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Research paper

A comparison of neighborhood characteristics related to canopy cover, stem density and species richness in an urban forest

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HIGHLIGHTS

- ► Significant correlates vary between different measures of the urban forest.
- ► Canopy cover is correlated with development age; tree density and richness are not.
- ► Neighborhood characteristics are not strongly related to species richness.

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ABSTRACT

Urban forest patterns within cities are primarily governed by social factors such as neighborhood characteristics, municipal policy, and individual residents. While a growing body of literature has examined the influence of such factors on tree canopy extent, less attention has been given to other aspects of the urban forest, including tree density and species diversity patterns. Comparing the correlates of canopy cover to other measures of the urban forest is useful for understanding the complex factors shaping urban forest conditions, and can help guide future studies considering the causes of such patterns. This paper explores two inter-related questions: (1) are there differences in the neighborhood correlates of canopy cover, stem density, and species richness? and (2) is canopy cover alone a sufficient representation of the urban forest to understand the ways social factors are related to broader patterns of trees? The questions were addressed through statistical analyses to identify neighborhood socioeconomic and urban form variables correlated with plot-level measures of the three tree variables. The study area includes residential land within Peel Region, which is located in the Greater Toronto Area (Ontario, Canada). We found that significant correlates are different among the three urban forest variables examined, with neighborhood factors having the weakest relationship to species diversity. The results suggest that the underlying mechanisms associated with canopy cover, stem density and species richness patterns vary, and that future studies should consider multiple tree metrics when exploring social correlates to better understand how and why the urban forest varies across a city.

1. Introduction

The ecological and social contributions that urban forests make to city environments are vital. Urban trees improve air quality, sequester carbon, affect storm water runoff, moderate temperature, and provide habitat for a variety of organisms (c.g. Alberti, 2005; Tyrväinen, Pauleit, Seeland, & De Vries, 2005). Trees also positively contribute to house value and social interactions, and provide numerous spiritual, recreational and restorative opportunities for city residents who may otherwise have limited exposure to natural settings (Coley, Kuo, & Sullivan, 1997; Payton, Lindsey, Wilson, Ottensmann, & Man, 2008; Pedlowski, Adell, & Heynen, 2002; Ulrich, 1984).

Recent research has documented the strong relationship urban tree canopy has with neighborhood socioeconomic characteristics and built form (Hope et al., 2003; Iverson & Cook, 2000; Landry & Charkraborty, 2009; Luck, Smallbone, & O'Brien, 2009; Pickett et al., 2001; Sudha & Ravindranath, 2000; Troy, Grove, O'Neil-Dunne, Pickett, & Cadenasso, 2007). Additionally, a neighborhood's built and social history can significantly impact current canopy extent (Boone, Cadenasso, Grove, Schwarz, & Buckley, 2010; Luck et al., 2009; Troy et al., 2007).

To date, the majority of studies exploring social correlates of the urban forest have focused solely on the extent or percent of canopy cover (Grove, Troy et al., 2006; Landry & Charkraborty,

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2009). The emphasis on canopy cover is likely because leaf area it is related to the level of ecosystem services provided by trees, an important management consideration, and it is relatively easy to measure across large spatial extents using remote sensing approaches (Bhaskran, Paramananda, & Ramnarayan, 2010; Xiong & Wu, 2007). However, canopy cover is just one measure of trees, and does not necessarily capture all components related to a healthy urban forest.

In addition to urban canopy cover, two other aspects of the urban forests are frequently measured: tree or stem density and species composition. To date, very few studies exploring the social correlates of the urban forest have examined stem density (for an exception see Pedlowski et al., 2002). Unlike canopy cover, stem density equally records trees across the age spectrum and, as a result, may be more representative of recent planting and removal activities. Residents also have more immediate control over stem density; while canopy cover can be quickly lowered through tree removal, it cannot be greatly increased over short time periods in the way stem density can. Additionally, if canopy cover is very high but the stem density is low, it suggests that additional planting is needed to ensure younger trees are in place, increasing the likelihood a full canopy will be present in the future.

Although a high diversity of tree species often exits within urban areas (Alvey, 2006), the relationship between tree species diversity and potential neighborhood-level correlates has also received less attention. Understanding the drivers of urban tree species diversity is important as higher levels of biodiversity generally provide greater security against environmental changes and stochastic events by increasing the potential for adaptation and survival (Jim & Chen, 2009). Greater levels of urban biodiversity also allows for more complex ecosystem functioning, while creating more niche opportunities that positively feedback to further increase biodiversity (Jim & Liu, 2001). Given that species diversity is recognized as a key component of strategic urban forest management (Kenney, Van Wassenaer, & Satel, 2011), more information about the patterns and underlying drivers of tree species richness in urban areas is needed.

This paper examines the relationship between neighborhood socioeconomics, built form and three components of the urban forest: canopy cover, stem density, and species richness. Specifically, two inter-related questions are addressed: (1) are there differences in the neighborhood correlates of these three tree measures? and (2) is canopy cover alone a sufficient representation of the urban forest to understand the ways social factors are related to broader patterns of trees? The study area is Peel Region (Ontario, Canada) located within the Greater Toronto Area. Plot-level tree data, derived from satellite imagery and field work, were employed in the statistical analyses. Given Peel's rapid rate of urbanization, it is important that the social controls over Peel's urban forest are understood to help develop policy and management plans that will protect and grown the urban forest in Peel, as well as other urban regions across North America.

2. Neighborhood correlates of urban forests

Several studies have identified significant disparities in the distribution of urban forest canopy across social and economic gradients, suggesting that canopy cover–and therefore the host of environmental, economic, social and health benefits imparted by trees – varies based on neighborhood composition (c.g. Emmanuel, 1997; Heynen, Perkins, & Roy, 2006; Landry & Charkraborty, 2009; Pedlowski et al., 2002). These trends reflect the inequality hypothesis, which describes uneven access to positive environmental amenities – such as urban trees – for different socioeconomic groups (Grineski, Bolin, & Boone, 2007; Landry & Charkraborty, 2009).

Central to discussions about the uneven distribution of urban trees is the positive relationship between neighborhood wealth and canopy cover (Emmanuel, 1997; Iverson & Cook, 2000; Luck et al., 2009; Morales, Boyce, & Favretti, 1976; Pedlowski et al., 2002; Talarchek, 1990). The wealth–canopy relationship, however, is not the dominant predictor of canopy extent across all urban landscapes; in Baltimore, Grove, Troy et al. (2006) found social stratification based on income to be the worst of seven models for predicting percent vegetation cover, while a combination of lifestyle behavior factors and median housing age proved more significant.

Additional neighborhood-level socioeconomic factors often correlated with measures of urban vegetation include ethnocultural or racial composition (Heynen et al., 2006; Landry & Charkraborty, 2009; Troy et al., 2007) and percentage of homes that are owner-occupied (Heynen et al., 2006). The ethnocultural relationships appear to reflect historic housing patterns – often linked with neighborhood segregation – political influence and/or cultural preferences in different cities. The significance of owner-occupied dwellings are likely a result of renters often lacking the authority to plant trees, while absentee owners and property managers may be less interested in such an investment.

There are also often significant relationships between specific components of built form and vegetation conditions, with factors such as housing type and road density explaining some of the variations in urban forest cover (Grove, Cadenasso et al., 2006; Heynen & Lindsay, 2003; Landry & Charkraborty, 2009; Smith, Gaston, Warren, & Thompson, 2005; Stone, 2004). Troy et al. (2007) found the percentage of houses within a residential (US) census block group that are single-family is positively correlated with canopy cover, which is not surprising as these homes are often associated with larger yards.

Others, however, have emphasized that canopy cover is more strongly a product of past events than current conditions (Grove, Troy et al., 2006). This is a consequence of the lag time between the planting of trees and their maturity, the period of maximum canopy size. Specifically, Grove, Troy et al. (2006) found that housing age is quadratically related to the amount of vegetation cover, due to an initial wave of planting, followed by natural growth and then mortality. Boone et al. (2010) and Luck et al. (2009) also found evidence of legacy effects when examining contemporary canopy cover in relationship to historic socioeconomic measures.

Although there is a growing body of work exploring neighborhood socioeconomic, built form, and historical legacy effects on tree canopy extent, little attention has been given to the neighborhood-level correlates of urban tree density or species richness. An exception is Pedlowski et al. (2002), who examined tree density on public spaces within residential neighborhoods in a Brazilian city. They found a significant positive relationship with neighborhood house value but no significant relationship with neighborhood age. It is unclear if these results are unique to the Brazilian study area or are capturing a more widespread pattern. A few studies have examined correlates of plant richness, combining trees and other species. For example, a study examining perennial woody vegetation in the arid environment of Phoenix found that income, former land use and housing age were related to diversity (Hope et al., 2006). In Paris, Cohen, Baudoinb, Palibrkc, Persynd, and Rhein (2012) found a relationship between income, building density and the type and diversity of flora in public semi-natural spaces. Kendal, Williams, and Williams (2012) examined correlated of species diversity based on all vegetation in residential front yards, showing that residents' age and presence of renters were key correlates, while neighborhood socioeconomic conditions were not related in an Australia city.