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Integrating multi-source remotely sensed datasets to examine the impact of tree height and pattern information on crimes in Milwaukee, Wisconsin

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ABSTRACT

There have been a great number of debates about the impacts of trees on crimes: some researchers believed that trees are a crime facilitator because of the concealment provision for potential criminals, while others argued that they are a crime deterrent because of the increased surveillance possibility and the therapeutic effect on psychological fatigue. To better answer this question, this study incorporated detailed tree features by using multi-source remotely sensed data at a very high resolution into environmental criminology analysis across the entire City of Milwaukee. Trees were extracted from aerial photographs, and broken down into two categories based on their heights to consider the effects of tree height on view obstruction. By controlling for confounding socioeconomic variables, the relationship between crimes and a series of composition and configuration indicators of trees with different height were investigated by using global and local spatial regressions. Results from classic and spatial statistical techniques finds complicated relationship between crimes and trees, which can be summarized in two aspects. First, the mixed effects of trees can be observed among different crime types. Second, the trends of spatial nonstationarity of the composition and configuration of trees with different heights were observed across the entire study area. The study outcomes could provide reasonable implications for making appropriate policies for crime prevention through environmental design to strengthen neighborhoods and communities in a city.

1. Introduction

Do urban trees facilitate crimes, or suppress them? There has been a great number of debates about the impacts of trees on crimes. On one hand, trees have long been recognized as a crime facilitator. It is believed that the dense vegetation facilitates crimes by providing an ideal concealment for potential predators (Fisher & Nasar, 1992; Forsyth, Musacchio, & Fitzgerald, 2005; Michael & Hull, 1994; Michael, Hull, & Zahm, 2001; Nasar, Fisher, & Grannis, 1993; Stoks, 1983). Also, general fear and fear of crime are directly linked to densely vegetated areas due to the diminishing visibility (Fisher & Nasar, 1992; Foster & Giles-Corti, 2008; Foster, Giles-Corti, & Knuiman, 2010; Kuo & Sullivan, 2001; Schroeder & Anderson, 1984; Shaffer & Anderson, 1985). On the other hand, other researchers have argued that trees are a suppressor of crime occurrence for the following three reasons (Cozens, Saville, & Hillier, 2005; Hartig, Mang, & Evans, 1991; Kaplan, 1987; Kuo, 2003; Kuo, Bacaicoa, & Sullivan, 1998; Kuo & Sullivan, 2001; Sullivan & Kuo, 1996). First, trees can promote more social activities on public land in a community, and accordingly informal surveillance may be increased. Second, trees can serve as an effective territorial marker, which is also known as one of "the cues to care" (Nassauer, 1988), such as good maintenance and management, and strong social organization and neighborhood involvement. Third, trees can alleviate mental fatigue and, therefore, reduces aggressive behaviors and impulsive crimes. Such a negative correlation between trees and crimes also has been found at the Census tract and Census block group level in different metropolitan areas in the United States (Lorenzo & Wims, 2004; Troy, Morgan Grove, & O'Neil-Dunne, 2012; Wolfe & Mennis, 2012). Recently, the mixed relationship between urban trees and crime rates also has been suggested. These studies argue that street trees in the public right of way and larger lot trees on private land suppress the occurrence of crimes, while smaller lot trees on private land encourage crimes (Donovan & Prestemon, 2012; Troy et al., 2012). However, the consensus between these two schools of thought has not yet been reached, and

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more evidence and further analyses are still needed in different urban areas.

To better understand the relationship between trees and crime, accurate characterization of different dimensions of trees may prove useful to improve crime modeling. A variety of approaches have been developed to characterize urban vegetation in classic studies. For example, photographs followed by greenness ratings by experts were used to describe tree density for studying the association between vegetation and crimes (Schroeder & Anderson, 1984; Talbot & Kaplan, 1984). Kuo et al. (1998) compared a few simulated vegetation conditions in a series of synthetic photographs with existing vegetation conditions in real pictures, in an effort to evaluate the relationship between crime and tree density, as well as tree arrangement and maintenance. Kuo and Sullivan (2001) further improved vegetation derivation by employing visual interpretation of low-oblique aerial photographs, in addition to ground-level photographs. Later, an effective and widely used spectral index of vegetation vigor from remote sensing satellite imagery, normalized difference vegetation index (NDVI), was employed for environmental criminology analysis (Lorenzo & Wims, 2004; Wolfe & Mennis, 2012). Urban tree canopy information were also obtained by using emerging geospatial data and techniques, such as the use of Geographic Information System (GIS) datasets (Phillips, 2013), and high spatial resolution digital orthophoto quarter quads (DOQQ; Donovan & Prestemon, 2012), etc. While tree information was derived in the literature by using the aforementioned methods, most of these studies relied mainly on subjective ratings, manual acquisition, digitizing, or indirect estimation. More recently, light detection and ranging (LiDAR) data was used to map tree canopy by using object-based image analysis (King, Johnson, Kheirbek, Lu, & Matte, 2014; Larondelle, Hamstead, Kremer, Haase, & McPhearson, 2014; MacFaden, O'Neil-Dunne, Royar, Lu, & Rundle, 2012; Troy et al., 2012). Despite novel geospatial datasets and techniques, detailed tree pattern features have not yet been extracted and used for more in-depth crime analysis.

Therefore, this study attempts to answer a frequently asked question in environmental criminology: how do urban trees essentially affect crime occurrences? Two specific aspects were further explored in this analysis. The first is to investigate whether detailed tree patterns (e.g., their patch size, density, and shape) with different heights have any effect on crime occurrences when controlling for confounding socioeconomic factors. The second is to examine the geographic variability of such associations across space. To perform a comprehensive crime analysis at the Census block level, three global and local spatial statistical techniques were employed to analyze geospatial datasets of different crimes and trees from multiple sources.

2. Materials

2.1. Study area

This research was implemented in the city of Milwaukee, WI, United States. There are roughly 600,000 residents living in this city with an area of 250 km^2. According to the crime records, there were over 240,000 total crimes (reported in 38 detailed crime categories) within the study site between 2005 and 2010. With a high unemployment rate (~10% in 2010) and poverty rate (population with incomes below the poverty line; ~30% in 2010), the violent crime rate in Milwaukee is approximately 3.3 times the national median level, whereas property crimes were approximately 1.8 times the national average according to statistics from Bureau of Labor Statistics, U.S. Census Bureau and Federal Bureau of Investigation (FBI). Not surprisingly, Milwaukee was listed as one of the top ten "most dangerous cities in the U.S." (FBI, 2010). It is therefore meaningful to conduct a crime analysis in this city due to its high crime rate. This research was conducted at the Census block level. However, not all Census blocks in Milwaukee were chosen for analysis, because of the diverse data sources that created some missing values for some blocks. By excluding these blocks, all other blocks with complete datasets in Milwaukee were used for the statistical analysis.

2.2. Data

Two major data types were used in this study: socioeconomic data and geospatial datasets. In terms of socioeconomic datasets, 2010 Census block data were downloaded from the U.S. Census Bureau website. The census variables include the population of white, Black, Asian, and Hispanic groups, as well as the population totals for each block. Due to the absence of the socioeconomic survey in the Census data at this level, detailed parcel and relevant tax-related datasets were obtained from Master Property Record (MPROP) on the City of Milwaukee website. Created in 1975 with daily updates, MPROP provides very rich information of land and building within Milwaukee (City of Milwaukee, 2015). MPROP records include parcel size and boundary, owner name and address, assessed house value, land use, zoning, building type, building features (such as the number of building stories, the number of rooms, the number of bathrooms, the presence/absence of air conditioner), and the year of construction, among others. The crime records between 2005 and 2010 were obtained from the website of the Map Milwaukee Portal. Crime information includes complete incident address (with zip code and city), time and type of crime, and police district. In terms of geospatial datasets, such datasets were obtained from different sources, including geographic boundary, land use, and remote sensing datasets. Geographic boundaries of census block were also downloaded from the U.S. Census Bureau website. Also, 2010 land use data of Milwaukee County were acquired from Southeast Wisconsin Regional Planning Commission (SEWRPC). Remote sensing images from different sources were collected during the summer 2010, including a multispectral aerial photograph mosaic with a spatial resolution of 1 m and a LiDAR surface model with a spatial resolution of 1.5 m. The high spatial resolution aerial photograph mosaic was used to calculate NDVI for urban vegetation detection, while the LiDAR data was used to obtain height information above ground. The aerial photograph was resampled to a spatial resolution of 1.5 m to match that of the LiDAR data for further processing. All remote sensing images and GIS shape files were re-projected to the Lambert conformal conic projection with the datum of the NAD 1983 State Plane Wisconsin South.

3. Methods

3.1. Automated extraction of trees across the entire city

The very high spatial resolution multispectral aerial photograph mosaic and LiDAR data were integrated for automated extraction of all urban tree canopies in the City of Milwaukee. Specifically, trees were extracted using a popular decision tree approach, known as the classification and regression tree (CART) algorithm. Two widely used indicators, NDVI and height information, were adopted as inputs in CART. The former was obtained from the aerial photograph mosaic, while the latter from the LiDAR imagery. NDVI can be calculated as follows:

$$NDVI = \frac{NIR - R}{NIR + R} \quad (1)$$

where *NIR* and *R* are the near infrared and red bands of the multispectral aerial photo, respectively. A confusion matrix, user's and