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Research article

The relationship between urban forests and race: A meta-analysis

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ABSTRACT

There is ample evidence that urban trees benefit the physical, mental, and social health of urban residents. The environmental justice hypothesis posits that environmental amenities are inequitably low in poor and minority communities, and predicts these communities experience fewer urban environmental benefits. Some previous research has found that urban forest cover is inequitably distributed by race, though other studies have found no relationship or negative inequity. These conflicting results and the single-city nature of the current literature suggest a need for a research synthesis. Using a systematic literature search and meta-analytic techniques, we examined the relationship between urban forest cover and race. First, we estimated the average (unconditional) relationship between urban forest cover and race across studies (studies = 40; effect sizes = 388). We find evidence of significant race-based inequity in urban forest cover. Second, we included characteristics of the original studies and study sites in meta-regressions to illuminate drivers of variation of urban forest cover between studies. Our meta-regressions reveal that the relationship varies across racial groups and by study methodology. Models reveal significant inequity on public land and that environmental and social characteristics of cities help explain variation across studies. As tree planting and other urban forestry programs proliferate, urban forestry professionals are encouraged to consider the equity consequences of urban forestry activities, particularly on public land.

1. Introduction

In the face of urbanization and global climate change, an international movement to "green" cities has emerged. This movement has encouraged both metaphorical greening activities to reduce consumption (e.g. energy efficiency improvements, public transportation investments) and physical greening activities that cultivate urban vegetation. Prominent in this second set of activities are city tree-planting initiatives that collectively aim to plant millions of trees globally (such as MillionTreesNYC, [www.milliontreesnyc.org; Fisher et al., 2015]).

Urban forests—the land in and around areas of intensive human influence which is occupied by trees and associated natural resources (definition modified from Strom, 2007) — provide many benefits to the physical, mental, and social health of urban residents (Haluza et al., 2014; Hartig et al., 2014; Lee and Maheswaran, 2011; Westphal, 2003) and improve local environmental conditions (Armson et al., 2012; Nowak et al., 2013; Zhang et al., 2012). In addition to their contributions to mitigating climate change (Nowak, 1993), new planted trees promise to provide local benefits to the communities in which they are planted. However, early evidence cautions that urban forestry programs have the potential to create or exacerbate inequity by planting in areas with higher existing canopy cover, higher income (Donovan and Mills, 2014; Locke and Grove, 2016), and with fewer minority residents (Watkins et al., 2016). Even were these programs to plant in low-income and minority neighborhoods, they might yield unintended consequences such as ecological gentrification—increasing property values and forcing low-income renters to relocate (Dooling, 2009; Pearsall and Anguelovski, 2016).

Unequal access of low income and minority residents to urban forests implies unequal access to the physical, mental, and social health benefits that urban forests provide—an environmental injustice. Scholars who have empirically examined the relationship between urban forest cover and race or ethnicity have found conflicting results—studies have found positive, negative, and no relationship between minority populations and urban forest cover (Danford et al., 2014; Flocks et al., 2011). These studies tend to be of a single city, however, potentially hindering the generalizability of

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results. In light of mixed findings, it is still unclear whether concerns of systematic inequity are substantiated by the existing research. Furthermore, there is little understanding of why we observe mixed findings across studies. Do observed differences across studies stem from differences between study sites (cities), or do they stem from methodological choices?

To address these lingering questions, we conducted a meta-analysis of the relationship between urban forest cover and race. A companion paper examined the relationship between urban forest cover and income (Gerrish and Watkins, 2017). We aggregated information from existing studies to estimate the unconditional mean effect size (the average relationship) between urban forest cover and race. The environmental justice (alternatively, environmental racism) hypothesis predicts that people and communities of color will have less access to environmental amenities; in this case, it predicts that people of color will live in areas with disproportionately low urban forest cover. While variation across studies complicates the comparison of the existent literature, it yields a rich opportunity for meta-analysis. We examined potential explanations for variation across studies by controlling for characteristics of the original studies, their empirical strategies, and their study sites using meta-regression, a tool of meta-analysis.

A note about terminology in this paper: for simplicity, in this paper we use *urban forest cover* as a catch-all term for a study's measure of urban trees and herbaceous plants, regardless of how it was operationalized in the original study. Many of the studies in this meta-analysis drew indicators from Census data to measure the percent of a population that is White, African American, Hispanic/Latinx (pronounced La-teen-ex), or another group. Studies often referred to these as measures of race, although some considered Hispanic an indicator of ethnicity. Given the complexity of racial and ethnic identity and the simplicity of the census indicators, this paper uses *race* to refer to a study's independent variable, regardless of how the original study identified it.

Meta-analysis is particularly useful in the case of urban forest equity because it can synthesize several literature that might not otherwise interact. In addition to including studies that are explicitly concerned with environmental justice and mapping and estimating inequity, our meta-analysis captured studies that described urban land use and land use change (Boone et al., 2010; Grove et al., 2006, 2014), study environmental stewardship choices by individuals (Grove et al., 2014; Pham et al., 2013) or public servants (Landry and Chakraborty, 2009), and advance methods for measuring urban forest cover (Szantoi et al., 2008).

Of note, we are constrained in our ability to examine the intersectionality of environmental inequity by the model specifications used in existing studies. We speak briefly to the intersectionality of race and class in our models and discussion, but acknowledge the limitations of this meta-analysis's contributions to a critical approach to environmental justice in this vein (Pellow, 2016) (we again refer readers to a companion study on income, Gerrish and Watkins, 2017). For example, a quantitative study might interact income and race variables to explore whether one variable moderates the other. Because the original studies in this meta-analysis do not conduct such tests, we cannot examine these relationships. Additionally, 35 of the 40 studies analyzed in this study are from the United States; a lack of English-language studies testing our hypotheses in other countries limits the generalizability of this work outside of the US.

To our knowledge, no meta-analyses have been done on municipal service provision equity and only one exists on environmental justice and environmental hazards (Ringquist, 2005; see also Mohai et al., 2009 for a review). Only a few meta-analyses have been conducted on topics in urban greening, and most of them are ecological studies; topics include amenity valuation (Brander and Koetse, 2011), intra-urban biodiversity (Beninde et al., 2015), local plant extinction (Duncan et al., 2011), organic material and environmental outcomes (Scharenbroch, 2009), and street tree survival (Roman and Scatena, 2011). Calls for synthesis of the environmental justice literature in urban forestry across many cities have been made (e.g. Frey, 2016).

This article is organized as follows: first we examine some of the theoretical reasons why access to urban forest cover may vary by race. Second, we explicate the literature search protocol, coding process, inter-coder reliability checks, tests for publication bias, and the methods for conducting meta-regressions. Third we examine the results of meta-regressions. Finally we discuss the implications for policy and research and conclude.

1.1. Understanding variation in urban forest cover

From the current literature, we hypothesized that estimates have varied across studies for four reasons: methodological choices, measurement choices for race, measurement choices for urban forest cover, and characteristics of the study site such as climate.

1.2. Methodological choices

Ongoing discourse in the environmental justice and urban forestry literature suggests differences in model selection and specification might yield differences in findings. Three conversations are particularly prevalent: whether to estimate unconditional or conditional effects, the importance of accounting for spatial autocorrelation, and the extent to which evidence of inequity varies with the size of the unit of analysis (see Noonan, 2008 for a discussion of these concerns with respect to environmental hazards).

1.2.1. Control variables

Results are likely to vary with the inclusion of covariates in regression models. It has become standard in the environmental justice literature to control for potential confounders expected to be related to both the outcome of interest and the environmental justice indicator, and inclusion of covariates is one indicator of a high study quality (Ringquist, 2005).

Including control variables allows authors to prevent spurious conclusions. For example, scholars might include indicators of both race and income in the same model (see Pham et al., 2012). This strategy addresses an enduring question in inequities research—-whether inequity is about race or about class or both (Mohai et al., 2009).

Moreover, urban forestry scholars use multiple covariates to compare competing theories. Findings suggest that features of the built environment such as terrain (Berland et al., 2015), street characteristics (Pham et al., 2017), construction age (Pham et al., 2017; Steenberg et al., 2015), vacant land (Nowak et al., 1996); or available planting space (Shakeel, 2012) help to explain urban forest distribution, and might explain variation better than social characteristics of a neighborhood (Berland et al., 2015; Pham et al., 2017; although see Meléndez-Ackerman et al., 2014 for contrasting findings). Because features of the built environment are collinear with socio-demographic characteristics, we expect studies that control for built environment features to find weaker evidence of race-based urban forest inequity.

1.2.2. Accounting for spatial autocorrelation

Researchers, particularly Geographers, argue that adjusting for spatially correlated errors is critical for correctly estimating the relationship between urban forest cover and sociodemographic characteristics (more accurately, to correctly estimate standard