# Assessing Heat Vulnerability and Access to Cooling Centers in Detroit, Michigan

Prepared by Corinne Kisner, Kevin Mulder, Benjamin VanGessel

Advisor Professor Joseph Grengs

Department of Urban and Regional Planning

University of Michigan

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**Abstract**
As climate change contributes to more frequent and intense extreme heat events, residents of Detroit are increasingly vulnerable to heat-related illness. In summer 2012, the City of Detroit provided cooling centers for relief from the heat. This study proposes a spatial methodology to analyze various geographies for heat vulnerable populations using the City of Detroit as a sample case. This study creates a vulnerability index to identify those areas of Detroit that are most at risk, and then calculated the service area of each cooling center for pedestrians and bicyclists. We determined that 79% of Detroit's most vulnerable population is within a 15 minute bike ride of a cooling center, but only 30% can reach a cooling center within a 15 minute walk. Therefore, we recommend that the city examine its current allocation of cooling centers and aim to strategically locate resources to improve the spatial coverage of this increasingly important service and improve the effectiveness of emergency response measures during future extreme heat events.

## Introduction / Background

Climate change is the defining challenge of the 21st Century. With increasing certainty and consensus, the scientific community reports that anthropogenic greenhouse gas emissions are rapidly altering global climate patterns (IPCC, 2007). The human experience of climate change differs within geographies, with spatial variation even within a relatively small region. For example, in Detroit, the average annual temperature from 1980-2010 has increased by 1.4°F, whereas the average annual temperature for Ann Arbor has only increased by 0.2°F over the same period (GLISA, Arbor; GLISA, Detroit). Although 1.4°F is a seems like a nominal change, a small increase in average annual temperature drastically increases the probability of extreme weather events such as heat waves, droughts, and torrential rains.

With these local climatic alterations come a host of human health impacts. In general, hotter days and longer and more frequent heat waves increase the potential for heat-related illnesses and death (Altman, 2012). Table 1 illustrates the projected increase in excessive heat event days due to climate change in cities across the United States; by 2099, Detroit is estimated to experience 36 excessive heat event days per summer, up from 9 days on average between 1975-1995 (Altman, 2012). This increase will be linked to an average of 48 excessive heat-attributable deaths per year, up from the average of 5.5 heat-related deaths annually between 1970 and 2004 (Kalkstein et al., 2010). The City of Detroit's official response to the increasing frequency and intensity of heat waves is a system of 21 cooling centers (City of Detroit, 2012). A cooling center is a temporary air conditioned public space where residents can seek relief from extreme heat. However, Detroit's sprawling geographic area and relatively low population density create challenges to efficiently providing city services to mitigate human health impacts.

## Problem Definition

We first seek to identify which areas of Detroit are most vulnerable to extreme heat events based on land cover type and socioeconomic risk. Second, we calculate the service area of each cooling center to evaluate whether they are adequately located to serve areas that are vulnerable to excessive heat effects. The City of Detroit presently designates 21 cooling centers co-located within existing facilities -- 17 are located in public library branches and four in recreation centers – therefore, this memorandum seeks to analyze how well the City's response adequately addresses the need of heat vulnerable individuals.

## Methodology

### *Vulnerability Index Variables*

Our analysis incorporated five primary factors that contribute to increased risk of heat-related illness: poverty status, educational attainment, access to a vehicle, and age -- both old and very young. To arrive at these five contributing demographic variables for a vulnerability index, we conducted a literature review of studies measuring sensitivity to extreme heat. This research revealed the importance of neighborhood socioeconomic position, or group-level factors, in predicting risk of illness, independent of the influence of the same variable measured at the individual level (Diez Roux 2004; Reid et al., 2009; Smoyer 1998). For this reason, and due to the difficulty in obtaining individual-level income or health data, we conducted our vulnerability analysis at the census block group level.

Two indicators of community-level socioeconomic status are associated with increased heat-related mortality: percentage of the population without a high school diploma, and percentage of the population living in poverty (Curriero et al., 2002). Research has demonstrated a link between low educational attainment and poor health (Brunner, 2001), and specific studies of heat-related deaths in cities across the U.S. found greater mortality rates among individuals with low levels of education (Medina-Ramon et al. 2006; O'Neill et al. 2003) because educational attainment is often a measure of quality of life, occupation and living conditions (O'Neill et al. 2003). Using census data obtained from Social Explorer, we calculated the percentage of each census block group holding no more than a high school diploma, as shown in Figure 1. Similarly, wealth mediates risk of heat-related death by increasing access to air conditioning and other opportunities to avoid heat. On an individual level, "there is little doubt that poverty leads to ill health" (Phipps, 2002), and community poverty levels have also been demonstrated to play a role in heat-related mortality (Curriero et al. 2002). Therefore we used census data to calculate the percentage of each census block group living under 200% of the federal poverty line, shown in Figure 2.

A significant body of literature has found old age to be a prominent vulnerability factor during extreme heat, effecting both hospital admission rates (Knowlton et al. 2009; Semenza et al. 1999) and mortality (Conti et al. 2005; Fouillet et al. 2006; Hutter et al. 2007; Naughton et al. 2002; Stafoggia et al. 2008; Whitman et al. 1997). Since we could not access individual-level age data by household, we used census data to calculate the percentage of each census block group over age 65, as shown in Figure 3. Similarly, very young people are also susceptible to extreme heat (Ready.gov, 2012); for each census block group, we calculated the percentage of people under age 5, as shown in Figure 4. Finally, we included access to vehicles as a contributing factor in the vulnerability index, since those without a vehicle are less able to drive to air conditioning or a cooler refuge during extreme heat events. Using census data, we mapped the percentage of each census block group lacking vehicle access, as shown in Figure 5.

Our analysis also included two land cover variables that have an influence on the effects of extreme heat events: impervious surfaces and tree canopy. Land use decisions resulting in the high concentration of low albedo, high-heat capacitance, impervious surfaces such as concrete, coupled with disparities in the distribution of tree cover, interact to make certain areas of the city much warmer in summer months; therefore, more vulnerable to extreme heat events (Landsberg, 1981). This effect is termed the Urban Heat Island effect (UHI effect) (Bornstein 1968; Oke 1973). Figure 6 shows the near surface temperatures throughout Southeast Michigan and Detroit (Hove, 2011) demonstrating the range of temperatures and highlighting distinctions of particular surface features such as roads. The average annual temperatures of the UHI areas of Detroit can be 1.8-5.4°F warmer than surrounding areas (GLISA, Detroit). However, vegetation cover has a negative influence on temperature, thereby decreasing vulnerability to extreme heat (Serrano, 2003). To analyze local variations in UHI effect we obtained land cover data from the United States Geological Survey Global Visualization Viewer (GloVis) available at usgs.glovis.gov; a more detailed explanation of this process is available in the appendix, and the land cover map is shown in Figure 7. Using this land cover data we calculated the percentage of each census block group's land cover that is impervious surface and that is tree canopy, shown in Figures 8 and 9, respectively. Since impervious surface and tree cover are essentially complements under this methodology, we chose to only incorporate one -- tree canopy cover -- into our analysis to avoid double-counting the impact of land cover.

In order to understand the cumulative risk of heat-related illness as determined by the six variables shown in Table 2, we calculated a vulnerability index. To do so required converting the variables to compatible scales so they could be combined to produce a single index. In order to normalize the variables, we computed the z-scores for each individual variable by subtracting the mean of each variable from each block group's value and then dividing the result by the standard deviation of the sample. This ensures that each of the rescaled variables has a mean of zero and a standard deviation of 1. The rescaling allows for the variables to be directly combined with or without factor weights, the relative contribution to vulnerability, to produce the final index of relative vulnerability. For the purposes of this investigation, we assigned a factor weight of 1 to each variable to produce the map shown in Figure 10.

*Cooling Center Service Areas*

To evaluate the effectiveness of Detroit's cooling center network, we computed service areas -- geographic zones based on access to particular amenity or service -- by three main modes of reaching the cooling centers: walking, bicycling, and driving. Due to Detroit's poor and consistently declining level of bus service, we excluded service area by bus from our study (Kleinfelter NPR, 2012). Our analysis seeks to show how well citizens can access the centers by each of the three selected modes. While automobiles can often provide the most immediate source of relief, whether by air conditioning in the vehicle or by quickest transport to a cooling center, 24% of Detroit households do not own a vehicle (American Community Survey, 2010). Additionally, within households that do own a vehicle, individual members may be without vehicle access during extreme heat events for a variety of reasons. In contrast to autos, walking and bicycling represent relatively inexpensive and reliable modes that are accessible to most of the population at any time, so including these modes in the analysis was an important consideration.

We used national working safety standards to determine the appropriate range of cooling center service areas. The Occupational Safety & Health Administration (OSHA) has determined threshold limit values (TLV) for external working conditions. The TLVs are designed to prevent body temperature from exceeding 100.4° F when experiencing light to moderate exertion (OSHA, 1999). Table 4 shows different proportions of working and resting, given varying temperature conditions and workloads. As shown, in 90° F heat events, each 15 minute period of light activity should be matched by 45 minutes of rest. Therefore, we used 15 minutes of outdoor exposure for the service area range of walking and cycling.

We then calculated the distance that pedestrians, bicyclists, and drivers can cover in 15 minutes. For pedestrians, 15 minutes translates into 0.8 miles, using an average speed of between 2.8 mph and 3.4 mph based on pedestrian age (Levine et al 1999; Knoblauch et. al, 1996). For cyclists, 15 minutes limits travel distance to 2.3 miles, using an average speed of 9.3 mph (NYDOT, 2006).

Automobile speeds vary, largely due to road type. Therefore, using categorical census feature class codes (CFCC2), which group roads into seven major categories, we approximated speed for each road segment, as shown in Table 5. This allowed us to calculate the distance a driver could reach in 15 minutes while accounting for differences in travel speeds throughout the city.

We created a 0.8 mile buffer from each cooling center to approximate the generally linear range of walking, as shown in Figure 11. To calculate the service areas for cyclists and motorists, however, we created a network dataset from existing road data, and we analyzed the resulting network to develop a more realistic picture of bike and automobile access. However, there are challenges in building the required network dataset to handle each service area:

- The available Detroit road data does not contain an elevation field, so the network contains more junctions than exist in reality. For example, many local roads are built over Interstate 75, but the network treats these overpasses as intersections.
- Bicycles are not allowed on interstates and various other road segments.

While there is no measure used to establish elevation data, the extensive grid network of roads throughout Detroit provides several alternative routes to the false intersections used in the analysis. Many of the road segments classified as A1 in Table 5, where false intersections occur, are paralleled by service drives or other roads. Therefore, we contend that even if the improper junctions were removed, the automobile service areas would not significantly change. To prevent cyclists from using limited-access roads and access ramps, we removed the CFCC2 categories A1, A5, and A6 from the bicycle service area; the result is shown in Figure 12.

**Findings**

As Figure 10 illustrates, heat vulnerability is fairly geographically distributed. In general, the most vulnerable census block groups are clustered roughly in the downtown area and the least vulnerable are in the northeast area of the city. The service areas of the cooling centers varied by travel mode, as expected. All of Detroit proper is accessible from a cooling center by car trips of five minutes or less, which is not shown. Calculations of the population served by each cooling center reveal that roughly 29% of Detroit's population is within a 15 minute walk of a cooling center, and 85% is within a 15 minute bike ride, as shown in Table 7.

Figures 13 and 14 show the walking and bicycling service areas overlaid on the vulnerability index map. Combining the service areas with the vulnerability map allowed us to answer the research question of whether the most vulnerable areas of Detroit are adequately served by the city's cooling centers. We selected the top 20% most vulnerable census block groups, and we calculated, as shown in Table 8, that the cooling center walking service areas only served 30% of the population residing in census block groups considered extremely vulnerable. Additionally, the bicycle service areas serve 79% of the population residing in census block groups considered extremely vulnerable. In Figures 15 and 16, the 20% most vulnerable census block groups are highlighted to show the comparison of vulnerable block groups to walking and bicycling service area coverage.

## Limitations

While this study provides an adequate framework to determine community risk of heat-related illness, one major shortcoming of this analysis is that it does not incorporate population density. We evaluated each census block group's vulnerability, but did not adjust for population density to assess the number of people exposed to such conditions. Furthermore, additional vulnerability factors play a role in individual risk of heat-related illness or death: medical condition is especially relevant, but remained outside the scope of this analysis, largely due to the challenge of acquiring such data. Similarly, disability status and whether one lives alone can also contribute to vulnerability but we chose not to include them here, instead focusing on a smaller set of variables. Lastly, we elected to include the percentage of people living below 200% of the poverty level (a binary measure) rather than a census block group's median income (a continuous range of values). This decision stemmed from the literature suggesting that concentration of poverty within neighborhoods plays a significant role in individual risk, despite whether the same condition is observed at the individual level. However, further analysis might compare the difference in using median income as a measure of wealth rather than neighborhood poverty status.

Furthermore, additional analysis should evaluate the merits of changing the factor weights in the vulnerability index. We experimented with adjusting these coefficients -- for example, by counting the poverty variable or the tree canopy variable as twice as important -- to observe the changes to the vulnerability map. However, further research is needed to defend different weighting schemes; for this analysis, we chose to use equal factor weights, but greater investigation is merited in future studies. Once a weighting scheme is determined, the analysis of service area coverage will also need refinement. We examined the 20% most vulnerable census block groups, but the complexity of vulnerability factors mentioned above indicate that there are at-risk individuals in less vulnerable block groups who also will need accommodation. Our choice of the 20% most vulnerable block groups illustrates the issue at the locations of greatest need.

## Conclusion

According to these findings, the city's official response to extreme heat events -- cooling centers -- is only partially sufficient at addressing Detroit's needs. Using OSHA guidelines and service area analysis, less than 30% of Detroit's residents residing in the most vulnerable census block groups are served by the cooling center system when walking. We acknowledge that the cooling centers are co-located with existing libraries and recreation centers, and are therefore likely to be a cost-efficient service at present. However, additional cooling centers are needed to reach a more acceptable rate of coverage. While further research and cost-benefit analysis is needed to fully develop the cooling center network, our work shows that priority consideration should be given to the near-east side. A new cooling center at Gratiot and Warren, for example, would significantly improve cooling center service coverage, by walking and bicycling, for some of the most vulnerable residents of Detroit.

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## Appendix

**Primary Data and Sources**

We obtained data from the following sources to conduct our research:

2006-2010 American Community Survey (ACS).
US Census 2010 Tiger/Line Shapefiles.
City of Detroit: Cooling Center Locations, as of 6/19/2012.
USGS Global Visualization (GloVis) Viewer: Landsat 7 ETM+ GeoTiff Bands 2, 4, 7.

Land cover data: Developing a land cover raster for the City of Detroit is possible using the USGS Global Visualization Viewer (GloVis) available at usgs.glovis.gov. GloVis is an online search tool for selected satellite image data. The viewer allows access to all available image data from various earth-observing satellites. Landsat 7 ETM+, or Enhanced Thematic Mapper +, images are preferred because the optics and sensors deliver extremely precise measurements of aspects including moisture, temperature, and, for our purposes, land cover (NASA). Once at GloVis, the user simply needs to navigate over the desired area, select the image cell and download the Geotiff file. Because Detroit is near to a seam between GloVis scenes, it is necessary to download two scenes to capture the needed data. To convert to the Geotiffs to a usable form simply use the Composite Bands tool in the Raster Process Toolbox. To join the two rasters, use Mosaic, another Raster tool.

Detroit Temperature data: Developing a temperature raster for the City of Detroit is possible using the USGS Global Visualization Viewer (GloVis) available at usgs.glovis.gov. GloVis is an online search tool for selected satellite image data. The viewer allows access to all available image data from various earth-observing satellites. Landsat 7 ETM+, or Enhanced Thematic Mapper +, images are preferred because the optics and sensors deliver extremely precise measurements of aspects including moisture, temperature, and, for our purposes, land cover (NASA). Once at GloVis, the user simply needs to navigate over the desired area, select the image cell and download the Geotiff file. Because Detroit is near to a seam between GloVis scenes, it is necessary to download two scenes to capture the needed data. To convert to the Geotiffs to a usable form simply use the Composite Bands tool in the Raster Process Toolbox. To join the two rasters, use Mosaic, another Raster tool.

**Table 1**. Increases in the Number of Excessive Heat Event Days (EHE Days) Caused by Climate Change. (Peter Altman, 2012).

| Table 1: Increases in the Number of Excessive Heat Event Days (EHE Days) Caused by Climate Change | | | | | |
|---|---|---|---|---|---|
| Location | Average Number of EHE Days per Summer (Historical Average 1975-1995) | EHE Days Per Summer | | | |
| | | by Mid-Century (2045-2055) | | by End-of-Century(2090-2099) | |
| | | Climate Change Will Increase Per-Summer EHE Days by... | ...Making the New Total Number of EHE Days Increase to | Climate Change Will Increase Per-Summer EHE Days by... | ...Making the New Total Number of EHE Days Increase to |
| Atlanta, GA | 5 | 43 | 48 | 53 | 58 |
| Baltimore, MD | 8 | 37 | 45 | 61 | 69 |
| Birmingham, AL | 5 | 19 | 24 | 51 | 56 |
| Boston, MA | 11 | 40 | 51 | 60 | 71 |
| Buffalo, NY | 3 | 0 | 3 | 12 | 15 |
| Chicago, IL | 5 | 13 | 18 | 28 | 33 |
| Cincinnati, OH | 4 | 18 | 22 | 26 | 30 |
| Cleveland, OH | 5 | 0 | 5 | 12 | 17 |
| Columbus, OH | 5 | -1 | 4 | 11 | 16 |
| Dallas, TX | 11 | 11 | 22 | 26 | 37 |
| Denver, CO | 9 | 79 | 88 | 68 | 77 |
| Detroit, MI | 9 | 6 | 15 | 27 | 36 |
| Greensboro, NC | 8 | 51 | 59 | 62 | 70 |
| Hartford, CT | 6 | 25 | 31 | 52 | 58 |
| Houston, TX | 1 | 4 | 5 | 12 | 13 |
| Indianapolis, IN | 5 | 17 | 22 | 27 | 32 |
| Jacksonville, FL | 7 | 17 | 24 | 36 | 43 |
| Kansas City, MO | 7 | 31 | 38 | 41 | 48 |
| Los Angeles, CA | 1 | 59 | 60 | 87 | 88 |
| Louisville, KY | 8 | -3 | 5 | 21 | 29 |
| Memphis, TN | 9 | 9 | 18 | 31 | 40 |
| Miami, FL | 0 | 14 | 14 | 55 | 55 |
| Minneapolis, MN | 8 | 15 | 23 | 22 | 30 |
| New Orleans, LA | 5 | 3 | 8 | 49 | 54 |
| New York, NY | 11 | 44 | 55 | 64 | 75 |
| Newark, NJ | 8 | 47 | 55 | 60 | 68 |
| Philadelphia, PA | 6 | 48 | 54 | 67 | 73 |
| Phoenix, AZ | 7 | 77 | 84 | 68 | 75 |
| Pittsburgh, PA | 5 | 47 | 52 | 54 | 59 |
| Portland, OR | 4 | 38 | 42 | 47 | 51 |
| Providence, RI | 7 | 31 | 38 | 56 | 63 |
| Salt Lake, UT | 0 | 0 | 0 | 0 | 0 |
| San Antonio, TX | 5 | 18 | 23 | 25 | 30 |
| San Diego, CA | 1 | 38 | 39 | 60 | 61 |
| San Francisco, CA | 2 | 64 | 66 | 52 | 54 |
| San Jose, CA | 0 | 4 | 4 | 4 | 4 |
| Seattle, WA | 2 | 52 | 54 | 55 | 57 |
| St. Louis, MO | 11 | 24 | 35 | 34 | 45 |
| Tampa, FL | 3 | 33 | 36 | 56 | 59 |
| Washington, DC | 16 | 37 | 53 | 53 | 69 |
| Current average of EHE days per year... | 233 | | | | |
| Plus the additional EHE days climate change will cause annually by mid-century... | | 1,109 | | | |
| Results in more than five time as many EHE days by mid-century. | | | 1,342 | | |
| Plus the additional EHE days climate change will cause annually by the end of the century... | | | | 1,685 | |
| And the result is more than EIGHT TIMES as many EHE days by the end of the century. | | | | | 1,918 |

**Table 2. Vulnerability Index Variables**

| **Variable** | **Directionality (effect on vulnerability)** |
|---|---|
| Educational Attainment | Positive |
| Community Poverty Status | Positive |
| Age: over 65 | Positive |
| Age: under 5 | Positive |
| No Vehicle Access | Positive |
| Tree Canopy Cover | Negative |

**Table 3. Vulnerability Index Factor Weights**

| Variable | Directionality (effect on vulnerability) | Factor Weight |
|---|---|---|
| Educational Attainment | positive | + 1 |
| Community Poverty Status | Positive | + 1 |
| Age: over 65 | Positive | + 1 |
| Age: under 5 | Positive | + 1 |
| No Vehicle Access | Positive | + 1 |
| Tree Canopy Cover | Negative | - 1 |

**Table 4. Exertion Limits by Work Load, OSHA 1999**

| **Work/rest regimen** | **Light** | **Moderate** | **Heavy** |
|---|---|---|---|
| Continuous | 86ºF | 80 ºF | 77 ºF |
| 75% Work, 25% rest, each hour | 87 ºF | 82 ºF | 78 ºF |
| 50% Work, 50% rest, each hour | 89 ºF | 85 ºF | 82 ºF |
| 25% Work, 75% rest, each hour | 90 ºF | 88 ºF | 86 ºF |

**Table 5. Estimated Speed of Travel by Type of Road, City of Detroit, Year**

| CFCC2 | Type of Road | Mileage | Miles per Hour |
|---|---|---|---|
| A1 | Interstate Highways | 43.49 | 70 |
| A2 | Primary Roads without Limited Access | 8.22 | 55 |
| A3 | Secondary Roads | 56.79 | 55 |
| A4 | Local Roads | 2,788.71 | 30 |
| A5 | Vehicular Trail | - | 10 |
| A6 | Road with Special Characteristics | 60.43 | 10 |
| A7 | Other Thoroughfare | .54 | 3 |

**Table 6. Land Area of Service Areas in Proportion to Total**

| Detroit Block Groups | Square Miles | % of Whole |
|---|---|---|
| City of Detroit | 139.1 | 100.0 |
| Bike Service Area | 109.0 | 78.3 |
| Pedestrian Service Area | 33.8 | 24.3 |

**Table 7. Population of Service Areas in Proportion to Total**

| Detroit Block Groups | Population | % of Whole |
|---|---|---|
| City of Detroit | 759,340 | 100.0 |
| Bike Service Area | 643,525 | 84.7 |
| Pedestrian Service Area | 218,485 | 28.8 |

**Table 8. Percentage of The Top 20% Most Vulnerable Census Block Groups in Service Areas, in Proportion to Total**

| Detroit Block Groups | Square Miles | % of Land Area | Population | % of Population |
|---|---|---|---|---|
| City of Detroit | 139.1 | 100.0 | 759,340 | 100.0 |
| Vulnerable Area | 28.4 | 20.4 | 120,448 | 15.9 |
| *% Vulnerable Areas Served* | | | | |
| Pedestrian Access | 6.9 | 24.4 | 35,696 | 29.6 |
| Bicycle Access | 21.3 | 75.2 | 94,785 | 78.7 |

Figure 1. Educational Attainment by census block group, City of Detroit, 2010.

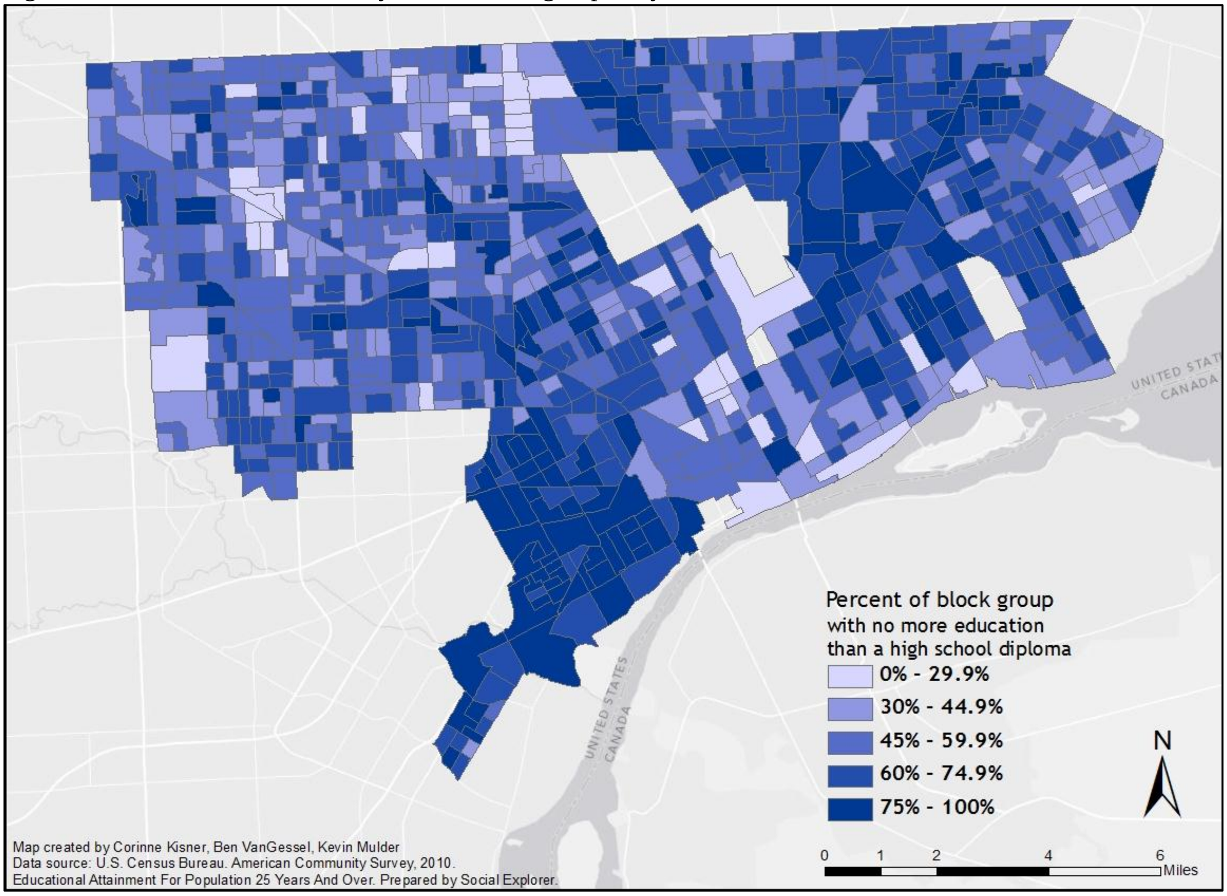


Figure 2. Poverty status by census block group, City of Detroit, 2010.

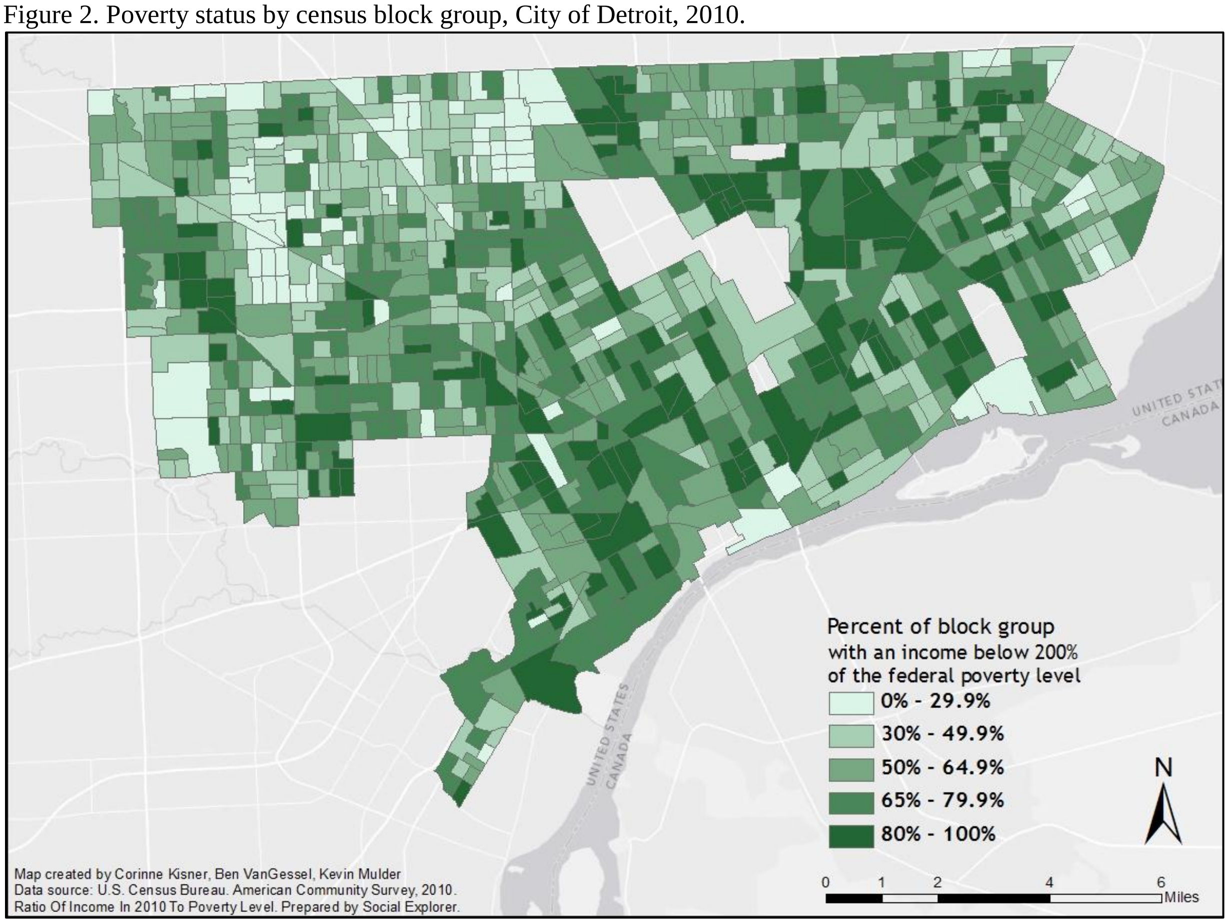

Figure 3. Percent of population over age 65 by census block group, City of Detroit, 2010.

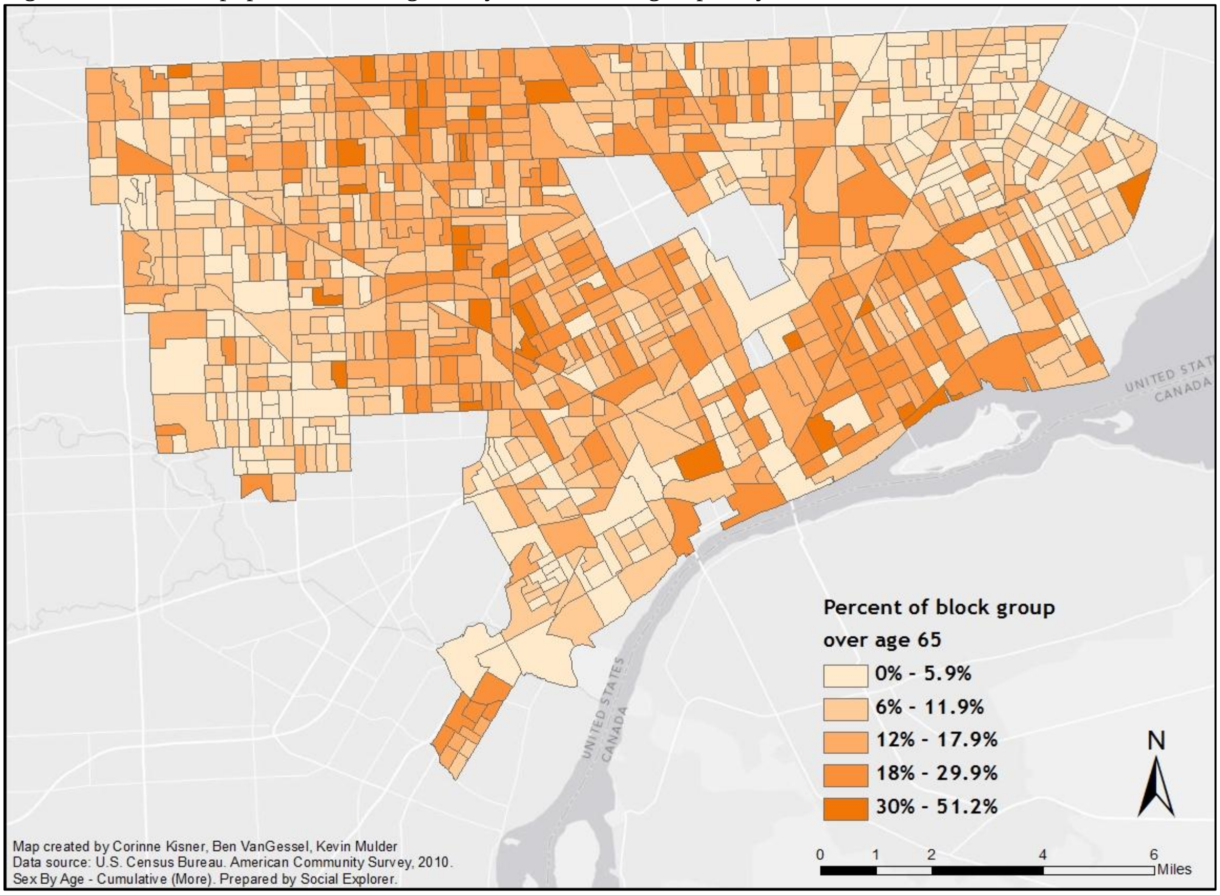


Figure 4. Percent of population under age 5 by census block group, City of Detroit, 2010.

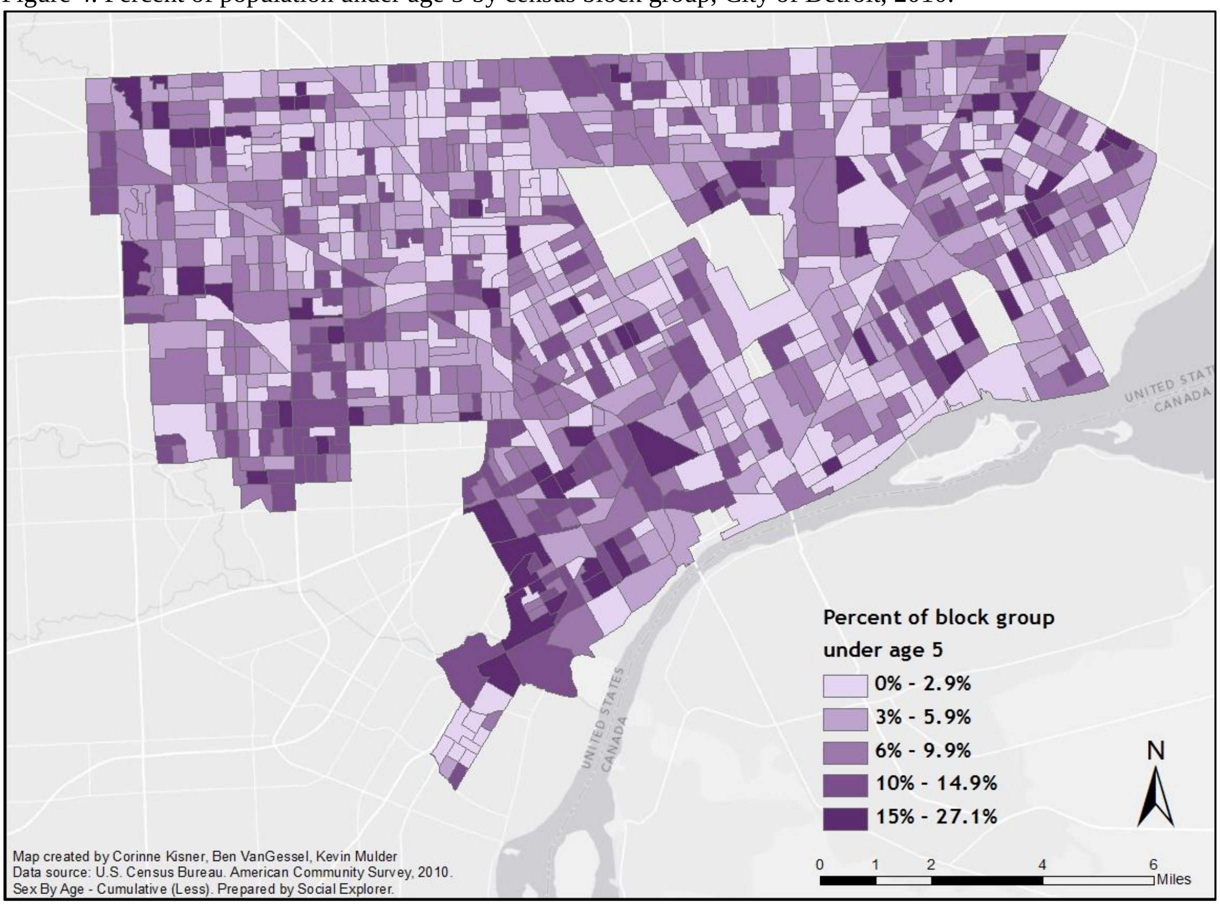

Figure 5. Percent of population lacking vehicle access by census block group, City of Detroit, 2010.

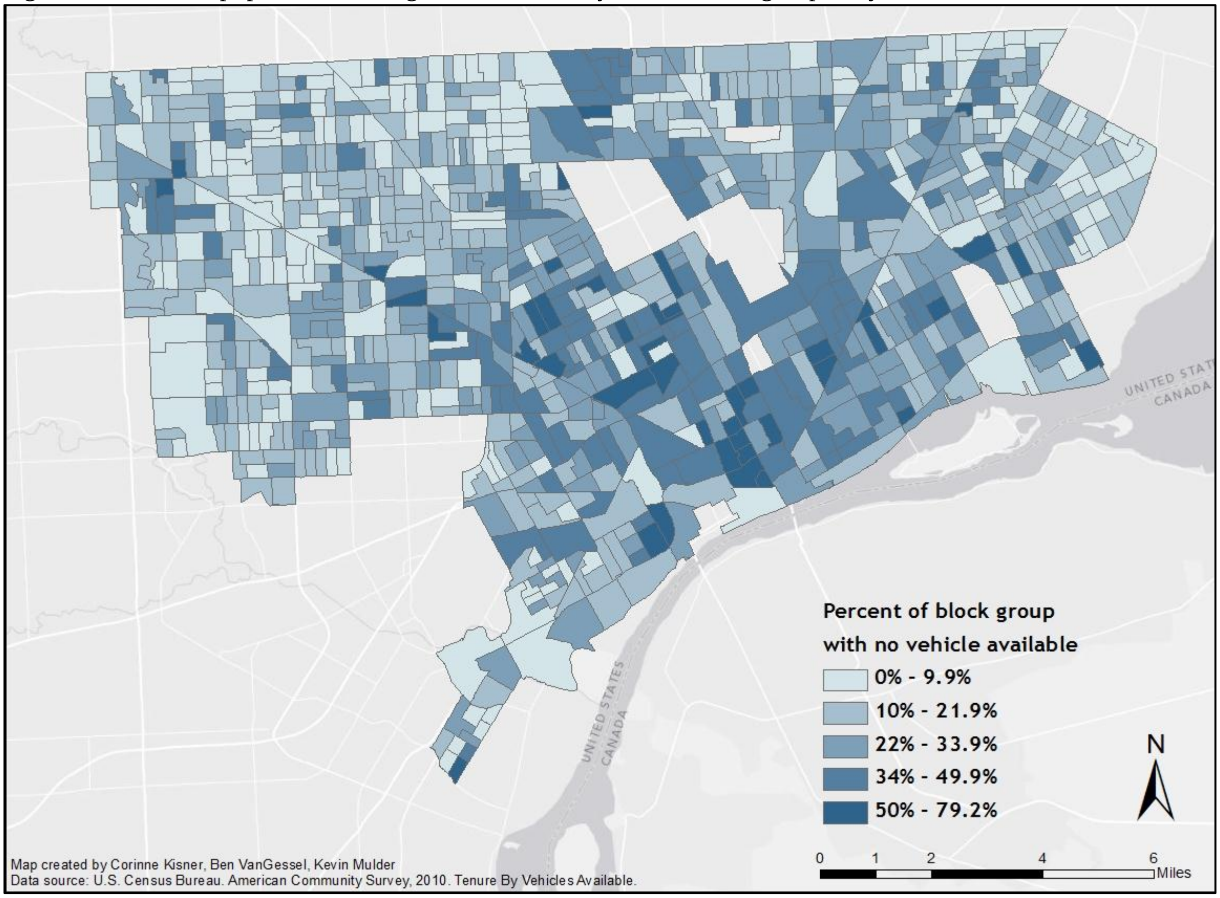


Figure 6. Regional near-surface temperatures, City of Detroit, 2011

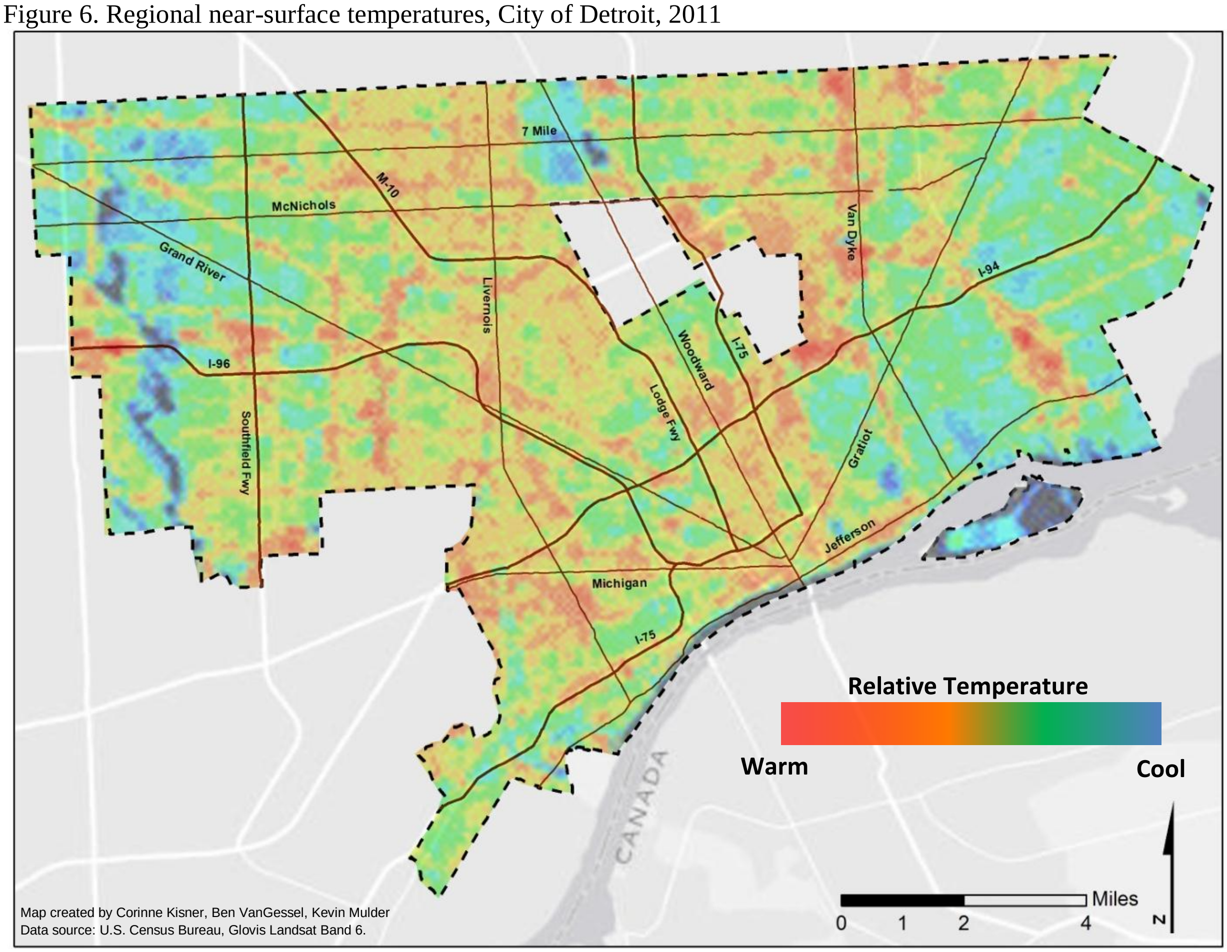

Figure 7. Land cover by 10' x 10' grid cell, City of Detroit, 2012.

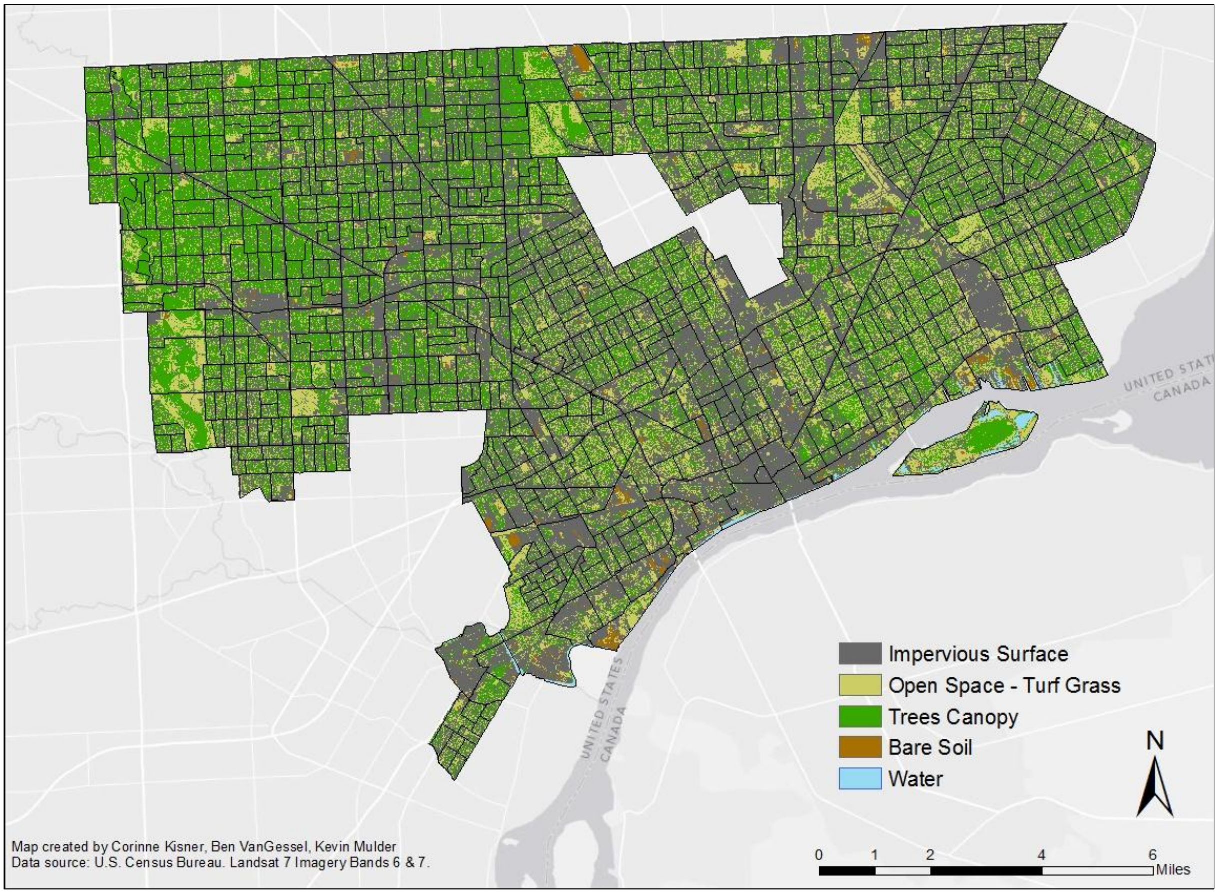


Figure 8. Percent impervious surface cover by census block group, City of Detroit, 2012.

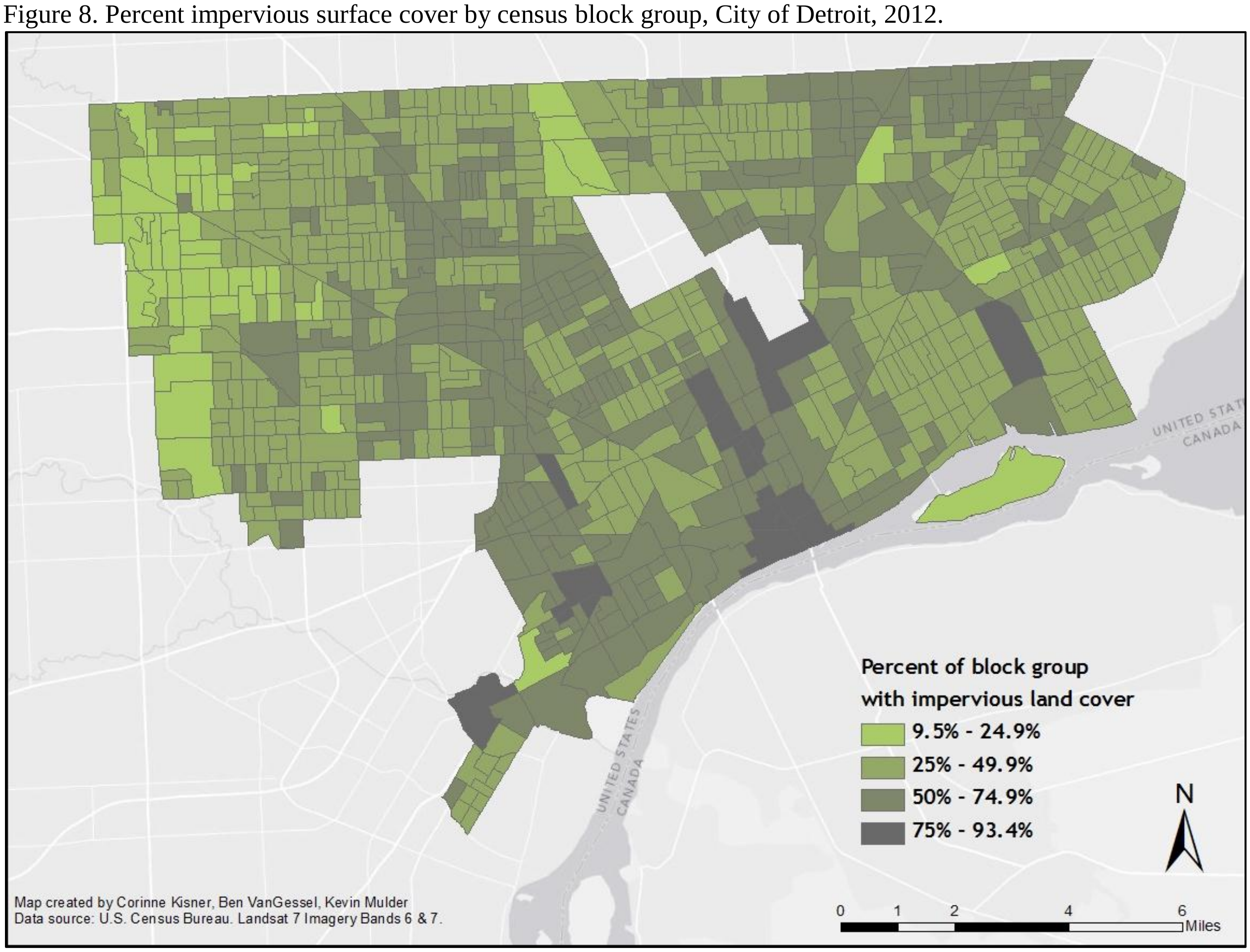

Figure 9. Percent tree canopy cover by census block group, City of Detroit, 2012.

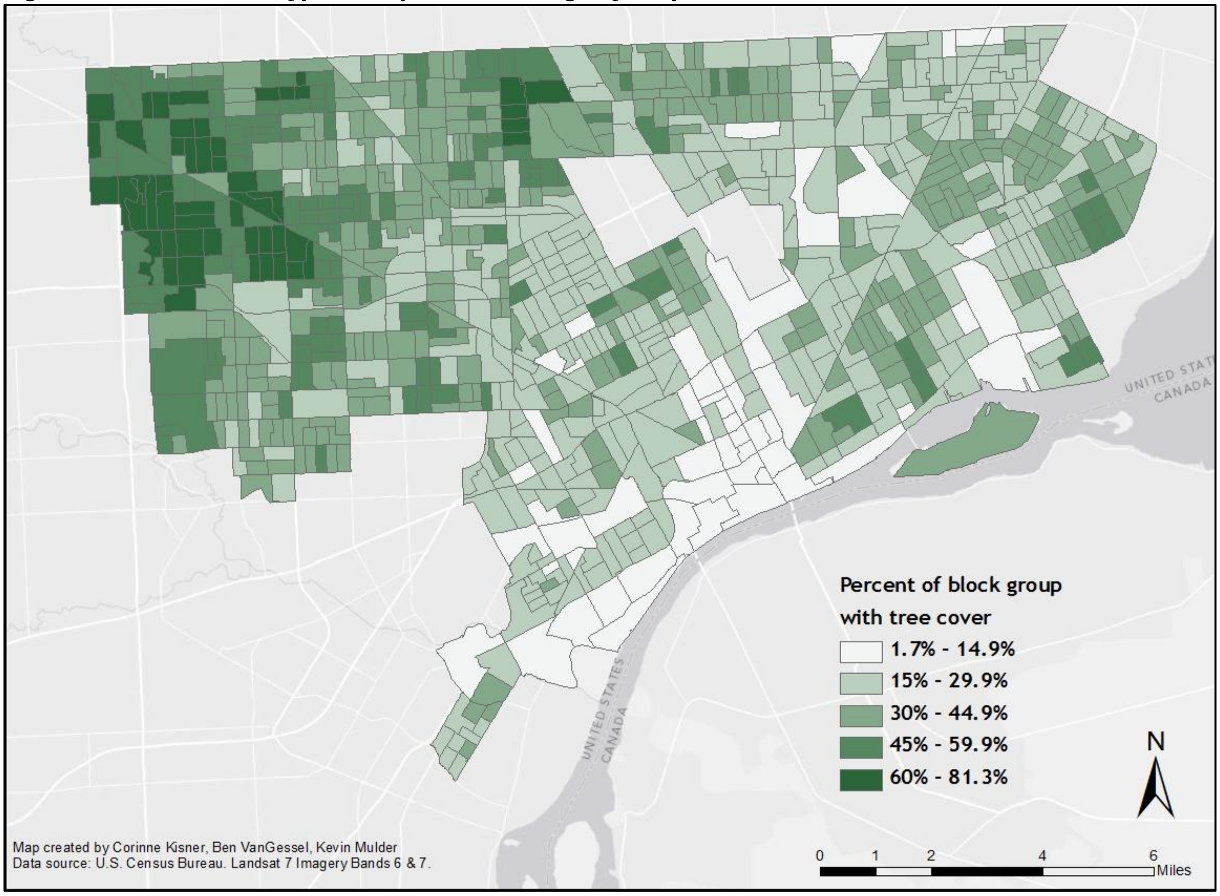


Figure 10. Vulnerability Index (factor weights of 1) by census block group, City of Detroit, 2010.

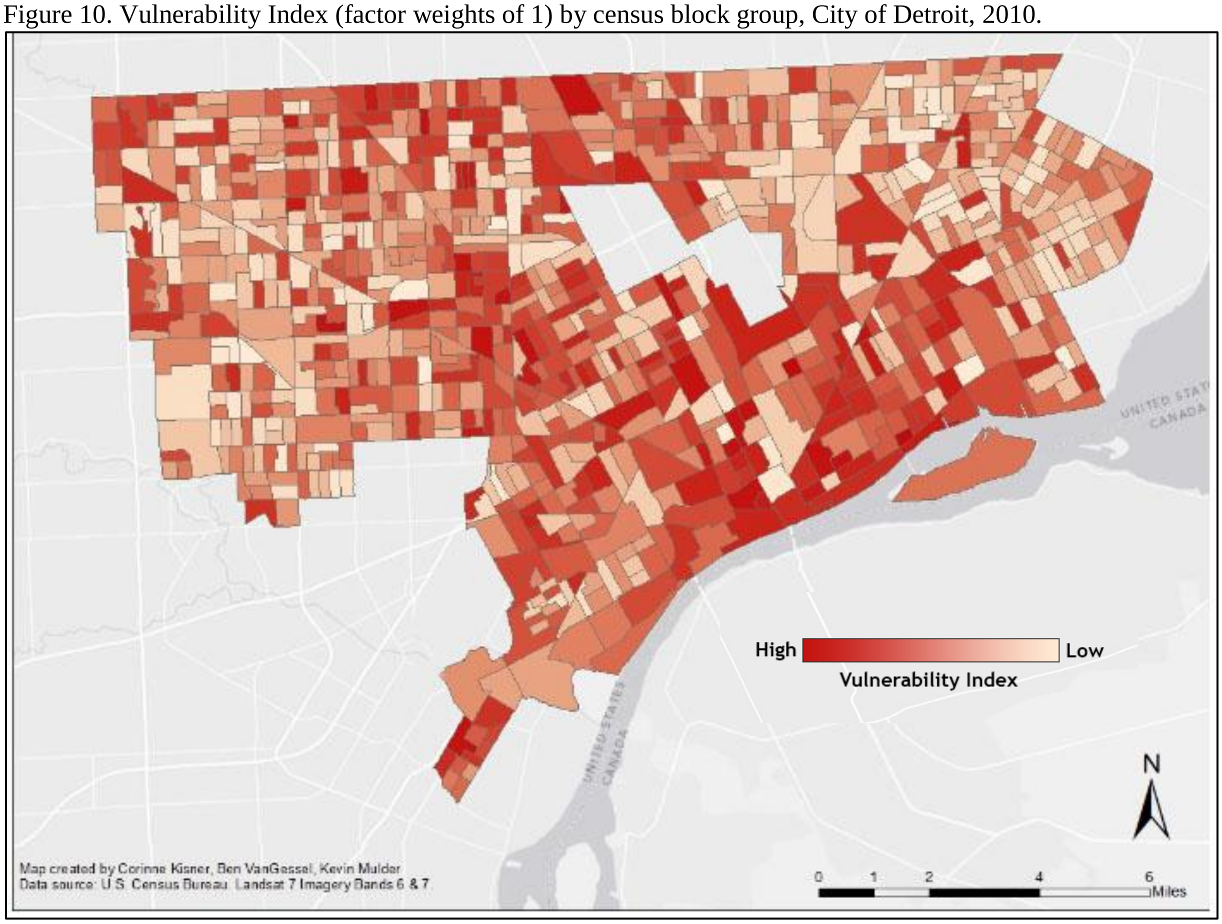

Figure 11. Pedestrian Service Area of Cooling Centers, City of Detroit, 2012.

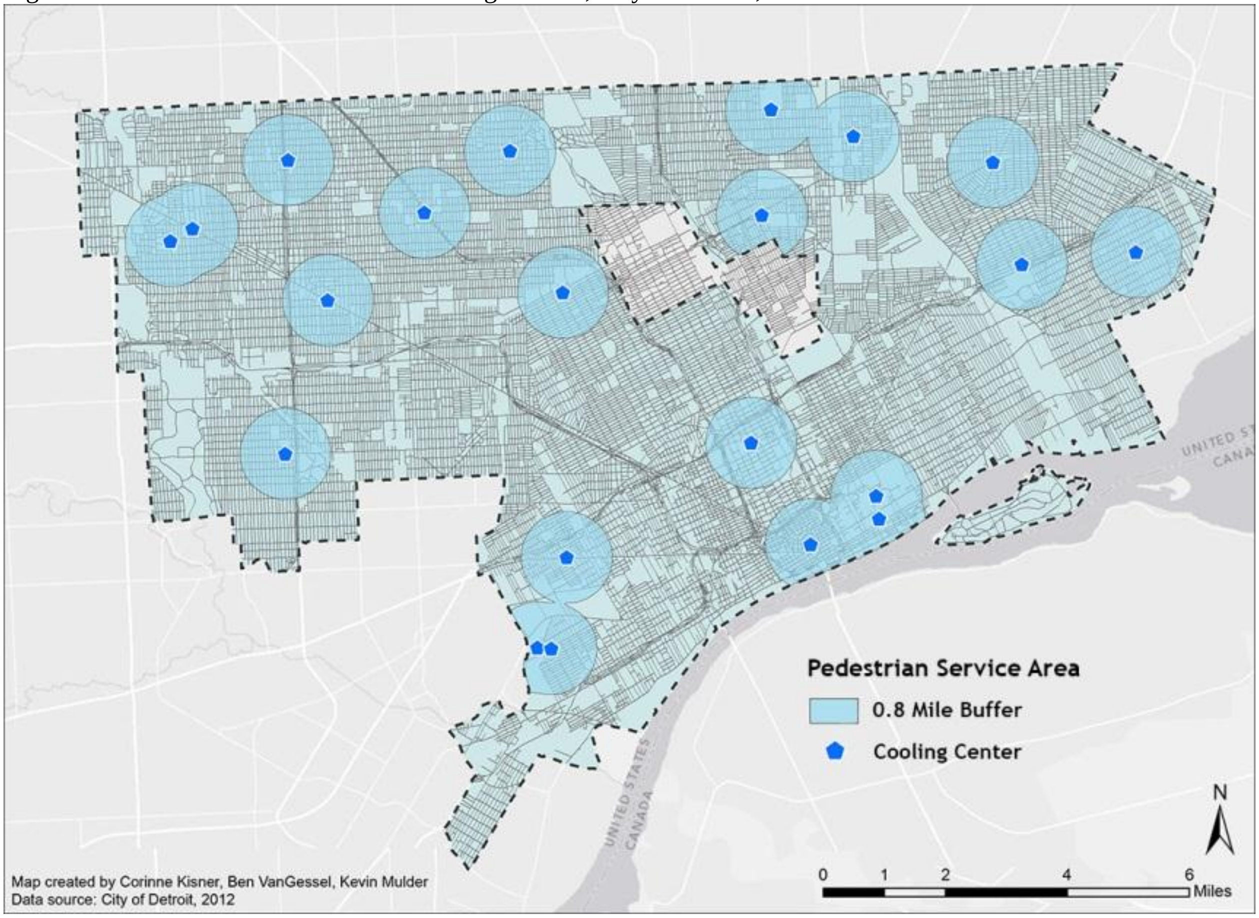


Figure 12. Bicycle Service Area of Cooling Centers, City of Detroit, 2012.

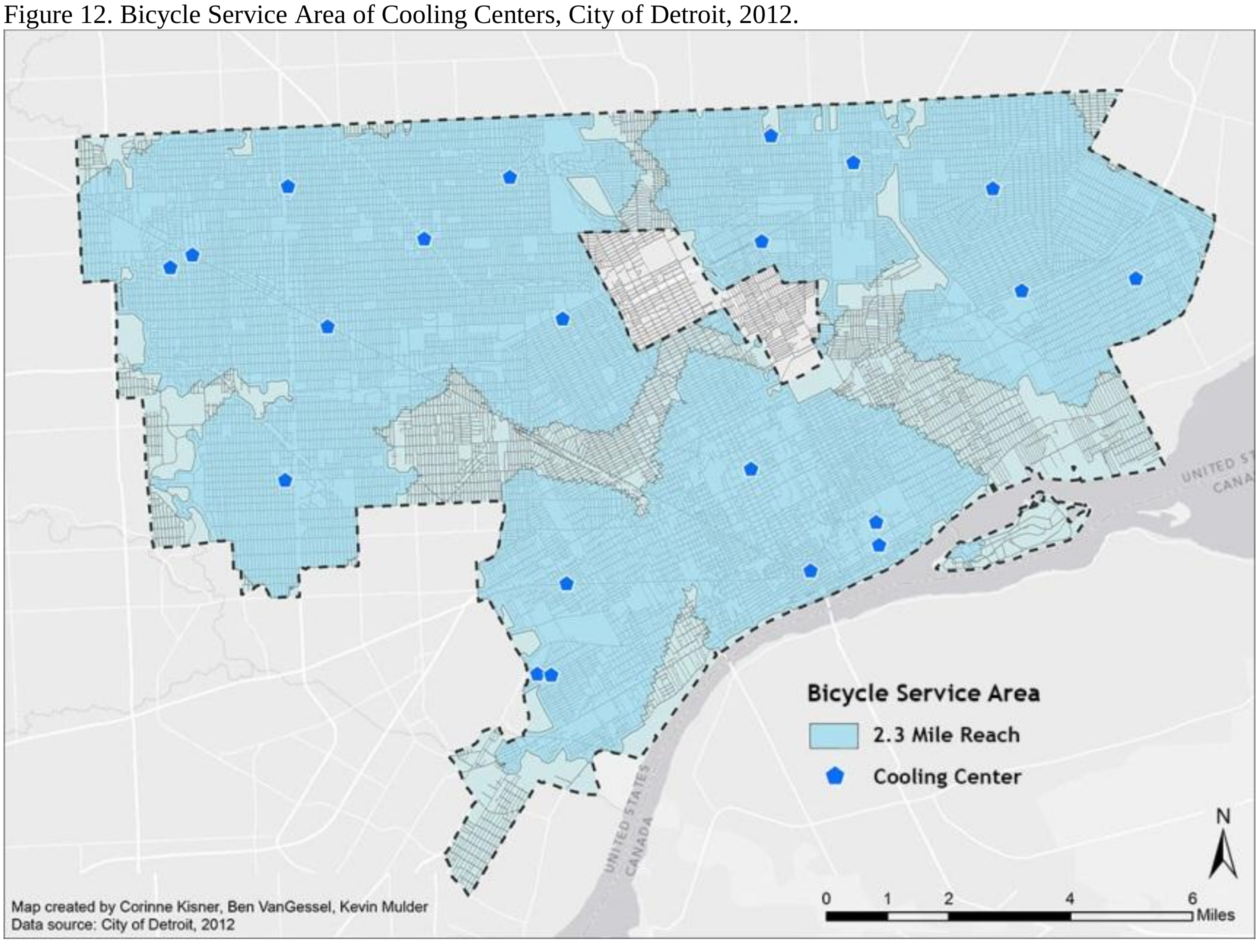

Figure 13. Pedestrian Service Area of Cooling Centers with Vulnerability Index by census block group, City of Detroit, 2012.

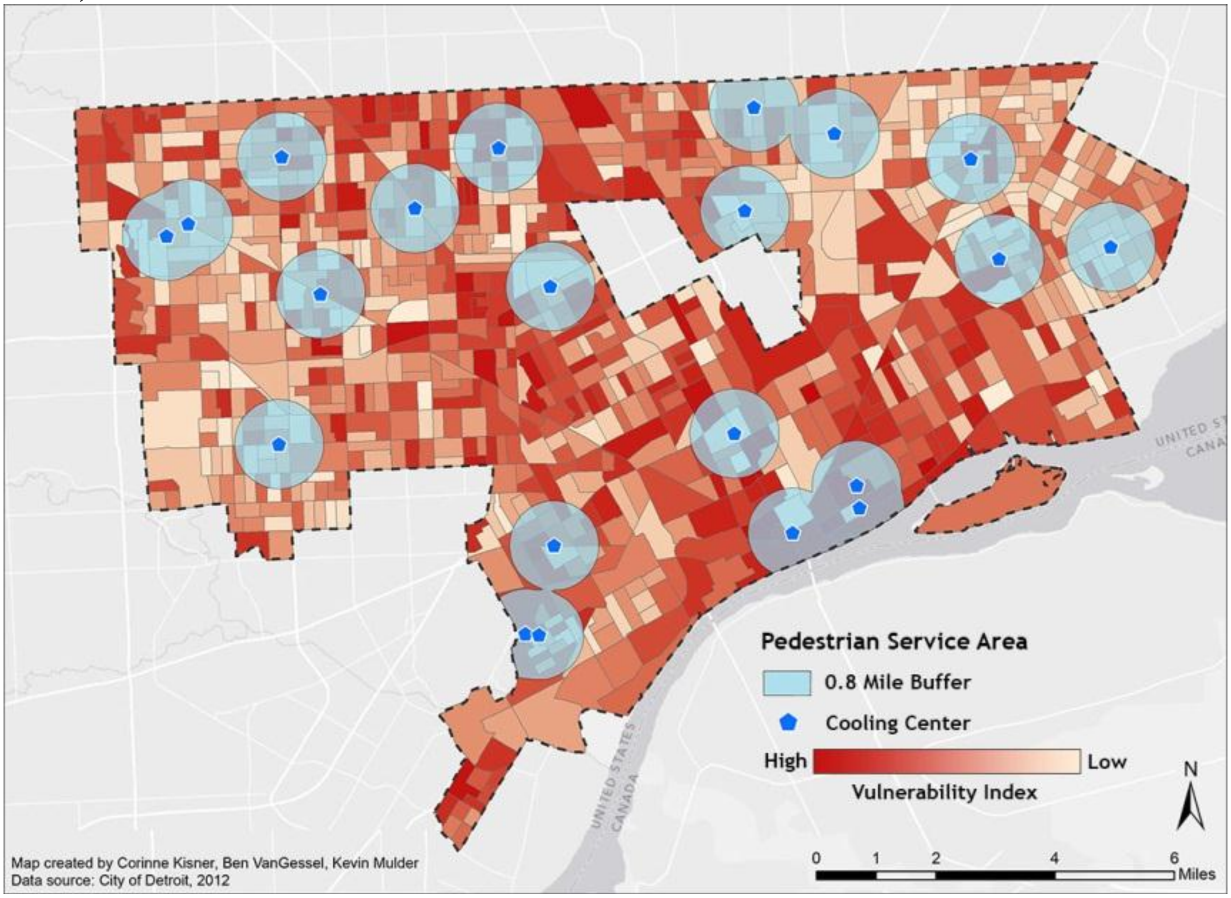


Figure 14. Bicycle Service Area of Cooling Centers with Vulnerability Index by census block group, City of Detroit, 2012.

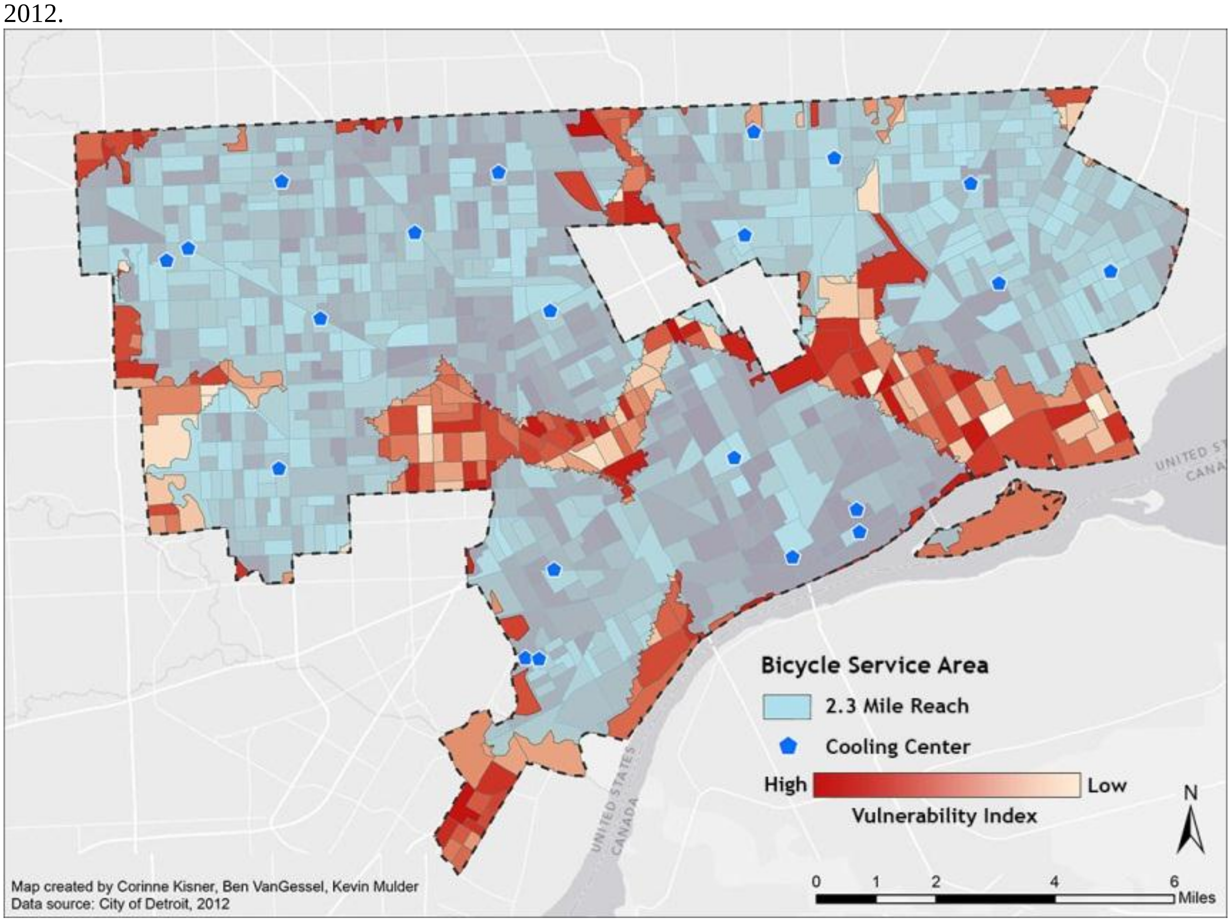

Figure 15. Pedestrian Service Area of Cooling Centers with the 20% most vulnerable census block groups, City of Detroit, 2012.

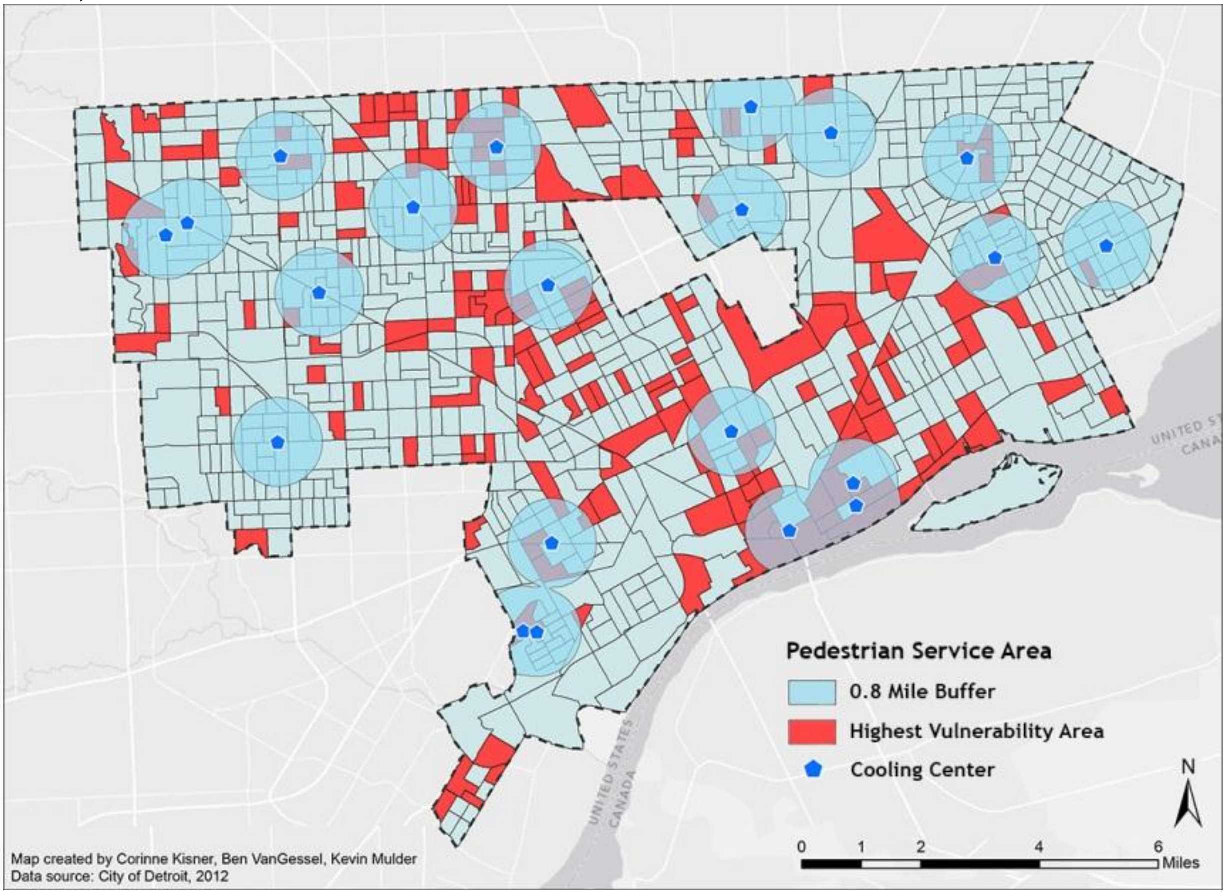


Figure 16. Bicycle Service Area of Cooling Centers with the 20% most vulnerable census block groups, City of Detroit, 2012.