



Using remote sensing to assess the relationship between crime and the urban layout



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ABSTRACT

The link between place and crime is at the base of social ecology theories of crime that focus in the relationship of the characteristics of geographical areas and crime rates. The broken windows theory states that visible cues of physical and social disorder in a neighborhood can lead to an increase in more serious crime. The crime prevention through environmental design (CPTED) planning approach seeks to deter criminal behavior by creating defensible spaces. Based on the premise that a settlement's appearance is a reflection of the society, we ask whether a neighborhood's design has a quantifiable imprint when seen from space using urban fabric descriptors computed from very high spatial-resolution imagery. We tested which land cover, structure and texture descriptors were significantly related to intra-urban homicide rates in Medellín, Colombia, while controlling for socioeconomic confounders. The percentage of impervious surfaces other than clay roofs, the fraction of clay roofs to impervious surfaces, two structure descriptors related to the homogeneity of the urban layout, and the uniformity texture descriptor were all statistically significant. Areas with higher homicide rates tended to have higher local variation and less general homogeneity; that is, the urban layouts were more crowded and cluttered, with small dwellings with different roofing materials located in close proximity to one another, and these regions often lacked other homogeneous surfaces such as open green spaces, wide roads, or large facilities. These results seem to be in agreement with the broken windows theory and CPTED in the sense that more heterogeneous and disordered urban layouts are associated with higher homicide rates.

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Introduction

Macro-level or social ecology theories of crime are focused in how the characteristics of geographical areas influence crime rates, i.e., how crime rates vary by ecological units rather than how the characteristics of individuals relate to their involvement in criminal behavior (Cullen & Agnew, 2011). Since the 19th-century, early French social ecologists Guerry and Quetelet were interested in explaining differences in community crime levels in terms of the varying social conditions of the resident population (Anselin, Cohen, Cook, Gorr, & Tita, 2000). Social disorganization theorists linked high crime rates to neighborhood characteristics such as low income, high unemployment, ethnic heterogeneity, and residential mobility, and the impact these characteristics have on the

community ability to exert social control for the prevention of crime (Shaw & McKay, 1942). The link between place and crime is also central to the perspective of Routine Activities theory, which states that criminal acts require convergence in space and time of a motivated offender, a suitable target, and the absence of capable guardians against crime, and relates crime patterns to the everyday patterns of social interaction (Cohen & Felson, 1979).

Urban neighborhoods differ by the types of households they contain and by the types of physical environments they provide (Roncek, 1981), and these physical environments can influence the likelihood of crime occurrence (Taylor & Harrell, 1996, p. 32). Environmental criminology studies that have addressed the spatial distribution of crime demonstrate that certain land uses, i.e., the concentration of commercial and residential areas, are associated with crime hot spots (Anselin et al., 2000). Land use, sociodemographics, open spaces, and residential density affect the types and intensity of crimes (Salleh, Mansor, Yusoff, & Nasir, 2012). The broken windows theory states that visible cues of physical and social disorder in a neighborhood can lead to an increase in crime (Wilson & Kelling, 1982). Physical disorder refers to the presence of

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abandoned and deteriorated houses and vehicles, graffiti-painted walls and litter, and this phenomenon is also related to social disorder and the occurrence of minor offenses within a neighborhood. Similar ideas support planning approaches that seek to deter criminal behavior by designing ordered, highly visible and easily defensible urban spaces, such as crime prevention through environmental design (CPTED), and New Urbanism (Cozens, 2008). DeFrances and Titus (1993) found that whether a burglary was completed or aborted was associated with neighborhood disorganization and home occupancy, and Keizer, Lindenberg, and Steg (2008) tested the broken windows theory in six field experiments and reported that when people observe that others have violated certain social norms or legitimate rules, they are more likely to violate other norms and rules, causing disorder to spread and escalate.

Previous research addressed the relationships between crime in urban settings and physical and environmental variables such as altitude and slope (Breetzke, 2012), temperature and weather conditions (Anderson & Anderson, 1984; Butke & Sheridan, 2010; Carlsmith & Anderson, 1979; Cohn & Rotton, 2000; DeFronzo, 1984; Field, 1992; Salleh et al., 2012; Sorg & Taylor, 2011), vegetation (Donovan & Prestemon, 2012; Kuo & Sullivan, 2001; Troy, Grove, & O'Neil-Dunne, 2012; Wolfe & Mennis, 2012), land use (Kurtz, Koons, & Taylor, 1998; Wilcox, Quisenberry, Cabrera, & Jones, 2004), nighttime lighting (Weeks, 2003), and the spatial pattern of the built environment (Browning et al., 2010; Foster, Giles-Corti, & Knuiiman, 2010; Shu & Huang, 2003; Taylor & Harrell, 1996, p. 32). Cerdá et al. (2012) found reduced violence outcomes in some neighborhoods of Medellín, Colombia, that were the focus of an urban development plan that included a transportation system and public space improvements such as additional lighting, new pedestrian bridges and street paths, a library park, and buildings for schools and recreational centers. Vegetation measures and land use diversity indices in those works were derived from remote sensing imagery, and the spatial pattern descriptors were computed from expensive and time-consuming field surveys and appraisals.

Spatial effects affect crime as a phenomenon—spatial dependence and spatial heterogeneity—and these effects should be considered when investigating the relationships between crime and place (Anselin et al., 2000; Anselin, 1988, p. 284). However, few studies have considered spatial effects in the literature on crime and the physical features of urban places. Another undertaken issue is the potential effects of selecting improper spatial units of analysis, such as spurious autocorrelation (Anselin, 1988, p. 284) and the “ecological fallacy” (Openshaw, 1984; Robinson, 1950). Based on the hypothesis that the surface appearance of a settlement is the result of the human population's social and cultural behavior and interactions with the environment, and that people living in urban areas with similar physical housing conditions have similar social and demographic characteristics (Jain, 2008; Taubenböck et al., 2009), we use remote sensing data to investigate the relationship between homicide and the urban environment while controlling for potential socioeconomic confounders in Medellín, Colombia. This city is well suited for such a study because it is affected by high crime rates and because of the high variability in the urbanism and socioeconomic conditions of its neighborhoods; these factors make Medellín a useful laboratory for studying urban issues from the spatial analysis perspective.

The remainder of this paper is organized as follows. Section [Study site and data](#) presents the study site, the socioeconomic and remote sensing data, and the spatial unit of analysis. Section [Methods](#) describes a classic econometric model of homicide rates for Medellín and the results from including remote sensing data in that classical model. Section [Discussion](#) presents a discussion of the results, and conclusions are presented in Section [Conclusion](#).

Study site and data

Medellin

Medellin is the second largest city in Colombia and has a population of 2.4 million (DANE, 2012), with 93.4% of its population considering themselves white descendants (which includes mixed Spanish and indigenous Amerindian descent); another 6.5% claim African descent, and 0.1% claim to be indigenous Amerindian (DANE, 2010). This city extends over a narrow valley crossed by Medellín River from South to North, with the most western and eastern neighborhoods of the city built over slopes steeper than 20%. Medellín is a useful location for conducting intra-urban variability studies because it has experienced high population growth rates since the 1950s owing to a combination of factors such as industrial development, which offered job opportunities, and then the political violence and the drug war in the rural areas of the country, which forced many farmers and peasants to move from rural areas to the city. Initially the city grew over the alluvial plain of the river, but in the last decades it spread towards the western and eastern slopes of the valley in an unplanned way. The rapid and unplanned urban growth exceeded the capacity of the local authorities to deliver affordable housing, public services and infrastructure in some parts of the city and resulted in the current high degree of spatial heterogeneity in both the socioeconomic and physical characteristics of its neighborhoods (Juan C. Duque, Royuela, & Noreña, 2013): the more affluent neighborhoods are located in the West and the South parts of the city, while the less affluent are in the North and towards the urban-rural fringe in the steepest slopes of the valley in the East and West.

During the last two decades, Colombia has sustained a reputation as one of the most violent countries in the world, and Medellín is considered to be its most violent city (Giraldo Ramírez, 2010). The average annual homicide rate in the country between 1998 and 2003 was 60 homicides per 100,000 inhabitants, whereas in Medellín, the rate reached 156; from 2004 to 2009, the rates decreased to 37 for Colombia and 50 for Medellín (SISC, 2010, p. 102). Homicide rates in Medellín in the late 1980s correlate with the rise in narco-violence and the strategy of guerrillas and paramilitary groups of bringing the conflict to the cities, whereas the decreasing trends have their starting points in the peace agreements with guerrillas in 1990, the end of the Medellín drug cartel and the death of Pablo Escobar in December 1993, the joint Orion operation between the police and the army to retake control over the most western part of the city in 2002, and the demobilization of paramilitary groups in December 2003 (Giraldo Ramírez, 2010). Statistics for Medellín in recent years show a decreasing trend, from 380 homicides per 100,000 inhabitants in the early 1990s (Gaviria, 2000) to 34 in 2007, and this number peaked again at 94 in 2009 (Giraldo Ramírez, 2010) (Fig. 1).

Socioeconomic data and homicide counts

Socioeconomic variables were computed from the 2005 National Census and the 2009 Quality of Life Survey of Medellín. This survey is developed annually since 2004 by the municipality of Medellín to measure standards of living throughout the city, and to have updated information at inter-census dates to inform policy making. The 2009 Quality of Life survey comprises 237 questions on 11 dimensions: housing, households, demographics, gender and family violence, education, social security, social participation, mobility, security and crime victimization, income and employment, and nutrition. The sample contains 20,782 households that represent 84,474 persons.

Homicide counts by administrative neighborhood for Medellín for the years 2010 and 2011 were provided by the *Sistema de*

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