green roofs city-wide results in a heat mitigation ranking of this alternative as medium.

Equity (Rating: Low): Green roofs are not only expensive, but their immediate effects are not always felt by vulnerable populations. Under this alternative, the expansion of green roofs would be specific to municipal buildings. While the creation of green roofs will mitigate heat and benefit the City, the majority of the immediate beneficial effects will be felt by the inhabitants of the buildings themselves. Equitably speaking, low-income and vulnerable populations will not experience immediate effects unless they travel to said buildings during high heat events. Under our alternative, green roof expansion does not incorporate low-income housing or privately-owned buildings or homes where inhabitants lack access to air conditioning—and where high heat event public health risks are most felt. Our analysis therefore ranks this alternative's equitable impact as low due to the limited benefits to vulnerable populations.

Positive Externalities (Rating: High): The positive externalities of green roofs are plentiful. The building owners receive clear economic benefits associated with decreased AC reliance and an overall decrease in energy costs. The EPA cites a reduction of 0.7 percent in building energy use compared to conventional roofs (EPA 2022). A decrease in AC usage actively decreases the carbon footprint, which is associated with a host of positive climate effects. Another economic benefit is the increased lifespan of green roofs, which last two to three times longer than conventional roofs (National Institute of Building Sciences 2016).

Green roofs are cited as substantially effective tools in managing stormwater runoff, reducing nearly 50 to 60 percent annually, detaining 90 percent of volume for storms with less than one inch of rain, and 30 percent of larger storms (The Center for Clean Air Policy 2011). Intensive roofs are approximately twice as good in reducing stormwater runoff than extensive roofs. New York City found that installing one 40-square-foot green roof can lead to the capture of 810 gallons of stormwater captured by the roof annually (The Center for Clean Air Policy 2011). Furthermore, studies have found that green roofs can reduce noise pollution in nearby city street traffic (Renterghem 2018). Given the positive externalities associated with green roofs, our analysis ranks this alternative's positive externality criterion as high.

Recommendations

The recommendations below follow from our analysis. We recommend employing long-term solutions by increasing tree canopy, pocket parks, along with short-term solutions like cooling centers and cool surfaces.

***Recommendation 1**:* Employ urban tree canopy expansion and pocket park creation to mitigate the urban heat island effect experienced throughout the City.

Rationale: Given specific budget constraints and the feasibility of implementation, combining the urban canopy and pocket parks allows La Crosse to implement various green space opportunities with beneficial heat mitigation. To mitigate heat in the short term, La Crosse should increase the number of trees on city-owned property. Urban canopy expansion along city streets and other city-owned lands will increase heat mitigation, especially on existing asphalt or impervious surfaces, and create positive externalities with stormwater management and carbon sequestration.

At the same time, the City should be planning where potential pocket parks could be. The first step in planning is getting community input from areas that lack access to green spaces. After hearing from the community, the City will better understand what the community wants to see in a small park, allowing it to get better cost estimates. The cost estimates should include purchasing the property, converting the property to a park, and the labor and materials needed for construction. It should also include the cost of potentially re-zoning the area and any permits needed for the project. With these estimates, the City can purchase vacant lots or old buildings within its budget and convert the property into pocket parks. Depending on the available space in vulnerable areas, as previously mentioned, the trade-offs of using pocket parks are ideal for defunct or obsolete areas and can revitalize those neighborhoods. Scattering pocket parks in high heat index areas can narrow the equity gap for access to green space for vulnerable populations.

Engaging with the community will also provide insight on how to avoid the potential adverse impacts of ecological gentrification. While adding pocket parks and urban tree canopy will make neighborhoods more desirable and healthy to reside in, it is important for decision-makers to incorporate feedback from stakeholders. Using the "just green enough" strategy can avoid gentrification by scattering ecological restoration projects and avoiding large-scale projects that will significantly increase housing costs.

Recommendation 2: Target green space expansion to areas with vulnerable populations and those lacking access to green space.

Rationale: Green space and tree canopy are currently inequitably distributed throughout La Crosse, as evidenced by our Gini coefficient calculations. Focusing on the census tracts with the lowest percentage of tree canopy and highest percentage of impervious surfaces will help La Crosse create a more equitable distribution of its resources. Additionally, focusing on these census tracts will have the greatest effect on heat mitigation, as these tracts also have the highest average summer temperatures and the highest peak summer temperatures. Based on our data analysis, we recommend La Crosse focus on Census Tracts 8, 10, and 11.01.

Recommendation 3: Conduct a feasibility study to identify municipal buildings that can support green roof construction and draft a policy that requires municipal buildings to incorporate either solar panels, cool roofs, or green roofs.

Rationale: Despite high costs and lower equitable distribution, green roofs have significant UHI mitigation effects and substantially high positive externalities. The most recent La Crosse Climate Action Plan identified the creation of cool or green roofs on all new and existing municipal buildings (without solar panels already installed or planned to be installed on them) as a "phase one" step the City can take. A policy could be created to make this a requirement for municipal buildings that meet the feasibility standards for construction. There are currently no codes or ordinances that mention green roofs.

A feasibility study would investigate the existing roof structure (flatness, building material, etc.), load-bearing capacity, waterproofing ability, zoning restrictions, and unique maintenance issues that the various municipal buildings have, as well as the anticipated implementation/maintenance cost of installation. If green roofs cannot be constructed on an existing roof, other cool roof/solar roof strategies can be pursued. Further research into incentive strategies for private building owners to implement green roofs should also be explored.

Other solutions

The present study focused on long-term solutions to mitigate heat. However, projections of climate conditions show average temperatures increasing across the county, making heat-related illness a continued threat to human health (U.S. Global Change Research Program 2016). Given the UHI context, the City should have plans for immediate interventions regarding heat risk. La Crosse's plan should include where residents can get support, such as cooling centers, and immediate solutions like implementing cool surfaces.

Short term: Cooling centers

One immediate solution to a heat wave risk is to have designated cooling centers throughout the City. A cooling center or shelter is an air-conditioning cooled building that provides a break from the heat wave (Widerynski et al. 2017). Cooling centers can be community centers, religious facilities, homeless shelters, government office buildings, libraries, etc. Studies have found that those who spend a few hours in cooling centers are less likely to suffer from heat wave mortality (Vandentorren et al. 2006). A plan for a cooling center is one way the City can be more prepared for an emergency response to a heat wave.

To implement a cooling center plan, La Crosse should consider the following:

1. Scope of cooling centers
    a. Where do cooling centers already exist?
    b. What buildings does the City have available?
2. Identify Partners
    a. What community organization or nonprofit partnerships can the City leverage?
    b. What is the role of the Public Health Department?
    c. Who are other stakeholders the City should engage with?
3. Assess what communities are vulnerable. Which census tracts have high exposure to heat risk?
4. Planning
    a. Are there any policies or ordinances affecting response to a heat wave?
    b. Identify several locations for cooling centers.
    c. Identify how residents could get to those locations.
    d. Is there an incentive for residents to leave their houses and sit in a cooling center?
        i. Can snacks be provided?
        ii. Alternatively, have activities available, like watching a movie/coloring/toys for children/etc.
5. Implementation
    a. Communicate heat wave risk and cooling center locations.
6. Evaluation
    a. Where are residents able to safely get to cooling center locations?
        i. If residents chose not to come, what other barriers could they face?

By strategizing this plan before a heat wave, the City will be better equipped to reduce the mortality risk and protect the well-being of residents.

Short term: Increasing urban albedo

Increasing urban albedo is the other side of the UHI mitigation coin. A surface's albedo can range from a scale from zero to one, and it measures the fraction of sunlight that the surface reflects. If a surface completely reflects sunlight, it has an albedo of one. Conversely, if a surface completely absorbs all of the incoming sunlight, it has an albedo of zero. Dark surfaces like black asphalt have significantly low albedo measurements, whereas bright and reflective surfaces like snow or white surfaces have significantly higher albedos. A low albedo surface absorbs more sunlight, which results in an increase in the surface temperature as well as an increase in the ambient air temperature felt right above the surface. One study found that, during peak solar conditions, a black asphalt or tar surface with an albedo of 0.05 has about 90 °F higher temperature than the ambient air temperature, whereas white or reflective surfaces with an albedo of 0.8 are only 18 °F hotter than the surrounding air (Synnefa et al. 2008).

Heavily urbanized areas are associated with a lot of impervious (low albedo) surfaces such as roofs, pavement, asphalt, etc. The UHI effect is exacerbated by these low albedo structures, and researchers and policymakers have identified some creative ways to increase surface albedo, thus mitigating the UHI effect.

Short term: Cool roofs

Green roofs were extensively discussed earlier in this analysis, but "cool roofs," or bright or reflective roofs, are a much cheaper option. The EPA claims that the various types of cool roofs can range from $0.75 to $3.00 per square foot, while also saving about $0.50 in annual energy savings per square foot (Environmental Protection Agency n.d.). According to the Department of Energy, conventional roofs can reach temperatures of 150 °F, and converting these roofs to cool roofs could lower that number by 50 °F (Department of Energy n.d.). Ambient heat can decrease by up to 3.6 °F, according to some figures (Yale School of Environment n.d.). Cool roofs are created by using light-colored materials such as wood, ceramic tile, metal, etc., but roofs with pure white coloration have the largest cooling effects. Some cities have implemented initiatives in which they paint their blacktop roofs white, and some studies have found that cool roofs can decrease the UHI by up to 23 percent (Macintyre and Heaviside 2019). It should be noted that cool roofs can increase energy use during winter months compared to more heavily insulated green roofs (Costanzo, Evola, and Marletta 2016).

Short term: Cool surfaces

The same beneficial effects of cool roofs can extend to different kinds of impervious surfaces like sidewalks, pavements, asphalt lots, etc. While simply changing the color of pavement to be lighter would work, the EPA has identified pavement types that are more porous or permeable can allow more absorption of stormwater into the ground (Environmental Protection Agency n.d.). While lighter-colored pavements would decrease surface temperatures, increase evening visibility, and have UHI mitigation effects, they also present challenges. The largest limitation of reflective surfaces is the glare they can produce in high solar events such as days with high UV indices. In some cases, the glare of sunlight can distract drivers, hurt individuals' eyesight, and heat up surrounding structures that offset the UHI mitigation effects that they initially achieved. The glare effect applies to cool roofs as well (Costanzo, Evola, and Marletta 2016). The City should take locations and unintended consequences into consideration and consider using light-colored surfaces that are less "bright" or opt for other shade options such as tree canopy.

Considerations For Implementation

Proactive community engagement is crucial for the successful implementation of green space expansion efforts. The City of Detroit, for example, received funding in 2014 to ramp up an existing reforestation effort (Mock 2019). To meet ambitious tree-planting goals, Detroit's nonprofit partner approached 7,500 residents to offer free tree-planting in front of their homes. Of those 7,500 residents, one quarter declined the offer. Christine E. Carmichael, a researcher from the University of Vermont, investigated this trend, interviewing residents who turned down the free trees. According to Carmichael, some African American interviewees "linked the tree-planting program to a painful racist moment in Detroit's history, right after the 1967 race rebellion, when the City suddenly began cutting down elm trees in bulk in their neighborhoods" in an effort to increase law enforcement surveillance (Ibid). While Detroit claims that Dutch elm disease caused the large-scale tree removal, residents' sense of trust in city government suffered as a result. Further, some residents who opposed tree planting cited that "existing, large trees on city property were not adequately cared for and affected the appearance of the neighborhood, and presented a safety concern" (Ibid). Detroit's failure to proactively address the community and to understand the concerns of long-time residents ultimately hindered its reforestation effort and further eroded trust in government among residents.

The City of La Crosse has a unique local context and history. We recommend proactive outreach to and engagement with a variety of community stakeholders to anticipate and better understand potential concerns. Involving community members in decision-making processes—particularly those communities who UHI disproportionately impacts—will promote environmental justice and may help to address implementation issues such as vandalism and maintenance. Bringing communities into the planning process early on could promote a shared mission and vision and serve to educate the public on the importance of protecting newly planted trees.

Conclusion

Our study contributes to a nationwide conversation about heat resilience and how to plan long-term for climate change effects. By the year 2100, on average, the City of La Crosse will be 6 to 12 °F hotter than it is today, and extreme heat events are becoming more common. Urban environments are particularly vulnerable to the urban heat island effect because city infrastructure—such as buildings, concrete, and other infrastructure—absorbs rather than reflects and re-emits the sun's heat. To distribute how UHI was experienced throughout the community, we conducted a quantitative analysis to examine further the environmental distribution in La Crosse.

Our team was tasked with identifying viable green space expansion options to mitigate the UHI effects felt by the City. We started by conducting a thorough literature review of UHI as a concept, mitigation strategies, environmental justice concerns, and how they all relate to La Crosse. As a result, we identified three potential urban green space policy alternatives that have been proven to mitigate UHI effects: urban tree canopy expansion on city streets, pocket park construction on unused land, and the construction of green roofs on municipal buildings. A goals–alternatives matrix was formulated through our analysis, and we ranked each policy alternative's economic and political feasibility, effectiveness in mitigating heat, equity, and positive externalities. The top two scoring alternatives were identified as tree canopy expansion and pocket park creation.

A second stage of our analysis incorporated La Crosse census tract data collection. We identified census tracts that had the least amount of green space, the most amount of impervious surfaces, and the highest experienced summer temperatures. Our analysis also considered the socioeconomic and racial makeup of these census tracts. We identified Census Tracts 8, 10, and 11.01 as the three census tracts where tree canopy and pocket park expansion should be prioritized due to their low percentage of tree canopy, high percentage of impervious surfaces, and high summer temperatures. Our group recommends an expansion of tree canopy and pocket park creation within these census tracts. We also recommend that the City takes the initial steps of identifying municipal buildings that can feasibly host green roofs. With these solutions, La Crosse can proactively mitigate UHI while protecting its most vulnerable residents.

Appendix A: Goals–Alternatives Matrix

Scored:
Low: If a policy is significantly unlikely to overcome the barrier of that criteria.
Medium: If obstacles can be overcome, policy entrepreneurs need sustained effort.
High: When a policy sufficiently meets the requirements in that column

Goals–Alternatives Matrix				
	Feasibility: The project's monetary cost and implementation practicability.	**Heat Mitigation:** The project's ability to reduce the urban island heat effect is measured on a scale of one to five.	**Equity:** The project's impact on increasing green space in marginalized communities is measured via the Gini coefficient.	**Positive Externalities:** Any additional benefit to the City beyond the other measures the proposed policy solution will provide.
Tree Canopy Expansion	**MEDIUM** While increasing tree canopy on city-owned property is doable, the potentially high cost of soil cells and increased tree maintenance throughout the City led our analysis to rank feasibility as medium. According to the City of La Crosse's Dan Trussoni, from an interview, buying and planting a tree costs approximately $650 plus additional annual maintenance costs that slowly increase. The forestry department would also need to rely on soil cells, which are structures that allow trees to grow efficiently in urban environments without harming nearby infrastructure and costs $7,500 per tree. However, under this policy option, the City already owns the land to plant trees, meaning it has the least	**MEDIUM** It is difficult to measure the exact UHI effects increasing tree canopy would have in La Crosse's context. Given the nuance of heat mitigation, we scored increasing tree canopy as medium. Trees use evapotranspiration, which combines evaporation and transpiration, where water collected from plants is released to cool the surrounding air and surfaces. The area of planting trees affects heat mitigation as the surface temperature on asphalt decreased by 10.8 °F compared to grass at 5.4 °F (Rahman et al. 2020). However, the literature surrounding the effectiveness of trees reducing UHI varies on the number, size, density, and species of vegetation.	**MEDIUM** Our group ranks this alternative's equitable impact as medium because it could help lower-income and minority households, but there could be some unintended negative consequences. The environmental justice aspect of urban tree canopy can help alleviate health disparities among different neighborhoods and mitigate intra-UHIs through cooling effects with evapotranspiration and increased shade. However, previous research shows that increasing urban canopy can increase housing and property prices, which may increase the likelihood of ecological gentrification (Donovan et al. 2021).	**MEDIUM-LOW** While increasing tree canopy does have other benefits beyond heat mitigation, pocket parks and green roofs offer significantly more positive extra benefits, which is why our analysis scored positive externalities medium-low for tree canopy. La Crosse is particularly vulnerable to flooding due to combinations of contextual factors for being geographically flat between the bluffs and the Mississippi River and large snowpacks from winters that melt and increase the river depth. Urban canopy benefits stormwater management as trees can absorb and filter rain. However, pocket parks and green roofs offer similar stormwater and carbon sequestration benefits. Therefore, given that pocket parks and green

	administrative burden compared to pocket parks and green roofs.			roofs offer more positive external benefits, increasing tree canopy scored medium-low.
Pocket Parks	**MEDIUM-LOW** Due to the high up-front cost, our analysis scores the feasibility of pocket parks as medium-low. The cost ranges from tens of thousands to half a million dollars (Office of Real Estate Services 2015; Faraci 1967). Furthermore, the City would have to re-zone any land they would have to purchase. Our analysis added medium to the ranking because maintenance costs will likely be low over the long term. Compared to tree canopy expansion across the City, a pocket park is in one location, making ongoing maintenance easier.	**MEDIUM** Given that the park would provide micro-level cooling, our analysis scored pocket parks as medium. Since the literature surrounding the effectiveness of parks varies on the shape, size, species of vegetation, and tree canopy size, there is no precise estimate of how much a pocket park would reduce UHI (Feyisa, Dons, and Meilby 2014). Nonetheless, studies have shown that the shade effect of trees in parks is much more impactful than other shade-providing infrastructure (Shashua-Bar, Pearlmutter, and Erell 2009). While the concentration of trees allows parks to have a more significant cooling effect than trees planted in a line, most of the cooling effects from trees are localized to the park.	**MEDIUM** Our analysis ranked pocket parks right in the middle in terms of a successful policy that would improve equity. While adding one park does reduce the Gini coefficient, the City of La Crosse would have to create more than one pocket park to get the Gini coefficient as close to zero as possible. Since the implementation of pocket parks will be slow due to the high fixed cost, it could take years to have an equitable distribution of green space.	**HIGH** In addition to increasing tree canopy and heat mitigation, parks provide community benefits: 1. Economic benefits a. Increase local tax base and property values of surrounding neighborhoods b. Park increases stormwater retention saving retention facility costs. 2. Health and environmental benefits a. Improve water quality, protect groundwater, prevent funding, and other environmental benefits. b. Encourage residents in surrounding areas to be more active. 3. Social importance a. An important place for family and friends gathering. (National Recreation and Park Association n.d.)

Green Roofs	**LOW** The immediate costs and implementation hurdles resulted in our ranking the feasibility of this alternative low. While green roofs lead to energy savings in the long run, they have high up-front costs. The EPA estimates green roofs "$10 per square foot for simpler extensive roofing, and $25 per square foot for intensive roofs" (2022). Furthermore, factors such as load-bearing capacity, waterproofing ability, sun/wind exposure, zoning restrictions, and flatness, would all have to go into the consideration before implementing a green roof.	**MEDIUM** Overall, studies surrounding heat mitigation and actual temperature changes per green roof are lacking, so it is difficult to truly measure the exact effects in La Crosse's context. According to the EPA, green roofs could potentially lower the surface temperature of the actual roof by 30 to 40°F while decreasing city-wide ambient temperatures by up to 5 °F, which is significant for heat mitigation. Furthermore, since green roofs decrease the annual energy cost, they also actively reduce greenhouse gas emissions that increase UHI. However, how much heat mitigation is done, depends on the type of green roof and the vegetation on it. For example, larger and denser green roofs do more heat mitigation but are more expensive.	**LOW** Green roof expansion does not incorporate low-income housing or privately owned buildings/homes where inhabitants lack access to AC (and where high heat event public health risks are most felt). Green roofs are not only an expensive venture, but their immediate effects are not always felt by vulnerable populations. While the creation of green roofs will mitigate heat and benefit the City, the majority of the beneficial immediate effects will be felt by the inhabitants of the buildings themselves.	**HIGH** Besides decreasing the urban island heat effect, green roofs: 1. Economic benefits a. Energy savings because green roofs decrease cooling and heating load (EPA 2022). 2. Environmental benefits a. Reduce the building's carbon footprint (EPA 2022). Improve water quality, protect groundwater, prevent funding, and other environmental benefits (The Center for Clean Air Policy 2011). 3. Reduce noise pollution a. Studies have found that green roofs can reduce noise pollution in nearby city street traffic (Renterghem 2018).

Appendix B: Descriptive Statistics

Note: Analysis at the census tract level of all census tracts making up La Crosse, including those that only partially overlap with the City. As a result, this analysis captures a population that is somewhat larger than the City itself.

Table 1. City of La Crosse Demographics and Environmental Metrics

Total population	82,708
Percent of population aged 65+	15.1%
Percent of population that is white alone, non-Hispanic	90.0%
Percent of population below Federal Poverty Level	17.6%
Percent of population with a disability	11.6%
Percent of population aged 25+ with less than a high school education	5.4%
Median census tract summer average land surface temperature	86.8 °F
Median census tract maximum temperature anomaly	10 °F
Median census tract percent tree canopy	9.1%
Median census tract percent impervious surfaces	37.2%

Census Tracts 8, 10, and 11.01 collectively have the least percent tree canopy, greatest percent impervious surfaces, and greatest summer average land surface temperatures.

Table 2. Priority Census Tract Demographics and Environmental Metrics

	Census Tract 8	Census Tract 10	Census Tract 11.01
Total population	3,434	3,717	2,037
Percent impervious surfaces	55.3% (1.24)	58.3% (1.38)	63.3% (1.62)
Percent tree canopy	4.0% (0.99)	4.2% (0.97)	2.8% (1.06)
Summer average land surface temperature	93.7 °F (1.57)	94.8 °F (1.80)	93.9 °F (1.61)
Percent minority population	11.6% (0.33)	9.6% (-0.25)	2.1% (-1.37)
Percent below FPL	19.1% (0.24)	16.9% (0.11)	12.3% (-0.17)
Percent 65+	7.9% (-1.40)	13.4% (-0.42)	16.2% (0.08)
Percent disabled	7.4% (-1.10)	13.1% (0.29)	13.4% (0.37)
Percent 25+ with less than HS	2.8% (-0.76)	5.8% (0.26)	3.7% (-0.46)

(Gilbert n.d.).

Z-scores in parentheses.

Appendix C: OLS Results

Tree Canopy Regression Results

	(1)	(2)
	Percentage of Tree Canopy in a Census Tract	Percentage of Tree Canopy in a Census Tract
Percentage of Minorities in Census Tract	-0.277*	-0.546
	(-2.15)	(-1.09)
Percentage of People Living Under the Federal Poverty Limit in Census Tract	-0.186**	-0.265
	(-3.25)	(-1.83)
c.minoritypercentpercent#c.povertypercentpercent (Interacted Minority and Poverty Variable)		0.00955
		(0.64)
_cons	19.71***	21.83***
	(6.08)	(4.04)
N	54	54

t statistics in parentheses
* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

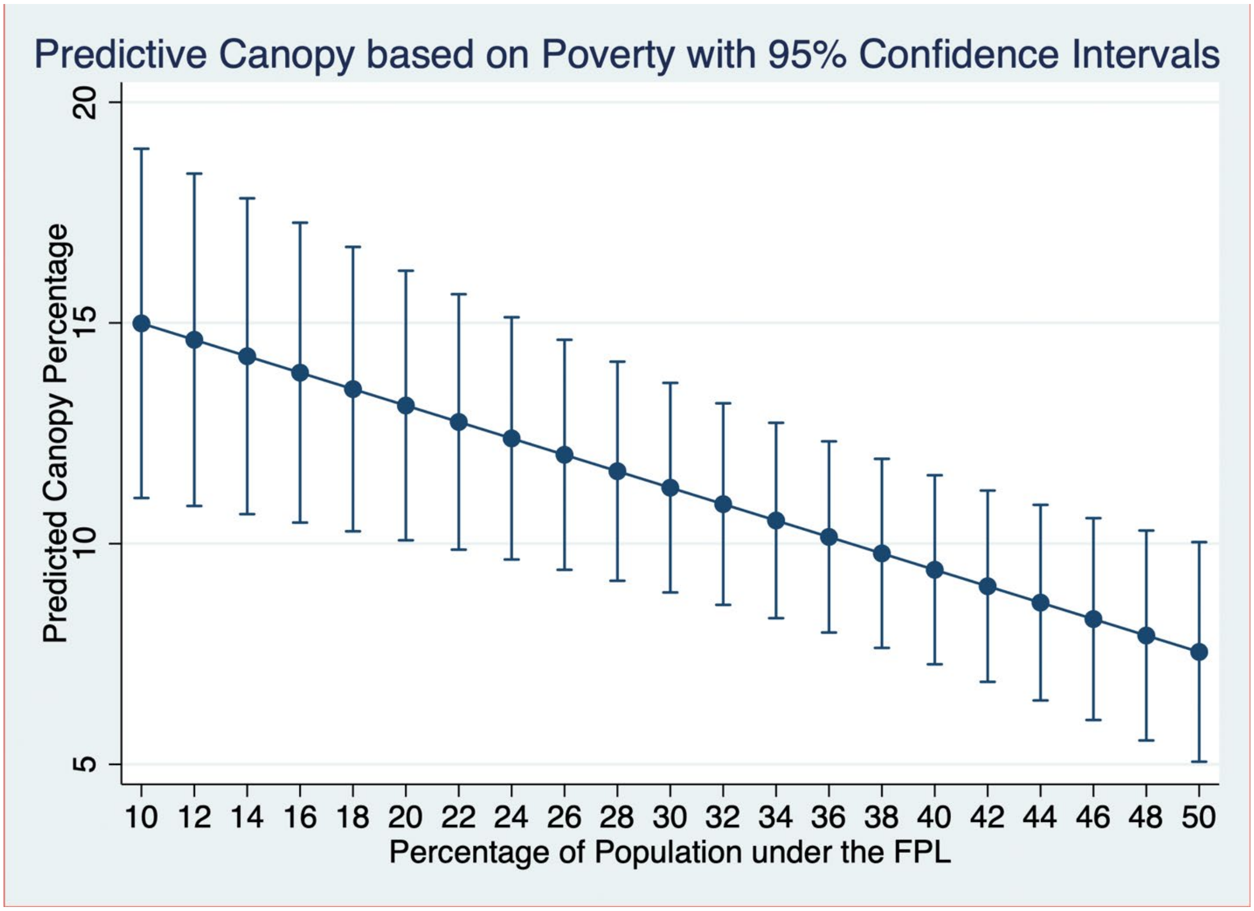


Figure 1: Illustration of Census Block Group Predicted Tree Canopy Percentage by Block Group Poverty Percentage

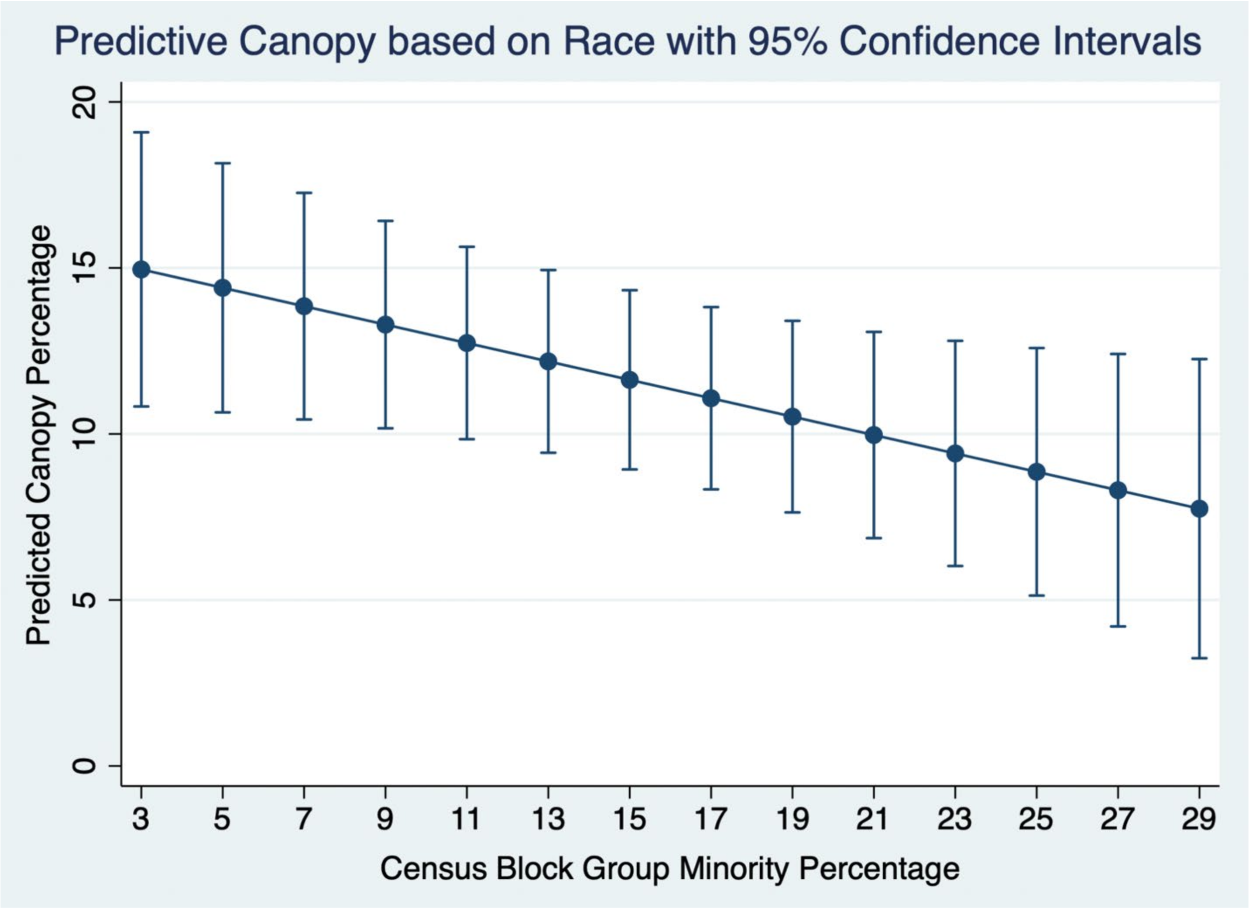
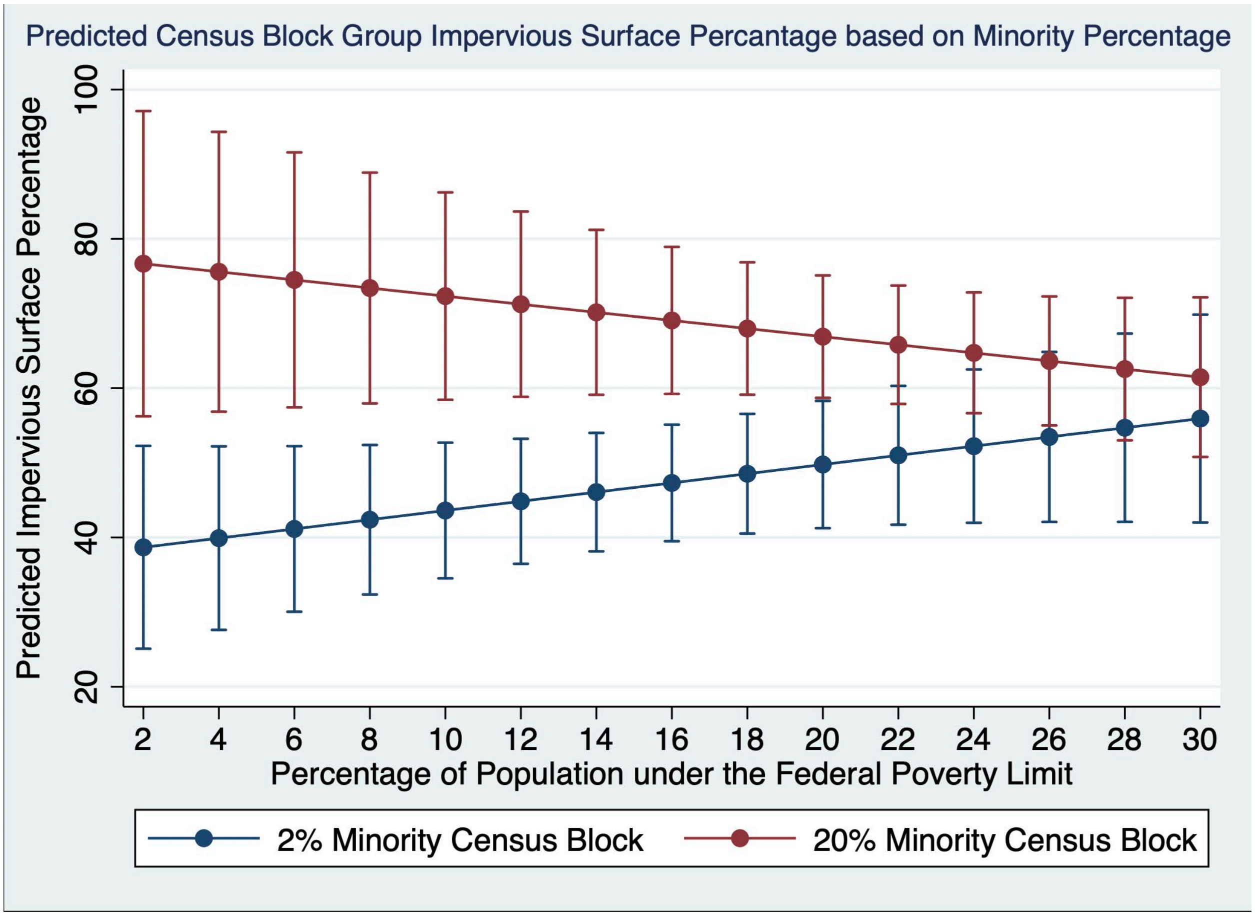


Figure 2: Illustration of Census Block Group Predicted Tree Canopy Percentage by Block Group Minority Percentage

Impervious Surface Regression Results

	(1)	(2)
	Percentage of Impervious Surfaces in a Census Tract	Percentage of Impervious Surfaces in a Census Tract
Percentage of Minorities in Census Tract	0.429	2.240*
	(0.66)	(2.46)
Percentage of People Living Under the Federal Poverty Limit in Census Tract	0.215	0.745
	(0.95)	(1.57)
c.minoritypercentpercent#c.povertypercentpercent (Interacted Minority and Poverty Variable)		-0.0644
		(-1.56)
_cons	47.21***	32.97***
	(7.39)	(3.66)
N	54	54

t statistics in parentheses



* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$

Figure 3: Illustration of Census Block Group Predicted Impervious Surface Percentage by Block Group Minority Percentage

Appendix D: Census Bureau Definitions

Our analysis uses both the Federal Poverty Limit and Census Bureau Definition of Poverty to measure poverty in La Crosse. We use the Census Bureau definition of minority population to measure the minority population in the City. The definitions of these measures can be found below.

Federal poverty limit

A measure of income issued every year by the Department of Health and Human Services (HHS). Federal poverty levels are used to determine your eligibility for certain programs and benefits, including savings on marketplace health insurance, and Medicaid and CHIP coverage. The 2023 federal poverty level (FPL) income numbers below are used to calculate eligibility for Medicaid and the Children's Health Insurance Program (CHIP). 2022 numbers are slightly lower and are used to calculate savings on Marketplace insurance plans for 2023 ("Federal Poverty Level (FPL)" 2023).

Federal poverty level (FPL)

Family size	2022 income numbers	2023 income numbers
For individuals	$13,590	$14,580
For a family of 2	$18,310	$19,720
For a family of 3	$23,030	$24,860
For a family of 4	$27,750	$30,000
For a family of 5	$32,470	$35,140
For a family of 6	$37,190	$40,280
For a family of 7	$41,910	$45,420
For a family of 8	$46,630	$50,560
For a family of 9+	Add $4,720 for each extra person	Add $5,140 for each extra person

Census Bureau Definition of Poverty

For a detailed description of the Census Bureau’s measurement of poverty, please visit https://www.census.gov/topics/income-poverty/poverty/guidance/poverty-measures.html.

Census Bureau Definition of Minorities

For a detailed description of the Census Bureau’s measurement of poverty, please visit https://www.census.gov/topics/population/race/about.html.

Appendix E: Maps

Map of Priority Census Tracts

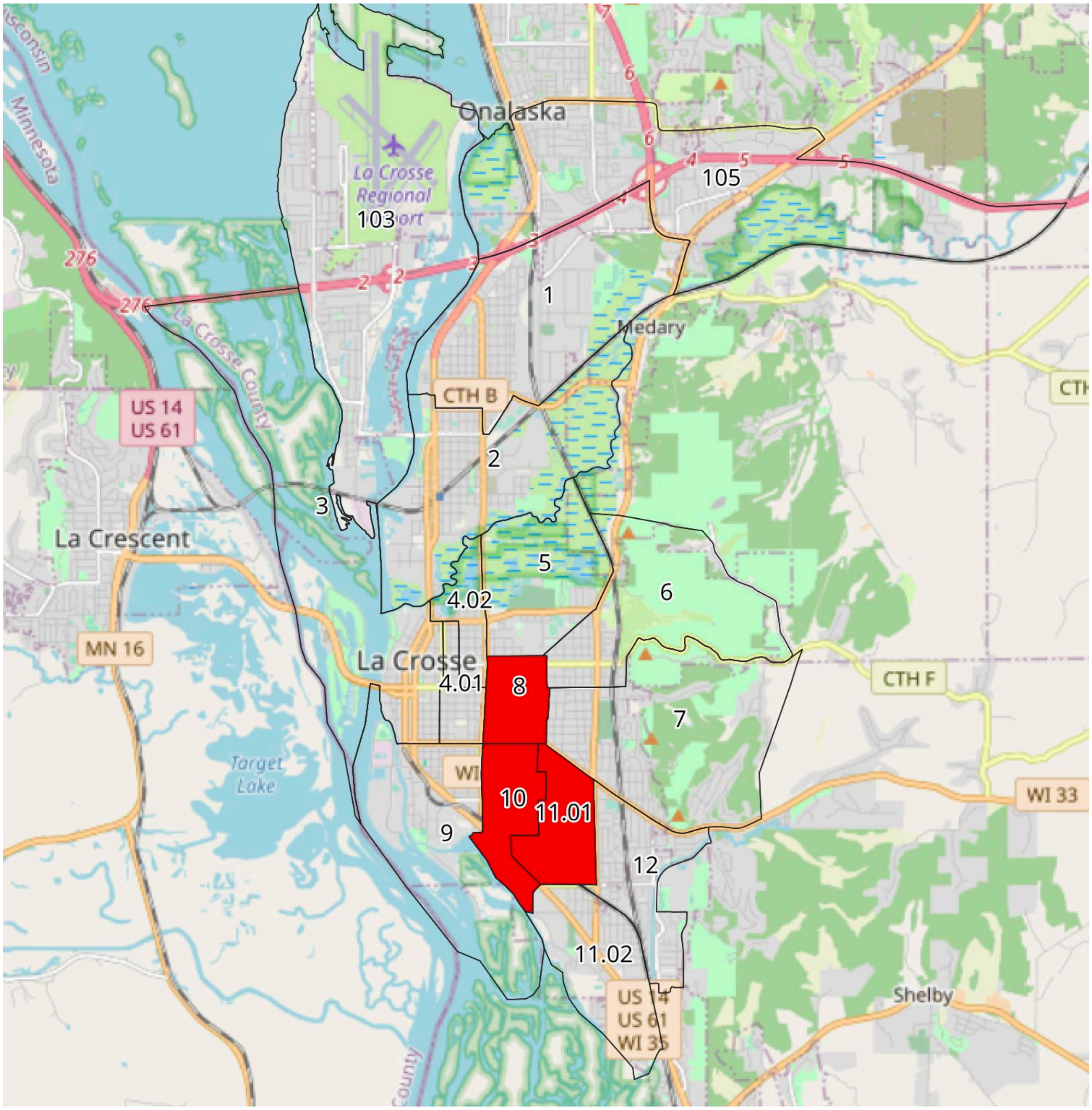


Figure 3: Map Showing Location of Priority Census Tracts in La Crosse

Heat Map of Tree Canopy Distribution

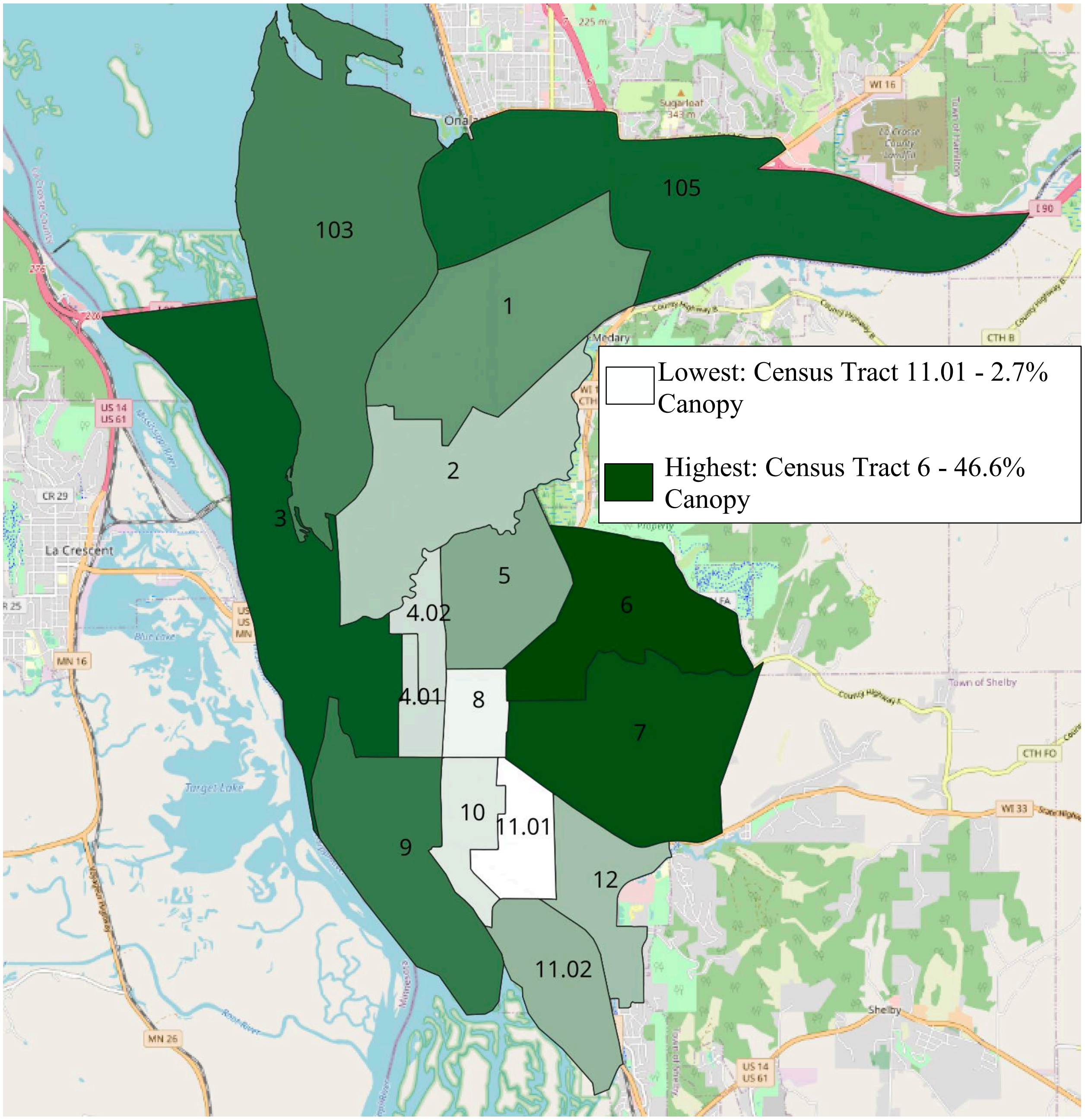


Figure 4: Heat Map of Tree Canopy Distribution by Census Tract

Heat Map of Impervious Surface Distribution

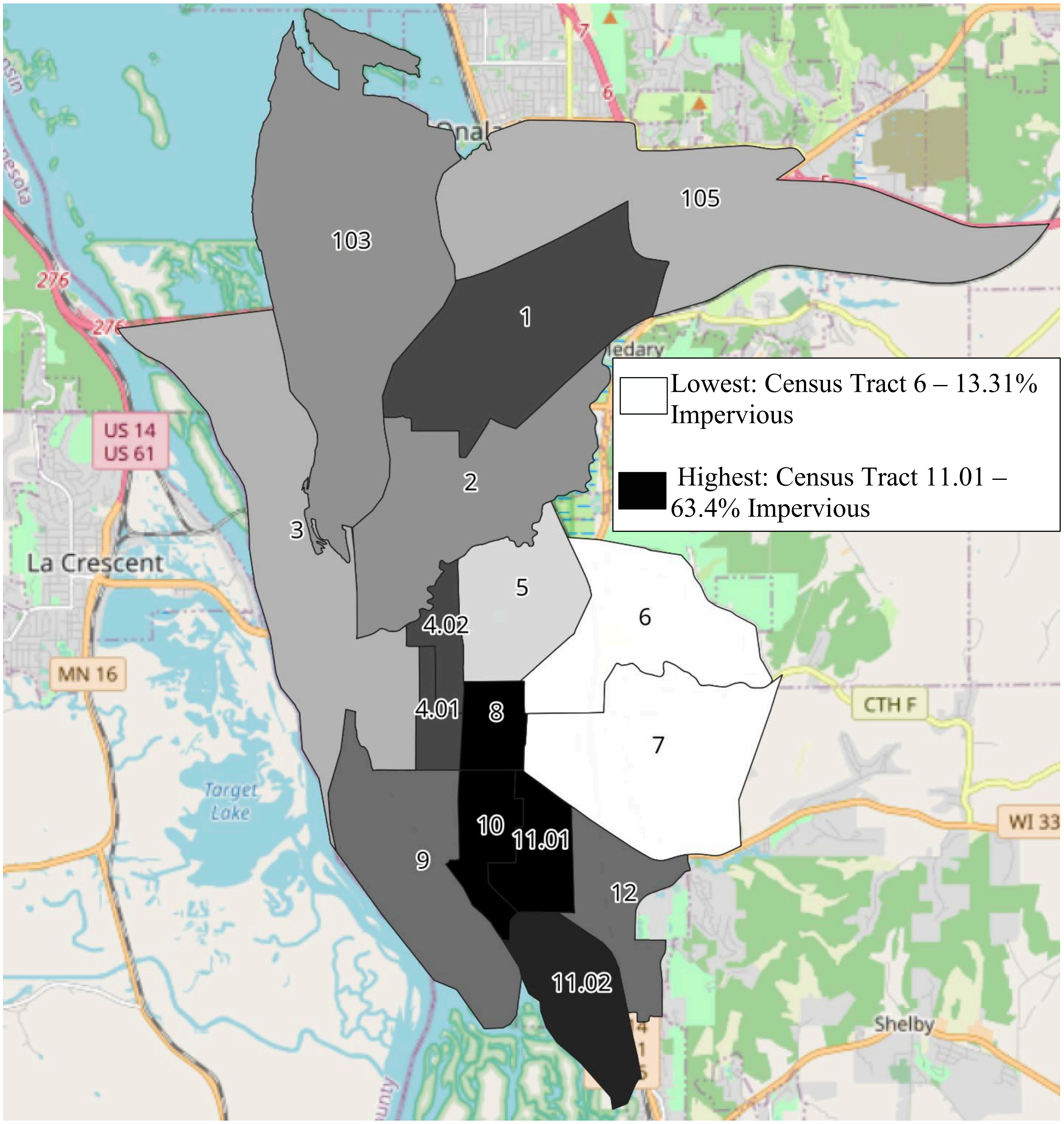


Figure 5: Heat Map of Impervious Surface Distribution by Census Tract

Heat Map of Summer High Heat Distribution

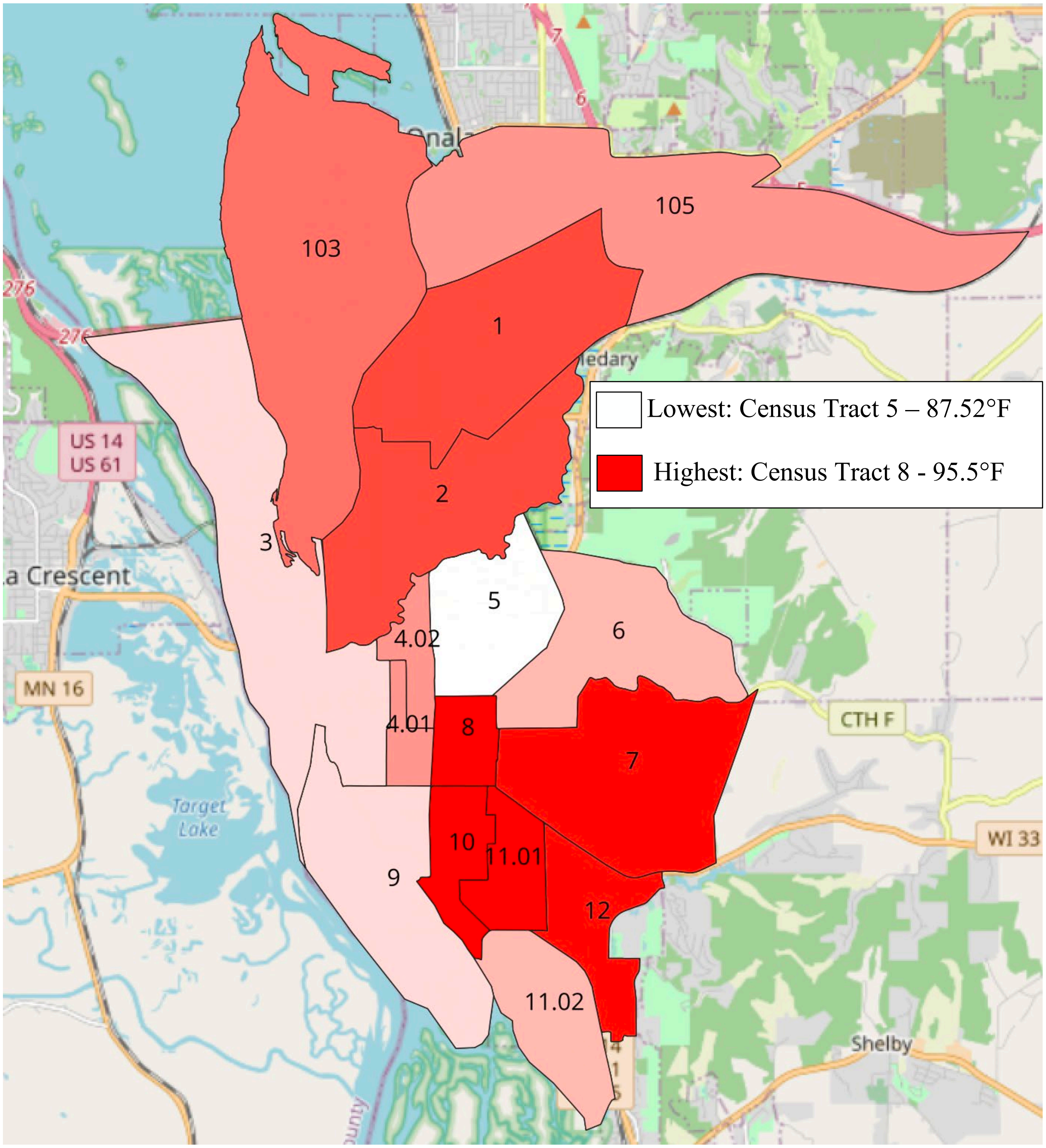


Figure 6: Heat Map of Highest Recorded Land Surface Temperature in Each Census Tract

Heat Map of Population Density

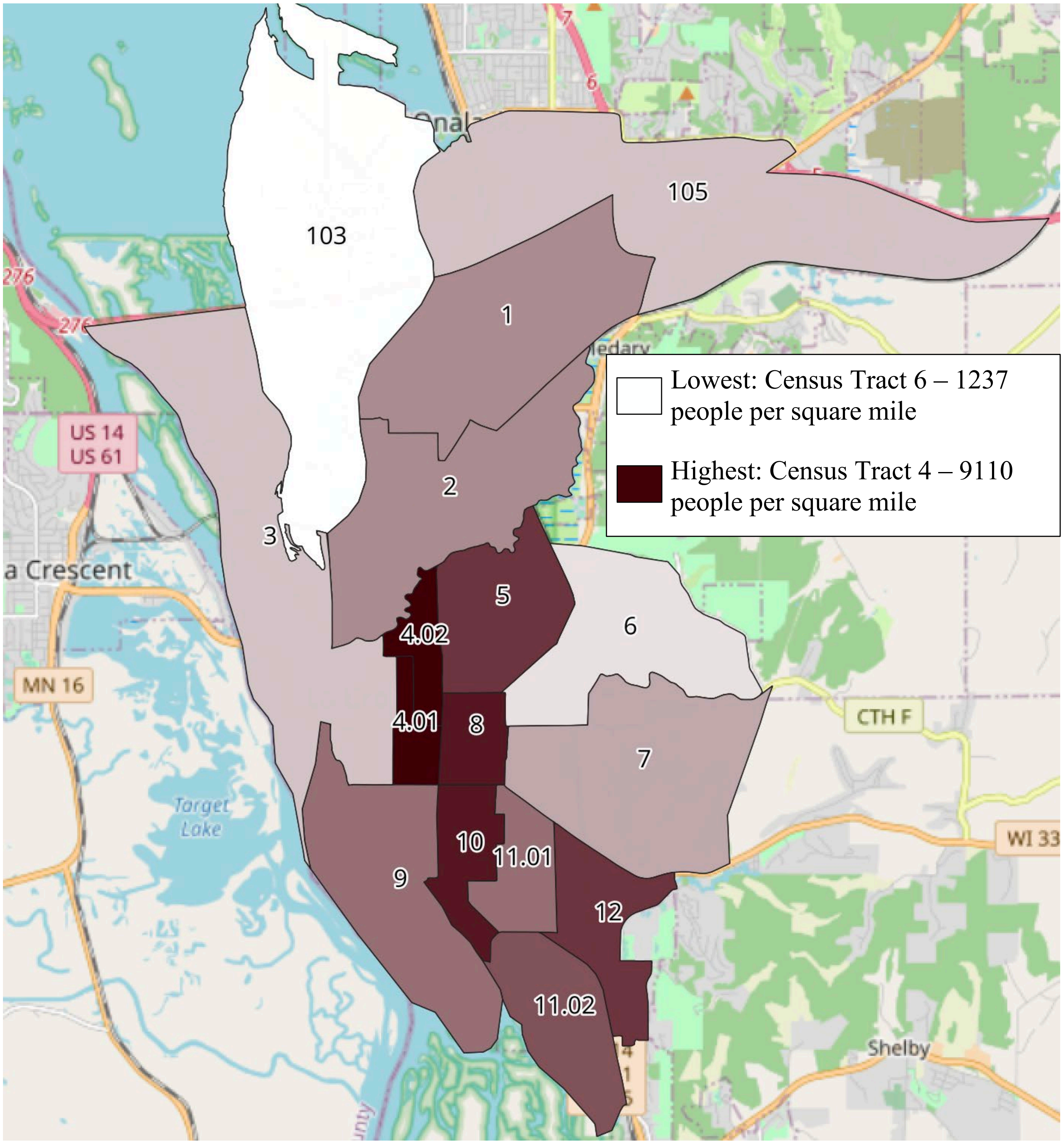


Figure 7: Heat Map of Population Density by Census Tract

Heat Map of Median Income

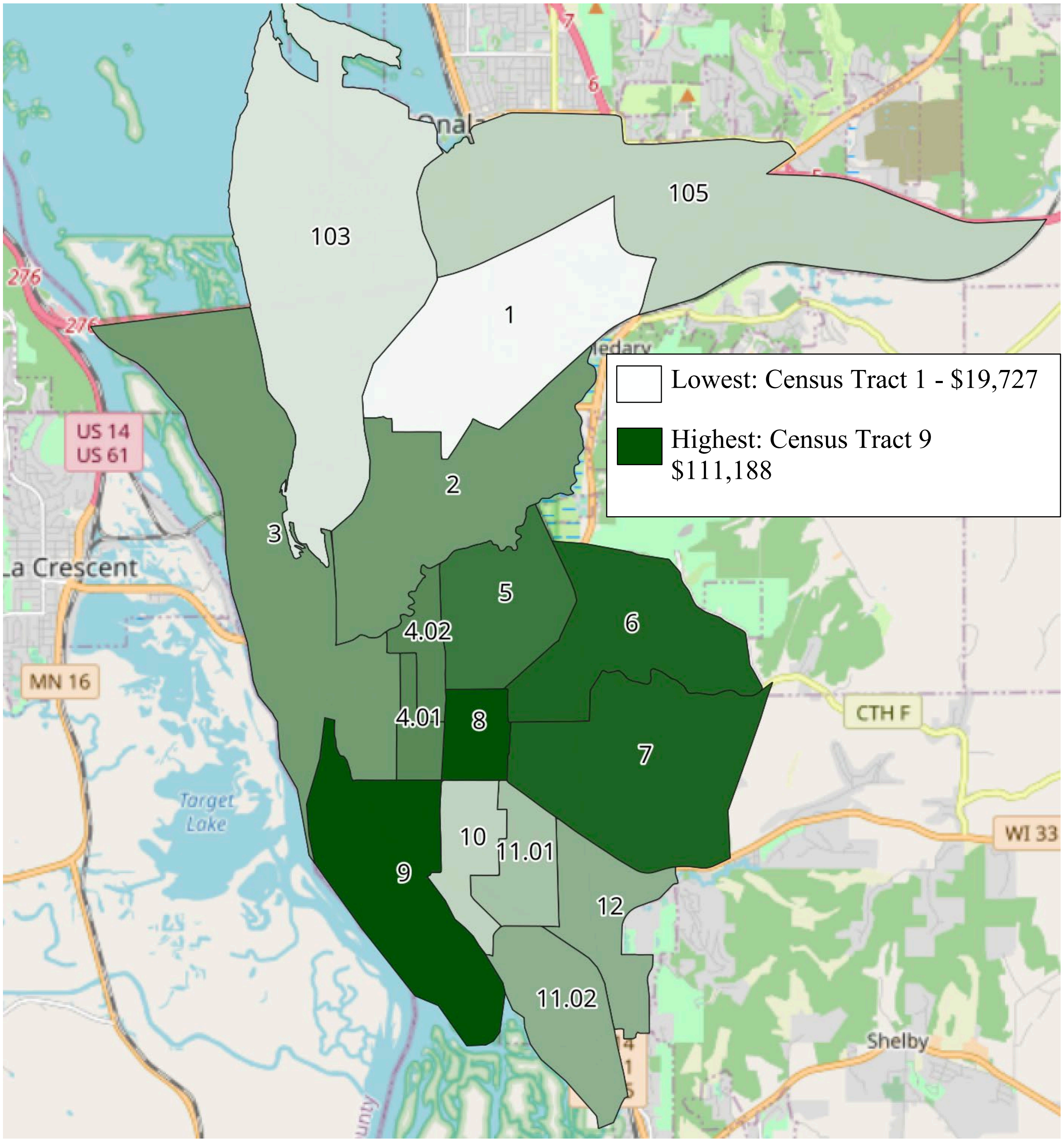


Figure 8: Heat Map of Median Income by Census Tract

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