

Urban forest inequality:
Assessing the distribution of trees and their services across
Twin Cities neighborhoods

Peter Kerns and Molly Watters

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Abstract

Urban forests provide important ecological and social benefits whose uneven distribution across a city and its residents can create inequality. This inequality could present an environmental injustice if socially marginalized groups are the ones lacking the environmental amenities of trees. This project seeks to study the extent and implications of this inequality in the Twin Cities, MN by comparing tree canopy cover with variables representing socioeconomic status, race, and age across neighborhoods. We argue that these variables are significantly associated with canopy cover, and our tenable hypotheses are that tree cover increases as socioeconomic status increases and presence of racial minorities decreases. This study contributes to literature on environmental equity and urban forestry in that it assesses the spatial inequalities of urban tree distribution by neighborhood. This scale is well suited to measuring resident-environment relationships as it is the level at which most community planning, NGO projects, and discussions occur. Using canopy cover data collected by the NLCD, U.S. Census data, ArcGIS and statistical software, this study analyzes percent canopy cover among demographically and socio-economically categorized neighborhoods in Minneapolis and St. Paul, MN. The percent canopy cover is strongly associated with socioeconomic status and less so associated with race and age. Specifically, we found that percent canopy cover is expected to increase with an increase in median household income, median housing value, percent unemployed, percent Hispanic, or percent below 18. However, we also found that percent canopy cover is expected to decrease with an increase in per capita income, percent Black or percent no high school degree.

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I. Introduction

Planting trees serves to bring nature into built settings and to improve the quality of life for urban residents. Traditional perceptions of “environment” or “nature” describe areas devoid of development, but this is shifting to include the areas in which humans live—especially cities (Cronon 1995, Flocks et al. 2010). An uneven distribution of trees across a city has social justice relevance because it reflects an uneven distribution of the costs and benefits associated with having trees. This can contribute to an unequal quality of life for residents across the city (Conway et al. 2011, Heynen 2003, Heynen et al. 2006, Jensen 2004). This project seeks to study the extent and implications of this inequality in the neighborhoods in the Twin Cities by comparing tree canopy cover across neighborhoods of varying demographic characteristics.

Definitions vary, but for our purposes an **urban forest** includes every tree in an urban area: trees lining streets, in city parks, and in private yards (Nowak 1994). The U.S. Census Bureau (2006) defines **urban areas** as densely settled census block groups of at least 1000 residents per square mile. Over half the world’s population today lives in urban areas, and this percentage is expected to increase dramatically over the next decade and exceed 60% by 2030 (United Nations Population Division 2004, 2006). This means we must continue to assess urban forest structures and the ways they interact with city residents’ lives.

There is a tendency by urban planners to focus on the social processes governing urban forest distribution because trees are, in effect, commodities produced and purchased to provide usefulness to people. Both planners and residents historically view the usefulness of trees as the provision of aesthetic and psychological benefits (Day 2005, Gorman 2004, Hull 1992). While valuable, this focus has led planners to neglect the ecological dynamics that play a vital role in urban environments (Heynen 2003). In the last twenty years significant research has determined

the extent and distribution of services provided by urban forests in an increasing number of cities across the country, especially using the UFORE model developed by Dr. David J. Nowak in Chicago. UFORE has been used in Minneapolis to quantify large-scale tree service data, but does not zoom into the neighborhood level to analyze tree distribution for local social inequality. Since the 1980s planners have begun using these assessments ecological services provided by urban forests and connecting them to associated social factors (Harvey 1996, Heynen 2003, Hobbs 1988, Holifield 2009, Flocks et al. 2010).

Both these tangible ecological services and intangible personal benefits are important aspects of trees as natural resources; the unequal distribution of these resources could present an environmental injustice. In this paper, we discuss the benefits, planning, and previous research into urban forest inequality before analyzing the urban forest distribution of the Twin Cities, Minnesota.

Benefits of Urban Trees

Urban forests provide many types of benefits that can create inequality if they are unevenly distributed across a city. Ecological services provided by trees include air pollution removal, volatile organic compound (VOC) emission reduction, decreased air temperature, reduced building energy costs due to shade and windblocks, improved water quality and stormwater drainage, reduced noise, and carbon storage and sequestration (Bolund and Hunhammar 1999, Dwyer et al. 1992, Nowak et al. 2006, Nowak et al. 2010, Rowntree and Nowak 1991). Some of these are more regional services, such as carbon sequestration and reducing of the “urban heat island” effect (Heisler 2010), while others can directly benefit residents on a local neighborhood level (Heynen 2003).

Urban trees contribute to improved physical and psychological well-being in residents (Day 2006, Dwyer et al. 1992, Flocks et al. 2010, Gorman 2004, Hull 1992, Jim and Chen 2006, Jordan et al. 1997, Kuo et al. 1998, Nowak). Local social benefits of urban trees include decreased incidents of road rage and car accidents (Cackowski 1999), increased recovery rates of hospital patients (Ulrich 1984), improved child development (Taylor et al. 1998), increased sense of safety (Kuo et al. 1998, Kuo 2003), and decreased incidents of crime and domestic violence (Kuo and Sullivan 2001). In addition, urban trees can contribute to increased real estate values and local economic development (Dwyer et al. 1992, Tyrvaïnen and Miettinen 2000, Wolf 2003). Urban trees have been shown to decrease stress (Ulrich 1981), improve mood (Hull 1992), increase emotional and spiritual experiences (Dwyer et al. 1991, Schroeder 1991), and increased attachment to place (Dwyer et al. 1992, Kuo et al. 1998). Other important social benefits include an empowered inner city mentality (Heynen 2003, Roy 2010), a stronger sense of community (Dwyer et al. 1992, Rines 2011, Zhang et al. 2009), increased social ties and neighboring (Dwyer et al. 1992, Kuo et al. 2001, Kuo 2003), and a promotion of environmental responsibility and appreciation (Dwyer et al. 1992, Heynen 2003, Kuo et al. 1998, Schroeder 1991).

While “green space” or “open space” is often used as a measure of nature in urban areas, these variables reflect different purposes and effects than do trees. In our study, we chose to look specifically at trees for several reasons. First, nearly all urban trees are planted and maintained intentionally or “allowed to grow,” whereas open or green space might exist in the city without significant planning or maintenance efforts (Conway et al. 2011, Heynen 2003). Second, while green or open space provide ecological services such as water filtration, carbon sequestration, recreation, and a break from a built environment, trees can increase these services

and provide the added benefits of shade, wind-blocking, air pollution reduction, and noise control. Third, trees are especially iconic and symbolic elements of the natural world and hold unique spiritual and cultural significance. They are shown to be valued more highly by urban residents than other natural elements such as grass or water bodies (Dwyer et al. 1991, Schroeder 1982, Hull 1992). This value of trees was demonstrated in the aftermath of Hurricane Hugo, when residents of Charleston, South Carolina identified the urban forest as the most significant feature of the city that was damaged (Hull 1992). Although people's attitudes toward trees can vary by resident location and background, the number of community-led tree programs and several studies of how people value trees show that people tend to be passionate about trees and want them in the places where they live (Dwyer et al. 1991, Schroeder 1991).

Urban Forest Inequality

Most research on environmental equality and justice has focused on the distribution of environmental burdens across populations of varying demographic and socioeconomic characteristics and seeks to determine if socially disadvantaged groups are disproportionately impacted by negative environmental conditions (Landry and Chakraborty 2009, Flocks et al. 2010, Jennings 2012). Access to and effects of environmental amenities such as green space and vegetation are not explored in traditional environmental justice literature, but a more recent body of research has sought to include assess and explain distributions of environmental amenities as well (Landry and Chakraborty 2009, Jennings 2012). Urban forests are certainly environmental amenities due to the many benefits they provide residents, but little empirical research has studied urban amenity equity in the context of urban trees. However, studies that have looked at trees often find significant associations between socioeconomic status or race and the distribution of the urban forest across a city (Escobedo et al. 2006, Flocks et al. 2010, Heynen 2003, Heynen

2006, Heynen et al. 2006, Kirkpatrick et al 2011, Landry and Chakraborty 2009, McPherson et al. 2008, Pedlowski et al. 2002, Perkins et al. 2004, Warren et al. 2011). This research has begun to address the inequality that can both drive and result from uneven urban tree distribution; it also opens the door for exploring the environmental justice implications of this inequality. Furthermore, only in the last few years have studies of environmental amenity equity begun using statistics appropriate for geographic data and spatial analysis (Landry and Chakraborty 2009).

Urban Forest Planning

Urban forest planning is officially responsible for the distribution of a city's urban forest, especially trees on public property. Studies of urban forest inequalities provide implications and opportunities for urban planning; only recently have urban forest managers and scholars considered these studies to be suggestions in improving the inequalities and injustices in tree service distribution through various management practices (Pincenl et al. 2010).

Trees have been intentional pieces in the layout of cities for hundreds of years (Bradley 1995, Heynen 2003). Tree ordinances were long used in Europe to protect and develop urban forests in cities (Schmied and Pillmann 2003), and William Penn drafted the first U.S. tree ordinance to standardize planting near Philadelphia in 1700 (Zube 1971). Tree ordinances are usually created in response to community motivations as well as political will, with public attitude and preference as driving forces (Zhang et al. 2009). Developing tree ordinances provides both a legal framework and an interactive tool for fostering public participation and awareness of urban trees. The main responsibilities of tree ordinances are having a tree commission board, defining tree planting, removal and replacement of public trees, public tree protection and care, tree species selection, and dead tree removal on both public and private

property (Zhang et al. 2009). However, Zhang et al. (2009) found that less than half actually implement most of these practices, and about a third of U.S. cities do not have a tree commission board. In addition, little research has been done on tree policies related to managing trees on private property. Tree policies often neglect to interfere with private trees despite the large proportion of the city's urban forest they comprise (Conway and Urbani 2007, Greene 2011).

This could lead to an unintentional or haphazard urban forest structure, potentially resulting in an unequal distribution of trees and their services across city neighborhoods and their residents.

Urban forest programs involving both government and community involvement are often created in response to the type of unequal tree distribution we assess in this study, in hopes of spreading forest benefits more equally across residents (Pincenl et al. 2011). Public awareness and education of the social and ecological benefits of trees might be far more important than is currently considered in most cities, and were in fact the key to the success of Ohio's urban forestry program (Sievert 1988). Studies have found that resident and community involvement in urban forest planning is both a complicated and successful component of distributing trees and their benefits equally across cities (Conway et al. 2011, Greene et al. 2011, Heynen 2006, Perkins 2011, Roy 2010, Sievert 1988). Conway et al. (2011) found that a community's socioeconomic conditions and basic characteristics can drive involvement in urban forestry programs. Resulting levels of participation could compound the inequity in tree distribution in a city. This becomes problematic in light of the argument resident engagement, or a "bottom up" approach, is required and in fact the best method for maintaining and enhancing urban forests, especially on private property (Greene et al. 2011, Perkins 2011). This way the residents who can benefit from more trees are more likely to create a sustainable, valuable forest in their community out of their own demand, investment, and reward.

The distinction between resident and government involvement in urban forestry can get blurred. Even “bottom up” tree planting programs run by non-governmental organizations depend on government funding for their functions. For instance, over 60% of the income of Tree Trust, one of the biggest tree planting organizations in the Twin Cities, comes from federal, state, and local governments, and the rest comes from large corporations like Cargill; this is not uncommon for non-governmental tree programs (Pincetl et al. 2010). Although this government and corporate involvement seems slightly contradictory to citizen efforts, it might be one of the only ways the government can help improve the urban forest that falls on private and residential land. It might also be the only way for residents, especially low-income and socially marginalized groups, to implement positive changes to the urban forest around them. Private property laws and tree ordinances do not allow the city to plant or maintain trees on private land, even though the residents may desire more trees or need financial help planting or maintaining them (Greene 2011, Perkins 2011, Tree Trust, Heynen 2003). Tree policies and ordinances, as well as urban forestry as a whole, provide a collaborative project for the city that brings together residents, city officials, companies, and volunteers to make it work effectively (Conway 2011, Heynen et al. 2006, Pincetl 2009, Zhang 2011). While powerful, this can be a difficult process, as Pincetl found in her 2009 study of Los Angeles’s Million Tree Initiative; effective citywide urban forest management requires the coordination of multiple nonprofit and city agency programs, who are used to working separately and find it difficult to collaborate.

City planners and private property owners are decision-makers in planting trees. In the United States, more than 50 percent of urban forests lie on residential property (Ward 2007).

City planners and different groups of residents must struggle with decisions over how and where to plant and maintain trees; they all have different decision-making criteria and levels of ability

to actually implement them. Low-income minority communities have the greatest potential to benefit from planting trees (lower energy costs and less pollution-induced or noise-induced health effects), yet have the least resources with which to plant trees, in a way reinforcing the structural inequities that unfairly benefit their wealthier neighbors (Flocks et al. 2010, Heynen 2003, Kirkpatrick et al. 2011, Warren et al. 2011). There are many community initiatives in the Twin Cities aimed at increasing urban tree cover (Bolognesi 2000). An already present disparity in socioeconomic status between neighborhoods may make some community forestry programs more effective than others (Conway et al. 2011, Zhu et al. 2006), but these initiatives empower residents to strengthen the size and equity of their urban forest (Greene et al. 2011, Perkins 2011)

II. Study Area

We have chosen the area within the city limits of the Twin Cities (Minneapolis and St. Paul, Minnesota) as our study area. Several other urban environmental equity studies also use city boundaries, as opposed to metropolitan areas or whole regions, to define their study areas for research of urban trees (Landry and Chakraborty 2009). While most other studies of urban forests assess distribution across whole cities or by Census block groups and little research has been done on environmental amenities on the neighborhood level, we have chosen to conduct our analysis on the neighborhood level because it is the scale at which community planning, NGOs, work projects, and discussions occur (Bauer 2011, Bolognesi 2001, Heynen 2003, Wilson et al. 2008). Twin Cities neighborhoods offer a concrete area for locating, assessing, and analyzing inequities relating to the distribution of trees and their services on the most local level (Heynen 2003). Including both Minneapolis and St. Paul provides a demographically diverse set of neighborhoods, albeit not as diverse as the Twin Cities Metropolitan Region (Nega

et al. 2010). Furthermore, the Twin Cities are getting more diverse; from 2000 to 2010 the percent white has decreased from 65.1 to 63.8 in Minneapolis, and from 67 to 60.1 in St. Paul (U.S. Census Bureau 2000, 2010).

Urban canopy cover in the U.S. ranges from a high of 55% in Baton Rouge, LA to a low of 1% in Lancaster, CA, with an average of 26% across the United States (Nowak 1994). To put our study in the context of U.S. urban canopy cover, Minneapolis has a percent urban tree cover of 26.4% (Nowak et al. 2006).

The Twin Cities combined are home to 12.6 percent of the state's population (U.S. Census Bureau 2010, Bolognesi 2000). In 2000 the Minneapolis and St. Paul populations were 382,578 and 285,068 respectively (U.S. Census Bureau 2000). Minneapolis is divided into 86 neighborhoods with an average population of 4,396 and St. Paul is divided into only 17 neighborhoods with an average population of 16,953. For a base map of our study area by neighborhood, we acquired GIS shapefiles of Minneapolis and St. Paul neighborhoods from the GIS offices of each city.

III. Methods

Variables Used

Percent tree canopy cover is used as a proxy for the spatial distribution of trees, and, more importantly, as a proxy for the ecological and social services they provide (McPherson et al. 2005). United States canopy cover data was gathered from the Multi-Resolution Land Characteristics Consortium's National Land Cover Database. This data estimates percent tree cover at a 30-meter resolution based on satellite data for the entire lower 48 states (see Figure 1).

Demographic data from the 2000 Census was gathered by the U.S. Census Bureau and acquired through Mallika Jayaraman and Tsegaye Nega as used in their recent study of socioeconomics and traffic noise in the Twin Cities (2012).

We chose to investigate the explanatory variables of socioeconomic status, race, and age based on their use in previous environmental equity studies and because they have been found to have a relationship with tree cover, especially on a neighborhood scale (Conway Heynen 2006, Heynen and Lindsey 2003, Heynen et al. 2006, Landry and Chakraborty 2009, Pedlowski et al. 2002, Perkins et al. 2004, Talarchek 1990). Specifically we looked at socioeconomic status variables of median household income, per capita income, median housing value, percentage of unemployed residents, and percentage of residents with no high school degree. For race we used percentage of non-white, Black, and Hispanic residents. Age included percentage of residents below age 18 and percent over 65. Many studies also include and even focus on housing tenure as a study variable; it is often found to be correlated with canopy cover citywide and at the neighborhood scale (Conway et al. 2011, Emmanuel 1997, Heynen 2002, Heynen et al. 2006, Grove 2006, Landry and Chakraborty 2009, Perkins et al. 2004). We acknowledge the potential importance of this factor for its relationship to resident socioeconomic status and for its potential to influence tree planting and maintenance; however, we were not able to include percent rentership in our analysis due to data limitations.

Studies have consistently shown that median household income and other measures of neighborhood wealth are positively related to neighborhood tree cover (Conway et al. 2011, Heynen 2006, Heynen and Lindsay 2003, Iverson and Cook 2000, Landry and Chakraborty 2009, Pincenl 2001, Talarchek 1990). Income is an indicator of people's interaction with their physical environment because it can affect how much control they have over making that

physical environment better (Jennings 2012). Both private and public trees are commodities, and income is a measure of the money people have to spend either on trees themselves or on taxes giving the city revenue which can go toward planting trees (Harvey 1992, Heynen 2003, Zhu 2006). For instance, Zhu et al. (2006) found that higher resident income causes an increased demand for urban forests due to greater ability to buy and maintain trees, and Warren et al. (2011) found wealthier cities to be better able to maintain healthy urban forests than poorer cities. Income cannot account for all assets and indicators of wealth, but we will use a combination of per capita and median household income as a proxy (Heynen et al. 2006, Holifield 2009, Nega et al. 2010, Nega et al. 2012). Some studies do not include per capita income as a measure of wealth (eg. Heynen et al. 2006, Landry and Chakraborty 2009), but many deem it to be an important indicator of socioeconomic status. We include per capita income because median household income does not account for household size, and our study area includes both downtown-dwelling individuals and households in purely residential areas. This could create an inaccurate portrayal of wealth and therefore its relationship with canopy cover in certain neighborhoods, especially those in the downtown area. In addition, results of studies vary on whether or not education is statistically significant correlation with tree cover, and it is therefore left out of some subsequent studies (Heynen and Lindsey 2003, Landry and Chakraborty 2009). However, other studies have used level of education and found it to be correlated with canopy cover (Escobedo et al. 2006, Heynen et al. 2006, Talarchek 1990), so we included the education proxy of percentage of residents with no high school degree as a socioeconomic status variable.

Race is a commonly studied indicator of inequality in urban environmental amenity studies, with mixed findings for whether racial groups are at a disadvantage (Jennings 2012).

Studies focusing on park access sometimes find that racial minorities have higher access to parks and green spaces, but most studies of urban forests specifically find that the areas inhabited by racial minorities have fewer trees (Conway et al. 2011, Heynen et al. 2006, Jennings 2012, Landry and Chakraborty 2009, Pincenl 2011, Wilson et al. 2008, Wilson et al. 2010).

Percentage of non-white residents is used to encompass multiple racial groups, but percent black and percent Hispanic were also included since they are the two largest racial minority groups in the Twin Cities (U.S. Census Bureau 2000, 2010).

Age is not as commonly included as a variable in studies of urban forest equity as our other chosen variables because it is not commonly shown to correlate with urban tree canopy cover. However, we include it in our study for two reasons: it is often linked with socioeconomic status and race in terms of its spatial distribution, and it has a unique relationship with trees based on health implications. The very young and very old are more physically vulnerable to negative environmental conditions, many of which, such as pollution, heat, noise, and crowdedness, can be ameliorated by the presence of trees (Nowak 1994, 2010). Children and the elderly also have greater potential to be positively influenced by the environmental benefits associated with trees such as improved physical health, increased psychological well-being, increased social integration, and a fostered connection with nature (Dwyer et al. 1992, Hull 1992). A presence of trees may significantly contribute to child development (Taylor et al. 1998), lower rates of childhood asthma (Lovasi et al. 2008), and increase longevity and social integration of elderly adults (Takano et al. 2002).

Data Preparation

The national canopy cover raster data layer was limited to the study area of the city boundaries of Minneapolis and St. Paul. This map is shown in Figure 1 with neighborhood

borders drawn on top. Then, with the cities' neighborhood maps as the input layers, we ran zonal statistics on these clipped canopy cover rasters to make a table of mean percent canopy cover for each neighborhood.

Census demographic data is taken by blockgroup, so we converted it to neighborhood which is our chosen unit of analysis. We summarized the variety of blockgroup data to represent neighborhoods, of which there were fewer. We did this by first assigning each blockgroup to the neighborhood in which that blockgroup's centroid falls. We then joined of the blockgroup data with the neighborhood names to assign a neighborhood to each blockgroup. We created a table of the demographic variables summarized for each neighborhood by dissolving the blockgroup data by neighborhood for the desired fields of demographic data. Neighborhood income variables were summarized as means of blockgroup income data. Variables in the form of percents, such as percent nonwhite and percent under 18, were recalculated for each neighborhood based on summed population values of those variables to increase their accuracy.

We then joined this summarized neighborhood demographics data with the data for mean percent canopy cover by neighborhood to create a layout of tree distribution and socioeconomic status by neighborhood and observe this distribution across each city.

Statistical Analysis Methods

To run regression analyses with so many variables of different units, we first attempted to check for distribution normality. The distribution of percent canopy cover across neighborhoods in both cities is skewed and non-symmetrical. In fact, most of the variable distributions were non-normal with the exception of percentage of residents below 18 years of age and over 65 years of age. To make interpretation easier, we log(base e)-transformed all 11 variables (both predictors and response).

In order to determine if there exists an unequal distribution of canopy cover across neighborhoods in the Twin Cities, we want to model the percent canopy cover as a function of our socioeconomic and demographic variables. Without the expertise to run an autocorrelation, we assume our independent variables are actually independent of each other and we assume that the predictor variables are effecting the response variable and the opposite is not true. In order to test for significant associations within 9 covariates, we perform a backwards stepwise linear regression. The regression analysis first tests the combined effects of the predictors on the response and then deletes the weakest/insignificant predictors. We used the software TIBCO Spotfire S+ to run the regression analysis.

IV. Results

Exploratory Data Analysis

We began our data processing with exploratory spatial data analysis to determine patterns in the relationships between socioeconomic/demographic variables and percent canopy cover. These patterns may display the spatial locations of urban forest inequality. First, we compared the distribution of urban trees in both cities, finding general patterns and clusters of high and low percent canopy cover in each city. Second, we explored the demographic patterns of each city separately, noting significant clusters of socioeconomic variables. Finally, we determined spatial patterns of association between canopy cover and significant socioeconomic variables in each city.

General percent canopy spatial patterns, both cities

The distribution of percent canopy cover in both cities shows a clear spatial pattern. In both cities, the central regions exhibit low percent canopy cover (Mpls - 0.323%-1.96%; Stpl -

0.22%-5.14%) while the neighborhoods on the periphery of the city proper exhibit higher percent canopy cover. Specifically, the southwest (SW) area of both cities and the southeast (SE) neighborhood of Sunray-Battlecreek-Highwood in St. Paul exhibit high percent canopy cover (>15% in St. Paul and >20% in Minneapolis).

The canopy cover in Minneapolis neighborhoods (n=87) ranges from 0 to 31.85% with a mean of 9.90 % and standard deviation of 6.69%. 50% of the neighborhoods have between 5 and 14% canopy cover. The canopy cover in St. Paul neighborhoods (n=17) ranges from 0.22 to 26.25% with a mean of 10.39% and standard deviation of 6.12%. 50% of the neighborhoods have between 7 and 11% canopy cover. The distribution in Minneapolis has greater spread and a much higher maximum. This could be in part due to the difference in average size of neighborhoods between the two cities, as noted above.

Income, race, and age spatial patterns – Minneapolis

Our study found significant spatial patterns of income, race, and age in Minneapolis (see Figure 1). We found significant clusters of both high median household income (> \$62000) and high per capita income (> \$32000) in the SW region of Minneapolis and a significant cluster of low income residents in the northwest (NW) region. Percent non-white closely follows this income pattern, with lowest percent non-white in the SW region (< 8.2%) and 6 of the 7 highest percent non-white neighborhoods are in the NW region (> 75.45%) and the south central region, located directly south of the downtown region. Looking closer at race we found the NW region to have a particularly high Black population (48.95-62.48%), including 4 of the 5 highest percent Black neighborhoods in the city. The 9 neighborhoods with the largest Hispanic populations are clustered in the south central region (> 17.5%). Finally, our data shows that neighborhoods of the highest percent under 18 are clustered in the same NW and south central regions.

In the NW region of Minneapolis we find less of a visual pattern of trees. Some of the neighborhoods have average (~9) percent canopy cover. However, the other half of neighborhoods in that region have very low percent canopy cover, and are the same neighborhoods with higher percent under 18. The downtown region of Minneapolis, which is termed the “Central” community by city planners, exhibits the lowest percents under 18 (< 10.6), relatively low levels of median household income and most importantly, the lowest percents canopy cover in the city.

Income, race, and age spatial patterns - St. Paul

Spatial patterns were also observed in St. Paul (see Figure 1.). In St. Paul, the SW region contains the highest per capita and median household income; per capita income is also notably high in the Downtown neighborhood. Neighborhoods with the lowest per capita (< \$15,379) and median household income (< \$35,463) are clustered in the north central region of the city. A cluster of the highest percent non-white neighborhoods lies in the north central region of city (> 45). Within this region, Thomas-Dale has the highest percent non-white at 71%, including both a high percent Black and percent Hispanic. This cluster shifts slightly when focusing on individual racial backgrounds; the neighborhood with the highest percent Black is Summit University (34%). A cluster of high percent Hispanic lies in the northeast region (7-11%) and West Side (31.4%). Three of the 4 lowest percent non-white neighborhoods are clustered in the southwest central region of the city (<12.04%). A cluster of high percent under 18 also lies in the north central region of the city minus the downtown. We further describe the patterns found in these different cluster regions below.

Sunray-Battlecreek Highwood in the southeast of the city did not fall in any of our pattern cluster regions, but it is the neighborhood with the highest canopy cover (26.25%) and

also contains a large Black population (13.54%).

Statistical Analysis

The above exploratory spatial data analysis gives us an overall picture of socio-economic clustering and canopy cover in the cities. We are able to visually estimate the degree to which the clusters are related but to quantify the relationship requires association statistics. In the second part of our analysis we use a backwards stepwise linear regression with mean percent canopy cover as the response variable and all ten covariates listed in Table 3 as predictor variables. The statistical analysis found that the percentage of non-white residents and the percentage of residents over 65 years of age do not significantly contribute to the model.

However, median household income, median house value, per capita income, percentage of Black residents, percentage of Hispanic residents, percentage of residents with no high school degree, percentage of unemployed residents, and percentage of residents below 18 years of age do significantly contribute to the model. The model equation:

$$\begin{aligned} (\log.\text{percentcanopycover}) = & \mathbf{2.737}(\log.\text{Median household income}) + \mathbf{0.627}(\log.\text{Median housing} \\ & \text{value}) + \mathbf{0.367}(\log.\text{percentunemployed}) + \mathbf{0.180}(\log.\text{percentbelow18}) \\ & + \mathbf{0.142}(\log.\text{percentHispanic}) - \mathbf{0.167}(\log.\text{percentNoHSdegree}) - \mathbf{0.184}(\log.\text{percentBlack}) - \\ & \mathbf{1.621}(\log.\text{percapitaincome}) - 19.039 \end{aligned}$$

This model predicted 86.21 percent of the variability in percent canopy cover. The F-ratio of 75.21 and p-value of 0 tell us that the null hypothesis, which says there is no interaction between the canopy cover and these variables, is false for at least one of the variables. According to the model, an increase in the median household income, median housing value, percentage of unemployed residents, percentage of residents below 18 years of age, or percentage of Hispanic residents is significantly associated with an increase in the percent canopy cover; an increase in

per capita income, percentage of Black residents, or percentage of residents with no high school degree is associated with a decrease in the percent canopy cover.

Median household income has the strongest association (coefficient = 2.737) with percent canopy cover. Interpretation of the model shows that, with all other variables held constant, a twofold increase in the median household income in a neighborhood is associated with an 85% increase in percent canopy cover. Percentage of Black residents and percentage of residents with no high school degree have negative relationships with canopy cover (coefficients -0.167 and -0.184, respectively). With all other variables constant, a 1% increase in residents with no high school degree and a 1% increase in Black residents, there is an association with a 0.18% decrease in percent canopy cover.

V. Discussion

The main purpose of this study is to determine the relationship between demographic/socioeconomic characteristics and percent canopy cover in Twin Cities neighborhoods and reveal inequalities in the distribution of tree services to residents.

Our results show a significant relationship between certain demographic variables and percent canopy cover across Twin Cities neighborhoods. Interestingly, we found some associations that followed our hypotheses and some that did not.

We found that neighborhood wealth, whether measured as median household income, median housing value, or per capita income, is a strong indicator of canopy cover (see Table 3). Our model showed median household income to be the strongest predictor variable for canopy cover. This supports the large body of literature that finds an association between tree cover and wealth, especially median household income (Conway et al. 2011, Heynen 2006, Heynen and

Lindsay 2003, Iverson and Cook 2000, Landry and Chakraborty 2009, Pincentl 2001, Talarchek 1990).

We encountered some result associations that do not support our hypothesis and cannot be explained by the data available. The negative relationship between per capita income and percent canopy cover is one such confounding association that warrants further study. Per capita income was included in our study because we wanted to evaluate income while controlling for household size. The results are seemingly contradictory - median household income has the strongest positive association with percent canopy while per capita income has the strongest negative association. However, during exploratory data analysis we found that in the downtown regions of both cities there were lower values of median household income along with average-high values of per capita income. These downtown regions also exhibited low percents canopy cover and so support the associations of the model, although we cannot explain potential reasons for these results.

In our exploratory data analysis we determined that non-white residential clusters were visually associated with clusters of low percent canopy. However, our results find that percent non-white does not significantly contribute to the model. This could be due to the fact that the largest cluster of non-white residents, the northwest region of Minneapolis, in fact exhibited higher canopy cover along the city's periphery. Furthermore, percent non-white, as a combination of all minority groups, did not contribute to our model, but the specific race variables of percent Black and Hispanic were significant indicators of canopy cover.

Our findings on race and canopy cover generally support the findings of recent and significant scholarship. Flocks et al. (2011) found that Hispanic population clusters enjoyed higher canopy cover than Black population areas. Black areas have also been shown to have less

tree cover than White areas (Flocks et al. 2011, Heynen 2003, Landry and Chakraborty 2009).

The positive association between percent Hispanic and percent canopy cover and the negative association between percent Black and percent canopy cover found in our model support the conclusions of related research. However, our results oppose other studies who find areas with high Hispanic populations to have low canopy cover (Landry and Chakraborty 2009).

Our study has policy and urban planning implications for the Twin Cities and other cities showing similar demographic characteristics. Pincenl says about the MillionTreesInitiative that the program was largely implemented to correct the uneven tree distribution that McPherson (2008) found in the city and attempt to remedy the associated inequality. This shows that studies like this one, that locate inequities in the distribution of trees and their services, have the potential influence important policy and program decisions which will hopefully improve the urban forest's quality to benefit more residents more equally.

While environmental justice literature has previously addressed environmental burdens on the neighborhood scale, very little urban forest research has been done that focuses on neighborhoods (Conway 2011, Escobedo 2006, Heynen 2003, Jennings 2012, Wilson et al. 2010). This study contributes to the environmental justice and environmental equity literature by assessing the spatial inequalities of urban tree service distribution by neighborhood, a unit particularly suited to studying the relationship city residents have with their physical environment.

In general, our findings support the idea that low-income minority communities have the greatest potential to benefit from trees' ecological and social services yet have the least resources to use on trees; a trend could reinforce structural inequities that exist across the city (Flocks et al. 2010, Heynen 2003, Kirkpatrick et al. 2011, Warren et al. 2011).

Our finding of a significant urban forest inequality in the Twin Cities could imply the presence of environmental injustice for several reasons. First, we see evidence that low-income, minority groups receive fewer urban tree benefits, and these are also the groups that environmental justice literature generally finds to be at the greatest disadvantage. Secondly, giving urban forest inequity due consideration and incorporating it into urban forest planning upholds environmental justice principles of equal access to environmental burdens and benefits (Flocks et al. 2010). There is also a known positive relationship between urban tree services and physical and psychological health, which is a primary concern of the environmental justice movement. Therefore, urban forest assessments should join the environmental justice literature in the discussion of urban amenities, and conversely environmental justice research should expand to include studies of urban tree distribution and services.

Limitations

One limitation of our study is that it does not use current data. We use canopy cover data from 2001 and demographic data from the 2000 Census. The fact that these two main datasets were collected a year apart presents another limitation/inconsistency.

The canopy cover data that we use from the NLCD is at 30-meter resolution. Advantages of this data are that it is free, is GIS compatible, and provides maps of percent canopy cover distribution; disadvantages are that it is not designed for a local scale such as city or neighborhood analyses, its relatively coarse resolution cannot display as detailed a picture of canopy cover as can data showing individual trees or a much finer resolution, and is shown to underestimate canopy cover by an average of 10 percent (Greenfield and Nowak, 2009).

Whole blockgroups were assigned to the neighborhood in which their centroids fall, but several blockgroups overlap neighborhood boundaries. This means each neighborhood's

summarized data does not precisely represent its distinct set of residents; the neighborhood data is based on the boundaries of the blockgroups assigned to it rather than the definite neighborhood boundaries. Furthermore, the aggregation of the blockgroup data by neighborhood inevitably limited the variation in the data within those neighborhoods. The influence of the summaries and the way they limit variation is amplified by an important difference in the neighborhood scale for the two cities: Minneapolis is divided into 86 neighborhoods with an average population of 4,396 while St. Paul is divided into only 17 neighborhoods with an average population of 16,953. Minneapolis's 86 neighborhoods provide our study with a larger, more variable data set than the 17 data point of St. Paul. This scale mismatch is an important limitation to our study and warrants further research. Are neighborhood identities or neighborhood organizational resources compromised by the scale of neighborhood? What implications does size of neighborhood have on effectiveness of tree planting initiatives?

Another limitation is that we placed neighborhood boundaries around the services provided by trees, yet neighborhoods are contiguous and these benefits can spill over those boundaries. We could not account for the possibility that the residents of one neighborhood can experience local services from the trees in another; regional ecological services also remain unaccounted for. Non-residential areas in neighborhoods, including land covers such as roads, industrial parks, or lakes, could have also affected tree distribution. This has the potential to skew findings of association between canopy cover and resident demographic data.

Lastly, we were limited by our timeframe of ten weeks; more elements certainly could have been included given a longer study period. When we began this project, we wanted to quantitatively analyze the ecological and social services of urban trees to determine inequality in the distribution of those services. Realizing the limits of our study's ten week timeframe and the

materials and skills required to accurately measure and quantify forest structure and thus compute ecological services, we decided to assess the distribution of services with percent canopy cover as a proxy for urban tree service provision.

VI. Conclusion

Urban forests provide residents with ecological and social services, and an uneven distribution of trees reflects an inequality in the benefits they provides to residents. This project seeks to study the extent and implications of this inequality in the Twin Cities, MN by comparing tree canopy cover with demographic variables representing socioeconomic status, race, and age across neighborhoods. Our study reveals an association between tree canopy cover and demographic and socioeconomic variables in Twin Cities neighborhoods. Our results largely support our hypotheses, our exploratory data analyses, and previous research. We were able to observe spatial patterns in canopy cover and demographic clustering (see Figure 1a,b.); these included a pattern of decreasing canopy cover moving away from the city center, and clusters of low-income, minority neighborhoods in certain areas of the cities. Our statistical model shows that an increase in the median household income, median house value, percentage of unemployed residents, percentage of residents below 18 years of age, or percentage of Hispanic residents is associated with an increase in the percent canopy cover, while an increase in per capita income, percentage of Black residents, or percentage of residents with no high school degree is associated with a decrease in the percent canopy cover. This demonstrated inequality suggests the need for an environmental justice inquiry of urban forests in future research.

Bibliography

- Bauer, M., Kilberg, D., Martin, M., Tagar, Z., 2011. Digital Classification and Mapping of Urban Tree Cover: City of Minneapolis. Department of Forest Resources, University of Minnesota.
- Bauer, M. Personal Communication. Nov. 16th, 2011.
- Bolognesi, M. C., 2000. Minneapolis Neighborhood Profiles. Official Website of the City of Minneapolis.
- Bolund, P., and S. Hunhammar. "Ecosystem Services in Urban Areas." *Ecological Economics* 29, no. 2 (1999): 293-301.
- Bradley, G.A. *Urban Forest Landscapes: Integrating Multidisciplinary Perspectives*: University of Washington Press, 1995.
- Cronon, William, ed., *Uncommon Ground: Rethinking the Human Place in Nature*, New York: W. W. Norton & Co., 1995, 69-90.
- Conway, T., and Urbani, L. "Variations in municipal urban forestry policies: A case study of Toronto, Canada." *Urban Forestry and Urban Greening* 6 (2007): 181-192.
- Conway, T., Shakeel, T., Atallah, J. "Community groups and urban forestry activity: Drivers of uneven canopy cover?" *Landscape and Urban Planning* 101 (2011): 321-329.
- Day, R. "Place and the experience of air quality." *Health and Place* 13 (2007): 249-260.
- Donovan, G. H., and D. T. Butry. "Trees in the City: Valuing Street Trees in Portland, Oregon." *Landscape and Urban Planning* 94, no. 2 (2010): 77-83.
- Dwyer, J. F., Schroeder, H. W., and Gobster, P. H. "The significance of urban trees and forests: Toward a deeper understanding of values." *Journal of Arboriculture* 17(1991): 276-284.
- Dwyer, J. F., and Nowak, D. J., 2000. A national assessment of the urban forest: an overview. In: Proceedings, Society of American Foresters National Conference, 11-15 September 1999, Portland, OR, pp.157-162.
- Escobedo, Francisco J., John E. Wagner, David J. Nowak, Carmen Luz De la Maza, Manuel Rodriguez, and Daniel E. Crane. "Analyzing the Cost Effectiveness of Santiago, Chile's Policy of Using Urban Forests to Improve Air Quality." *Journal of environmental management* 86, no. 1 (2008): 148-57.
- Flocks, Joan, Francisco Escobedo, Jeff Wade, Sebastian Varela, and Claudia Wald. "Environmental Justice Implications of Urban Tree Cover in Miami-Dade County, Florida." *Environmental Justice* 4, no. 2 (2011).
- Fuller, R. A., and K. J. Gaston. "The Scaling of Green Space Coverage in European Cities." *Biology Letters* 5, no. 3 (2009): 352-55.
- Galvin, Michael F., and David Bleil. "Relationship among Tree Canopy Quantity, Community Demographics, and Tree City Usa Program Participation in Maryland, U.S." *Journal of Arboriculture* 30, no. 6 (2004): 321-27.
- Glenn R, Matlack. "Microenvironment Variation within and among Forest Edge Sites in the Eastern United States." *Biological Conservation* 66, no. 3 (1993): 185-94.
- Gorman, J. "Residents' Opinions on the Value of Street Trees." *Journal of Arboriculture* 30, no. 1 (2004): 36-44.

- Greene, C. S., Millward, A. A., and Ceh, B. "Who is likely to plant a tree? The use of public socio-demographic data to characterize client participants in a private urban forestation program." *Urban Forestry and Urban Greening* 10 (2011): 29-38.
- Greenfield, E. J., Nowak, D. J., Walton, J. T. "Assessment of 2001 NLCD Percent Tree and Impervious Cover Estimates." *Photogrammetric Engineering and Remote Sensing* 75, no. 11 (2009): 1279-1286.
- Harvey D (1996) *Justice, Nature, and the Geography of Difference*. Oxford: Blackwell.
- Heynen, N. "The Scalar Production of Injustice within the Urban Forest." *Antipode* 35 (2003): 980-998.
- Heynen, N.C., Lindsay, G., 2003. Correlates of urban forest canopy cover: implications for local public works. *Public Works Manage. Policy* 8 (1), 33–47.
- Heynen, N., 2006. Green urban political ecologies: toward a better understanding of inner-city environmental change. *Environmental Planning A* 38, 499–516.
- Heynen, N., Perkins, H. A., and Roy, Parama. "The Political Ecology of Uneven Urban Green Space: The Impact of Political Economy on Race and Ethnicity in Producing Environmental Inequality in Milwaukee." *Urban Affairs Review* 42, no. 1 (2006): 3-25.
- Hobbs, Elizabeth. "Species Richness of Urban Forest Patches and Implications for Urban Landscape Diversity." *Landscape Ecology* 1, no. 3 (1988): 141-52.
- Hope, D., C. Gries, W. X. Zhu, W. F. Fagan, C. L. Redman, N. B. Grimm, A. L. Nelson, C. Martin, and A. Kinzig. "Socioeconomics Drive Urban Plant Diversity." *Proceedings of the National Academy of Sciences of the United States of America* 100, no. 15 (2003): 8788-92.
- Hull, R. B. Iv. "Brief Encounters with Urban Forests Produce Moods That Matter." *Journal of Arboriculture* 18, no. 6 (1992): 322-24.
- Iverson, L.R., and E.A. Cook. Urban forest cover of the Chicago region and its relation to household density and income. *Urban Ecosystems* 4 (2000):105-124.
- Jensen R., Gatrell J., Boulton J., Harper B., 2004, "Using remote sensing and geographic information systems to study urban quality of life and urban forest amenities." *Ecology and Society* 9(5).
- Jim, C. Y. and Chen, W. Y. "Perception and Attitude of Residents Toward Urban Green Spaces in Guangzhou (China)." *Environmental Management* 38, no. 3 (2006): 338-349.
- Jim, C. Y. and Chen, W. Y. "Assessment and Valuation of the Ecosystem Services Provided by Urban Forests" in *Ecology, Planning, and Management of Urban Forests: International Perspectives*. Eds. Margaret M. Carreiro, Yong-Chang Song, and Jianguo Wu. New York: Springer Science+Business Media, 2008.
- Kinzig, A. P., P. Warren, C. Martin, D. Hope, and M. Katti. "The Effects of Human Socioeconomic Status and Cultural Characteristics on Urban Patterns of Biodiversity." *Ecology and Society* 10, no. 1 (2005): 13.
- Kirkpatrick, J. B., G. D. Daniels, and A. Davison. "Temporal and Spatial Variation in Garden and Street Trees in Six Eastern Australian Cities." *Landscape and Urban Planning* 101, no. 3 (2011): 244-52.
- Kuo, F.E. "The role of arboriculture in a healthy social ecology." *Journal of Arboriculture* 29 (2003):148-155.
- Kuo, F.E., W.C. Sullivan, R.L. Coley, and L. Brunson. "Fertile ground for community: inner-city neighborhood common spaces." *American Journal of Community Psychology* 26 (1998):823-851.

- Kuo, F.E., and W.C. Sullivan. "Environment and crime in the inner city: does vegetation reduce crime?" *Environment and Behavior* 333 (2001):343-367.
- Lawrence, H.W. *City Trees: A Historical Geography from the Renaissance through the Nineteenth Century*: University of Virginia Press, 2008.
- Lovasi, G. S., Quinn, J. W., Neckerman, K. M., Perzanowski, M. S., Rundle, A. "Children living in areas with more street trees have lower prevalence of asthma." *Journal of Epidemiology and Community Health* 62 (2008): 647-649.
- McPherson, E. G., 1993. Monitoring urban forest health. *Environmental Monitoring and Assessment* 26, 165-174.
- McPherson, E. G., Simpson, J. R., Peper, P. J., Maco, S. E., Gardner, S. L., Cozad, S. K., Xiao, Q., 2005. City of Minneapolis, Minnesota Municipal Tree Resource Analysis. Center for Urban Forest Research.
- McPherson EG, Simpson JR, Xiao Q, Wu C (2008) "Los Angeles Million Tree canopy cover assessment. General technical report. PSWGTR-207. Pacific Southwest Research Station, Forest Service, U.S. Department of Agriculture, Albany, p 53.
- Nega, T., Fu, W., Vrtis, G. "Open space index: a GIS-based tool for assessing human penetration of a landscape." *Local Environment* 15, no. 8 (2010): 743-759.
- Nega, T., Smith, K., Chahara, L., Jayaraman, M. "Inequality and traffic noise in the Twin Cities Metropolitan Region." 2012.
- Nowak, David J. 1994. Understanding the structure of urban forests. *Journal of Forestry*, 92(10): 42-46.
- Nowak, D. J., Crane, D. E., Stevens, J. C., Walton, J. T., Bond, J. *Assessing Urban Forest Effects and Values: Minneapolis' Urban Forest*. Rep. Newton Square, PA: USDA Forest Service, 2006.
- Nowak, D. J., Crane, D. E., Stevens, J. C., Hoehn, R. E., Walton J. T., Bond, J. "A Ground-Based Method of Assessing Urban Forest Structure and Ecosystem Services." *Arboriculture & Urban Forestry* 34, no. 6 (2008): 347-58.
- Nowak, D. J. *Assessing Urban Forest Effects and Values*. Rep. Newton Square, PA: USDA Forest Service, 2010.
- Oke, T. R., J. M. Crowther, K. G. McNaughton, J. L. Monteith, and B. Gardiner. "The Micrometeorology of the Urban Forest [and Discussion]." *Philosophical Transactions of the Royal Society of London. Series B, Biological Sciences* 324, no. 1223 (1989): 335-49.
- Rines, D., Kane, B., Kittredge, D. B., Ryan, H. D. P., Butler, B. "Measuring urban forestry performance and demographic associations in Massachusetts, USA." *Urban Forestry and Urban Greening* 10 (2011): 113-118.
- Pickett, S. T. A., M. L. Cadenasso, J. M. Grove, Christopher G. Boone, Peter M. Groffman, Elena Irwin, Sujay S. Kaushal, Victoria Marshall, Brian P. McGrath, C. H. Nilon, R. V. Pouyat, Katalin Szlavecz, Austin Troy, and Paige Warren. "Urban Ecological Systems: Scientific Foundations and a Decade of Progress." *Journal of Environmental Management* 92, no. 3 (2011): 331-62.
- Pedlowski, M. A., Da Silva, V. A. C., Adell, J. J. C., Heynen, N. C. "Urban forest and environmental inequality in Campos dos Goytacazes, Rio de Janeiro, Brazil." *Urban Ecosystems* 6 (2002): 9-20.
- Perkins, H. A., Heynen, N., Wilson, J. "Inequity in an urban reforestation program: The impact of housing tenure on urban forests." *Cities* 21, no. 4 (2004): 291-299.

- Pincintl, S. "Implementing Municipal Tree Planting: Los Angeles Million-Tree Initiative." *Environmental Management* 45 (2010): 227-238.
- Roy, P. "Analyzing empowerment: An ongoing process of building state-civil society relations - The case of Walnut Way in Milwaukee." *Geoforum* 41 (2010): 337-348.
- Rowntree, A. R., Nowak, D. J. "Quantifying the Role of Urban Forests in Removing Atmospheric Carbon Dioxide." *Journal of Arboriculture* 17, no. 10 (1991): 269-275.
- Sievert, R. C. "Public awareness and urban forestry in Ohio." *Journal of Arboriculture* 14, no.2 (1988): 48-51.
- Schmied, A., and Pillmann, W. "Tree protection legislation in European cities." *Urban Forestry and Urban Greening* 2 (2003): 115-124.
- Schroeder, H. W. "Preferred features of urban parks and forests." *Journal of Arboriculture* 8, no. 12 (1982): 317-322.
- Schroeder, H. W. "Preference and meaning of arboretum landscapes: Combining quantitative and qualitative data." *Journal of Environmental Psychology* 11(1991): 231-248.
- Schroeder, H. W. "The psychological value of trees." *The Public Garden* 6 (1991): 17-19.
- Takano T., Nakamura, K., Watanabe, M. "Urban residential environments and senior citizens' longevity in megacity areas: the importance of walkable green spaces." *Journal of Epidemiology and Community Health* 56 (2002): 913-918.
- Talarchek, G.M. "The urban forest of New Orleans – an exploratory analysis of relationships." *Urban Geography* 11 (1990): 65–86.
- Taylor A. F. Wiley A, Kuo F. E. Sullivan W. C. "Growing up in the inner city: Green spaces as places to grow." *Environment and Behavior* 30, no. 1 (1998): 3–27.
- Totten, M. "Shading Our Cities - a Resource Guide for Urban and Community Forests – Moll, G, Ebenreck,S." *Issues in Science and Technology* 7, no. 1 (1990): 105-08.
- Tyrvaïnen, L., Miettinen, A. "Property prices and urban forest amenities." *Journal of Environmental Economics and Management* 39 (2000): 205-223.
- Ulrich, R. S. "Natural versus urban scenes: some psychophysiological effects." *Environment and Behavior* 13 (1981): 523-556.
- Ulrich, R. S. "View through a window may influence recovery from surgery." *Science* 224 (1984): 420–421.
- Ward, Kathleen T. and Gary R. Johnson. "Geospatial methods provide timely and comprehensive urban forest information." *Urban Forestry & Urban Greening* 6 (2007):15-22.
- Warren, P. S., R. L. Ryan, S. B. Lerman, and K. A. Tooke. "Social and Institutional Factors Associated with Land Use and Forest Conservation Along Two Urban Gradients in Massachusetts." *Landscape and Urban Planning* 102, no. 2 (2011): 82-92.
- Wolf, K. L. "Public Response to the Urban Forest in Inner-City Business Districts." *Journal of Arboriculture* 29, no. 3(2003): 117-126.
- Wolf, K. L., and Trb. "Assessing Public Response to Freeway Roadsides - Urban Forestry and Context-Sensitive Solutions." *Highway Facility Design 2006*, no. 1984 (2006): 102-11.
- Zhang, Y., Zheng, B., Allen, B., Letson, N., and Sibley, J. "Tree Ordinances as Public and Participation Tools: Development in Alabama." *Arboriculture and Urban Forestry* 35, no. 3 (2009): 166-172.
- Zhu, P. "Demand for urban forests: A national and regional study." Auburn University Graduate Thesis (2006): 1-62.

Zube, E. "Trees In Woodlands in the Design of the Urban Environment." In *Trees and Forest in an Urbanizing Environment. Planning Residential Development Service* no. 17. The University of Massachusetts Press, Amherst, Massachusetts. pp. 145-150.

Minneapolis Summary Statistics	Min	Median	Mean	Max	Std dev
Percent canopy cover	0.00	8.08	9.9	31.85	6.73
Median household income (in dollars)	5416.5	38663.5	43608.21	106854.25	18964.42
Per capita income (in dollars)	4287	20326.33	24703.86	73968.5	14149.13
Percent non-white	4	25.01	32.28	94.12	23.85
Percent below 18 years	0	20.68	21.28	48.24	10.79

Table 1 Summary Statistics of data for Minneapolis (NLCD 2000; US Census 2000)

St. Paul Summary Statistics	Min	Median	Mean	Max	Std dev	IQR
Percent canopy cover	0.22	9.41	10.39	26.25	6.31	3.48
Median Household income (in dollars)	29719.33	39600.69	42184.31	63071.55	9602.37	11377.86
Per Capita income (in dollars)	11693.54	21274.1	22368.15	36721.78	7328.76	8768.45
Percent non-white	7.1	29.06	30.3	71.34	18.4	27.43
Percent below 18	7.56	21.23	24.92	41.24	8.61	12.32

Table 2 Summary Statistics of data for St. Paul (NLCD 2000; US Census 2000).

Variable	Coefficient	Std. error	t-value	P-value
Intercept	-19.039	2.036	-9.353	0
log (base e) of median household income	2.737	0.246	11.1319	0
log (base e) of median housing value	0.627	0.191	3.276	0.002
log (base e) per capita income	-1.621	0.25	-6.491	0
log (base e) pct unemployed	0.367	0.058	6.313	0
log (base e) pct no high school degree	-0.167	0.086	-1.939	0.056
log (base e) pct Black	-0.184	0.081	-2.268	0.026
log (base e) pct Hispanic	0.142	0.061	2.344	0.021
log (base e) pct below 18 years	0.18	0.042	4.267	0

Table 3. Coefficient Estimates from the backwards stepwise linear regression for percent canopy cover.

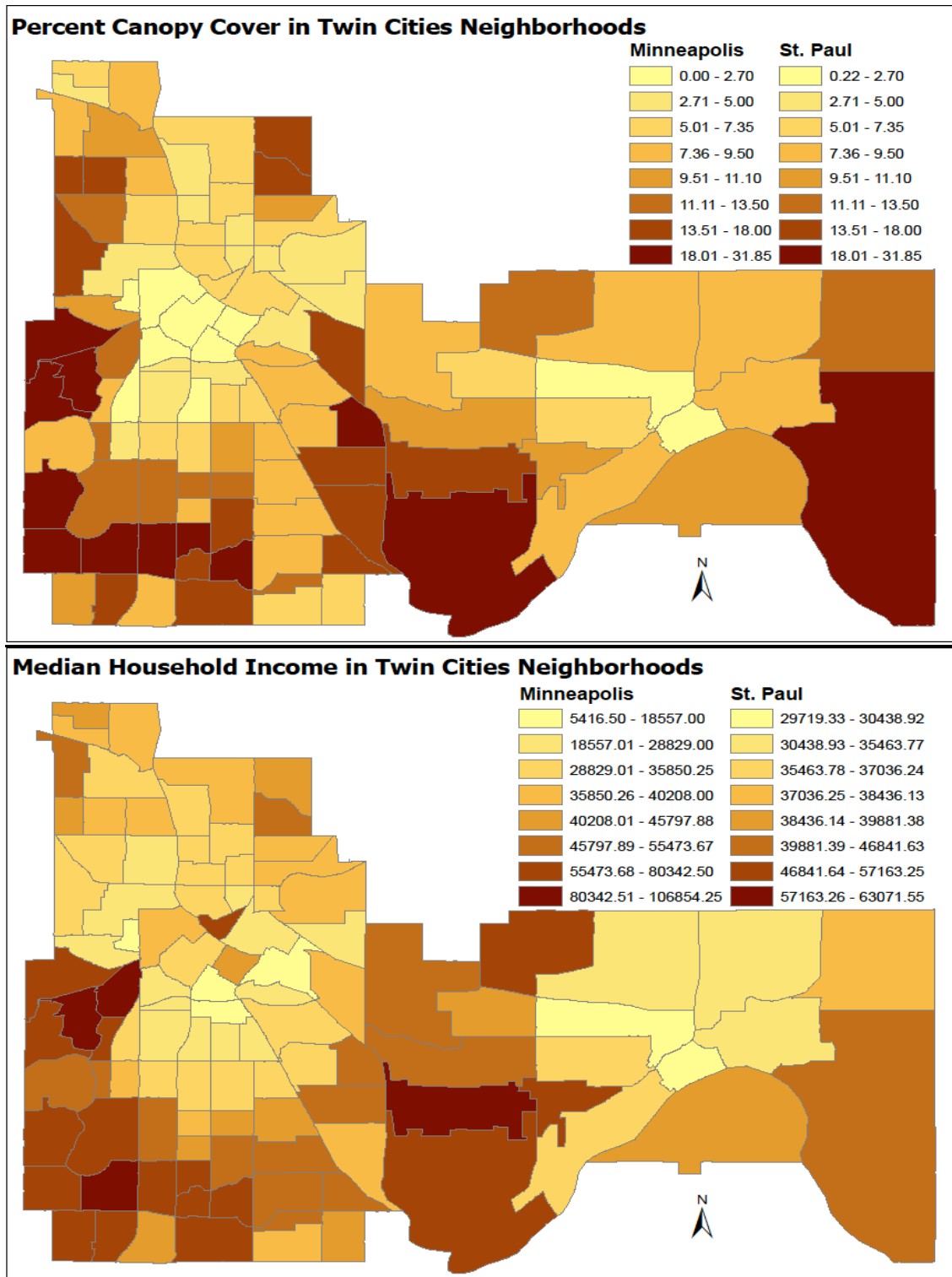


Figure 1a. Canopy Cover and Demographic Variables of Study. Percent canopy cover and median household income by neighborhood in the Twin Cities. Note the similar cluster patterns of the different variables; particularly in the central regions of both cities, the NW and SW regions of Minneapolis, and the North, Central and SW regions of St. Paul. Range in median household income was so different between the two cities that we chose to classify by natural data break.

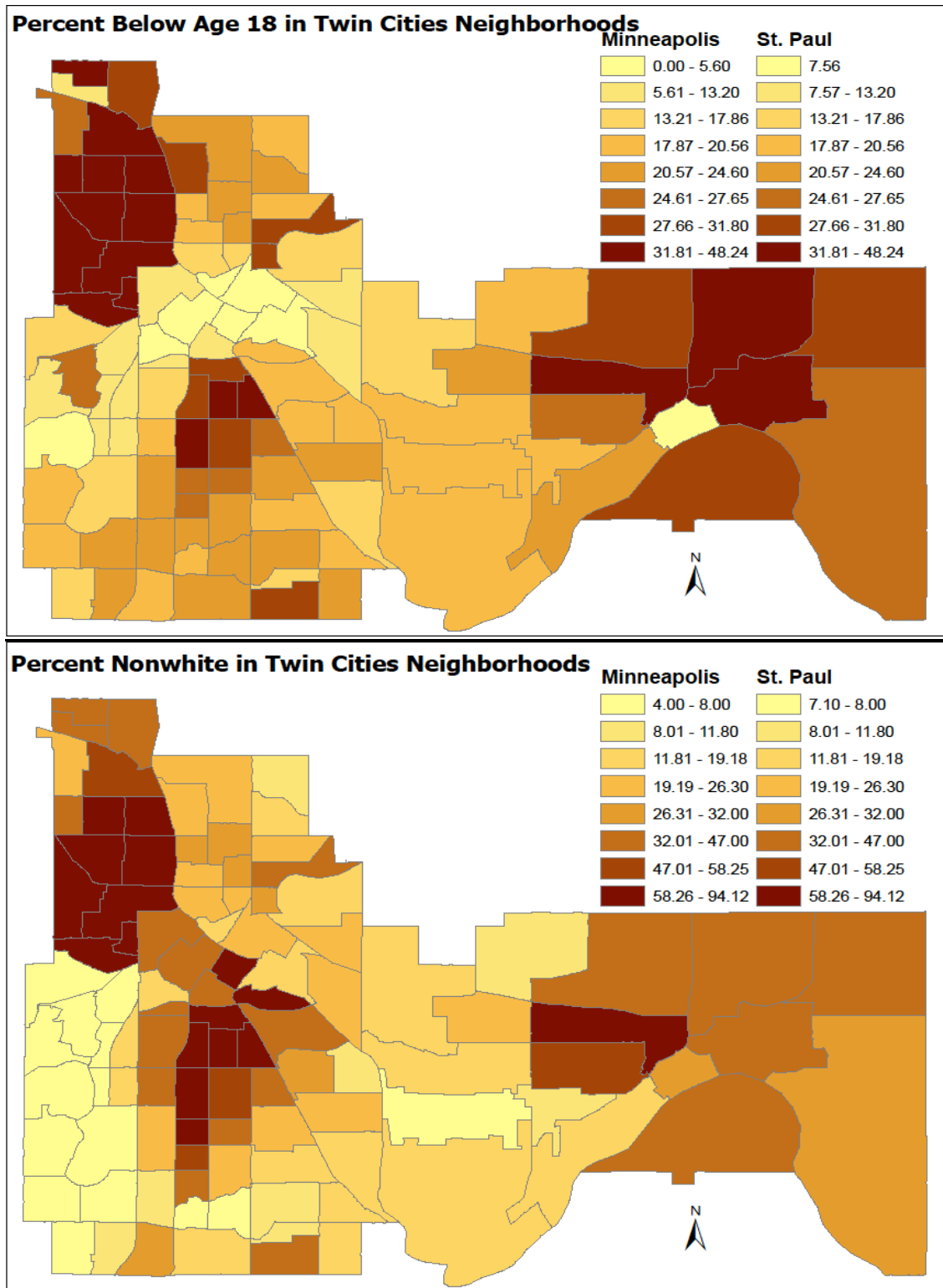


Figure 1b. Canopy Cover and Demographic Variables of Study. Percent nonwhite and percent below 18 by neighborhood in the Twin Cities. Note the similar cluster patterns of the different variables; particularly in the central regions of both cities, the NW and SW regions of Minneapolis, and the North, Central and SW regions of St. Paul.