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Article *in* Urban Studies · January 2020

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Community-driven disorder reduction: Crime prevention through a clean and green initiative in a legacy city

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Abstract

This study examines the effects of a neighbourhood greening and beautification strategy called Clean & Green on crime prevention and reduction. Point level data for all Part I index crimes and Clean & Green efforts in the study area from 2005 to 2014 are analysed using spatial and linear regression with two key modifications: (1) controlling for temporal and spatial dependencies between points; and (2) allowing for potentially non-linear temporal trends in the effect of cumulative greening. To accommodate those modifications, generalised additive models (GAMs) were employed. The analyses of violent and property crimes suggest that greening efforts are increasingly protective over time. The findings

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demonstrate that the elimination of blight and disorder via neighbourhood greening and beautification efforts can be an effective tool for crime prevention and control in communities.

Keywords
collective efficacy, community, crime, disorder, neighbourhood, social order

摘要
本项研究调查了一个名为“清洁与绿色”(Clean & Green) 的街区绿化和美化项目在预防和减少犯罪方面的效果。我们采用空间和线性回归分析，研究了2005年至2014年期间研究区域内（点层面数据）的所有第一类犯罪 (Part I Index) 与“清洁与绿色”项目方面的工作之间的关系，并做了两项关键修改：（1）剔除点之间的时间和空间依赖性；以及（2）考虑累积绿化效果的潜在非线性时间趋势。为了适应这些修改，我们采用了广义相加模型 (GAMs)。对暴力犯罪和财产犯罪的分析表明，随着时间的推移，绿化工作越来越具有保护性。研究结果表明，通过社区绿化和美化工作消除荒芜和混乱可以成为社区预防和控制犯罪的有效工具。

关键词
集体效能、社区、犯罪、混乱、街区、社会秩序

Received July 2018; accepted October 2019

Introduction

Criminal justice tactics such as arrest, incarceration and other types of court adjudications are not the only mechanisms available to reduce crime, nor are they necessarily the most cost-effective. Strategies focusing on public health outcomes might be more effective at reducing aggregate crime rates and cost less (Branas et al., 2011, 2018; Kondo et al., 2018; Moyer et al., 2019; Sadler et al., 2017). For example, research has linked community-driven physical disorder reduction (CDPDR) via the development and maintenance of green space (i.e. greening) to diminishing crime rates in urban areas (Branas et al., 2011, 2018). Greening generally refers to the beautification and maintenance of blighted properties by creating community gardens, mowing lawns and/or planting vegetation (Sadler et al., 2017). The reduction of physical disorders via greening initiatives has been associated with decreases in gun violence, vandalism, stress and sedentary lifestyles (Branas et al., 2011), as well as stronger ties among community organisations and a sense of accomplishment among participants (Sadler and Pruett, 2015).

Despite the growing evidence of the positive association these strategies have with crime rates, very few researchers have studied the influence of such programmes over a prolonged period of time. To date, only two studies have examined the association between greening and crime reduction over a 10-year or longer period. Branas and colleagues (2011) examined the effect of greening urban vacant lots on crime over a 10-year period and Locke and colleagues (2017) examined the associations of planting trees in city streets over a 12-year period. As a result, there is a need for more research that examines whether the association of greening programmes with crime levels endures for several years or is merely temporary.

The purpose of this study is to examine the relationship between CDPDR via

greening and crime over time while controlling for neighbourhood racial composition, socioeconomic and built environment characteristics. We operationalise greening as those properties maintained and beautified through a community lawn maintenance programme in Flint, Michigan, called Clean & Green (C&G). Analyses use point level data for all Part 1 violent and property crimes reported to the Flint Police Department, and greening efforts compiled by the Genesee County Land Bank Authority (GCLBA) from 2005 to 2014. This study builds on earlier work on the C&G programme in Flint – which considered the perceived effect among city residents of the programme on crime (Sadler and Pruett, 2015), the relationship between greening and assaults (Heinze et al., 2018) and the spatial colocation of crime and greening hot spots (Sadler et al., 2017). In so doing, this is one of the first studies to examine temporal trends in violent and property crimes for a prolonged period of time (i.e. 10 years +) with respect to greening while controlling for structural conditions.

Disorder, crime and greening

Prior research suggests that visible disorder in geographic locations is related to aggregate criminal behaviours (Markowitz et al., 2001; Rountree et al., 1994; Skogan, 1990). The literature identifies two types of disorders: social and physical (Sampson and Raudenbush, 1999; Skogan, 1990). Social disorder involves behaviour that is visible to the public and can be construed as potentially threatening (Sampson and Raudenbush, 1999). Physical disorders consist of visible signs of neglect and are defined as 'the deterioration of the urban landscape' (Sampson and Raudenbush, 1999: 604). Social disorder includes catcalling and street harassment, loitering, soliciting and playing loud music in public spaces. Physical disorder includes the presence of rubbish, litter, graffiti, abandoned housing and poorly maintained public spaces (Skogan, 1990). Skogan (1990) posits that these disorders erode community solidarity and discourage collective activities, heighten fear of crime, increase the occurrence of more serious crimes, and undermine residents' satisfaction with and commitment to the neighbourhood in which they live. Sampson and Raudenbush (1999) expanded on the relationship between disorder and crime by positing that disorder co-occurs with crime and that it shares the same structural precursors of concentrated disadvantage and social disorganisation.

Given the relationship between disorder and crime, researchers and practitioners alike have implemented and evaluated various CDPDR tactics in efforts to decrease and prevent crime in geographic areas. One such effort focuses on eliminating physical disorder via greening and beautification strategies in neighbourhood vacant lots. These types of efforts have been tested in multiple cities and with various methodologies and have shown robust positive results despite differences in sites and methods.

In one of the pioneering studies in the area, Branas and colleagues (2011) employed a difference-in-difference analysis over a 10-year period (1999–2008) in Philadelphia and found that elimination of physical disorders via greening efforts were related to reductions in gun assaults in all sections of the city, and a reduction in vandalism and criminal mischief in one section. They also found a reduced level of stress among residents and increases in outside exercise activities. Follow-up studies in Philadelphia have corroborated the findings related to crime reduction (Branas et al., 2018; Moyer et al., 2019). Moyer and colleagues (2019) found a statistically significant decrease in shootings resulting in serious injuries around the greened lots, and Branas and colleagues

(2018) found a statistically significant decrease in all crimes, gun assaults and burglaries after the implementation of the vacant lot greening programme. This body of work in Philadelphia has also found positive outcomes related to resident wellbeing. For example, Garvin and colleagues (2013) found that the residents in the greened areas reported a higher sense of safety, when compared with those from the control areas (Garvin et al., 2013). A more recent study found that residents perceived that crime and vandalism decreased in the treated areas (Branas et al., 2018).

The positive effect of greening vacant lots on crime rates is not unique to Philadelphia as researchers have found similar results in other cities. Using similar methods to those employed in the Philadelphia studies, Kondo and colleagues (2016) found a reduction in assaults, burglary, robberies and theft in at least one of the treatment lot types in Youngstown, Ohio. A later study conducted in New Orleans also by Kondo and colleagues (2018), however, only found statistically significant decreases with drug crimes; indicating that place context matters when examining the effect of greening initiatives.

Greening efforts have also been tested in the city of Flint. For example, Sadler and colleagues' (2017) examination of Flint with emerging hot spot analysis found that neighbourhoods in Flint that participated in the city's C&G programme experienced reductions in violent, property and public order offences. Their emerging hot spot analyses showed an inverse relationship between greening dosage and crime rates. They found that mowing vacant lots was associated with diminishing crime hot spots and generating new crime cold spots throughout the city. Crime remained higher in places with little greening or where implementation of C&G was absent. More recently, Heinze and colleagues (2018) found that street segments in the city of Flint that maintained vacant lots by using greening tactics experienced a reduction in violent assaults.

Other researchers suggest that the presence of trees and other vegetation is inversely related to crime, violence and aggression (Burley, 2018; Kuo and Sullivan, 2001a, 2001b; Snelgrove et al., 2004; Wolfe and Mennis, 2012). That is, the more vegetation and trees, the lower the incidence of crime. For example, Burley (2018) found that in neighbourhoods in Portland, Oregon, the planting of new trees was correlated with a decrease in violent crime and that the planting of new trees in neighbourhoods with lower median household incomes had a positive effect. These findings, however, appear to be place-specific since Locke and colleagues' (2017) examination of a similar initiative in New Haven, Connecticut, did not find an effect between these efforts and crime.

Researchers posit that the mechanisms linking greening efforts to decreases in crime are heightened levels of guardianship and strengthened collective efficacy among residents (Alaimo et al., 2010; Kuo and Sullivan, 2001a). For example, a descriptive case study observation conducted in Lawrence, Massachusetts, after greening efforts suggests that the maintenance of a community garden contributed to a reduction in fear of crime and increased social capital through the strengthening of civic engagement among residents who participated in the programme (McCabe, 2014). In another qualitative investigation conducted in Flint, Michigan, interviews with residents suggest that participation in the C&G programme increased levels of collective efficacy in participating neighbourhoods (Sadler and Pruett, 2015). Specifically, programme participants believed that the initiative was a critical factor in bringing people together to solve neighbourhood blight problems. Participants also indicated that greening served as a catalyst for building community pride and reducing crimes such as prostitution, drug dealing and break-ins.

Bringing neighbourhood residents together through projects that enable them to work as a group to solve problems may serve as a catalyst for increasing collective efficacy in the community despite poor structural conditions. Collective efficacy refers to the 'social cohesion among neighbours combined with their willingness to intervene on behalf of the common good' (Sampson et al., 1997: 918). Collective efficacy does not occur over-night and it takes time to develop. By coming together for a common purpose such as greening and beautification, residents strengthen private and parochial networks after repeat interactions (Aiyer et al., 2015; Alaimo et al., 2010; McCabe, 2014). As residents work together towards a common goal, they will get to know each other and build mutual trust, which in turn may result in collective efficacy.

The presence of greening programmes also offers an opportunity to enhance either directly or indirectly the informal social control within neighbourhoods. Participation in greening means more people out in the streets attending to their property and public spaces in their neighbourhood, and this simultaneously leads to increased levels of guardianship. Additionally, individuals having a stake in their community may result in a greater willingness to report crime and disorder to proper authorities (Aiyer et al., 2015; Jacobs, 1961). Related greening initiatives within communities reduce signs of physical disorder that may invite more serious offending (Skogan, 1990; Wilson and Kelling, 1982). As a result, offenders may become increasingly averse to committing crime in these communities because of their perception that residents care and, thus, would not allow criminal behaviour in the area.

Current study

The purpose of this study is to ascertain the relationship between CDPDR and crime by examining the association of CDPDR via greening through the C&G programme of the GCLBA from 2005 to 2014 in Flint, Michigan. This study focuses on the following research question: How does the relationship between greening and crime change over time while controlling for neighbourhood structural characteristics? This study builds on prior greening research by modelling the influence of specific social and environmental variables on greening's ability to reduce crime. Recent enquiries have linked greening to crime control gains; however, the bulk of these analyses do not control for important demographic, socioeconomic, housing condition and built environment variables that research suggests have a relationship with aggregate crime rates. Moreover, this is one of the few studies that examine the association of greening with data spanning more than a 10-year period.

This study also advances the current understanding of the greening–crime relationship through modelling the association longitudinally using semi-parametric regression models that allow for general modelling of the temporally varying relationship without pre-specifying its nature (e.g. linear). This allows for a very general understanding of how greening is related to changes in crime over time. This is important because – owing to the relative youth of greening as a strategy to reduce crime – few scholars have sought to investigate the temporal dimension in greening. Knowing whether greening efforts have a sustained association is important for policy development as well as increasing the theoretical understanding of these initiatives.

Site description

Flint has undergone vast transformations in recent decades following the steep decline of manufacturing jobs and financial investment. According to the 2014 American

Community Survey (ACS), African Americans comprised 55% of Flint's approximately 99,000 residents, while Caucasians comprised 39% (US Census Bureau, 2016a). Partly as a function of historical patterns of racial discrimination that tie redlining and white flight to neighbourhood disinvestment, the city faces severe economic challenges; among other indicators, its median income (US$24,679) and unemployment rate (13%) are much worse than state and national averages (US Census Bureau, 2016b, 2016c). Moreover, the prevalence of families with children under the age of 18 living below the poverty level is more than 30% higher in Flint compared with rates across the state and nationwide (US Census Bureau, 2016b, 2016c, 2016d).

Flint's population has been declining since the mid-1960s from its peak of nearly 200,000 residents. From 2000 to 2014 alone, its population decreased from 124,741 to 99,002, a 21% reduction (US Census Bureau, 2015). This rapid and ongoing outward population migration has drastically reduced the city's tax base, and substantially increased the amount of unoccupied housing stock and discarded properties (as discussed in more detail in Sadler and Lafreniere, 2017). With limited public resources, the city relies heavily upon its own residents to help eliminate urban blight. The GCLBA has been an important steward in stemming the negative effects of land that otherwise may be unmaintained: the state passes foreclosed properties to GCLBA, and GCLBA strategically maintains the properties through rehabilitation or demolition.

Through its C&G programme – which was created in 2004 to partner with community groups who mow and beautify vacant properties – the GCLBA has been able to cheaply and innovatively maintain thousands of parcels annually, addressing one of the biggest challenges of population decline (GCLBA, 2015). C&G efforts primarily include clearing debris and mowing lawns but can also include planting community gardens or other plants, establishing pocket parks or decoratively boarding-up vacant homes. C&G works via community groups who apply to and receive a stipend from the GCLBA each year to maintain at least 25 properties during the mowing season (from May to October). These groups work with GCLBA to identify properties in need of upkeep. Stipends are then used to pay for personnel and equipment to maintain these properties. Sadler and Pruett (2015) reported that in 2014, more than 50 community groups and 200 youth participated in the C&G programme and maintained over 1800 properties during that time. GCLBA estimates that, in recent years, more than 1000 people have participated in C&G annually.

In any given year, the distribution of properties maintained is partly contingent on who applies for the stipend and the lots owned by the GCLBA. Crime rates are usually not explicitly a part of the decision-making process, though local knowledge of trouble spots undoubtedly comes into play. Properties assigned to any one group also tend to cluster within a few blocks to concentrate the association with the greening. Figure 1 illustrates the net distribution of all properties maintained from 2005 to 2014.

Methodology

Data

This study employs various data sets to answer the research question of interest: How does the relationship between greening and crime change over time while controlling for neighbourhood structural characteristics? We use crime incident data compiled by the Flint Police Department and extracted from their data information system. These data include all of the crimes that came to the attention of Flint PD from 2005 to 2014. We grouped the crime incident data based on the

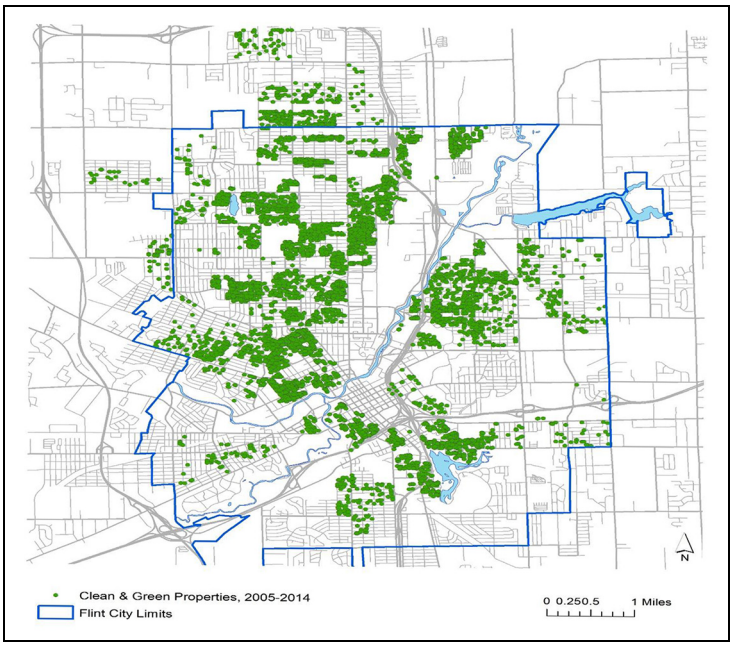

Figure 1. Clean and green lots.

Uniform Crime Report Categorization of Part 1 and Part 2 crimes and, for the purpose of this study, focused only on Part 1 violent and property offences. Violent offences include homicide, sexual assault/rape, aggravated assault and robbery. Property offences include burglary, larceny/theft, motor vehicle theft and arson.

We also employ C&G data compiled by the GCLBA. These data contain information on parcel maintenance and greening efforts for the years 2005–2014. Specifically, C&G participants were required to track all parcels maintained every 3 weeks. We digitised these maintenance records, which include date and location of all greened parcels, and joined them to a parcel database to derive a final shapefile that indicates the number of times participants maintained each parcel per year.

In order to control whether place racial composition, socioeconomic status and built environment mediate the association of C&G greening efforts on crimes we also employed racial composition and socioeconomic data compiled from the National Historical Geographic Information System (Minnesota Population Center, 2011) and the City of Flint. These data include information on variables such as economic disadvantage, ethnic composition and citywide population at the census tract level. Finally, we compiled housing survey and environmental data from the City of Flint Department of Planning and Development (2012, 2016). These include parcel status, neighbourhood housing condition and land use. Parcel status is parcel specific. Neighbourhood housing condition was collected at the census block level. Land use was collected at the census tract level.

Unit of analysis. Given that C&G activities occurred in property parcels, the unit of analysis of this study is residential parcels. As a result, we assigned the variables

extracted from the aforementioned data sources to residential parcels, with observations for each year in the data set inclusive. That is, we assigned to each parcel the neighbourhood-level characteristics of the larger unit in which it resides. This parcel-level approach enables a fine-grained analysis of the relationship between levels of greening and crime when controlled by parcel-level and neighbourhood-level characteristics, and overcomes some issues associated with the modifiable areal unit problem.

Dependent variables. This study examines two dependent variables: violent crime density and property crime density. We calculated violent and property crime densities by using the incident addresses provided in the Flint PD crime incident reports. Specific addresses were geocoded using ArcGIS 10.3 (ESRI, 2015), yielding a 95% match rate (remaining incidents were matched manually). Incidents reported at hospitals or police stations are not included because the actual crime incidents did not occur in those locations. We employed kernel density analysis to compute violent and property crime density for individual years and appended the density at that point to each parcel. We used the default search radius, which does not assign a specific distance but instead is based on the number of input points and corrects for spatial outliers (ESRI, 2015). We then extracted the resulting value of the kernel density analysis – signifying the relative density of crimes in any location – at each individual residential parcel through a raster value to feature join function in ArcGIS. Owing to the focus on the association of greening activities, these analyses were restricted to the active mowing season established by C&G (1 May to 31 October); specifically, we assume that the associations of greening are diminished during the season when active greening is not taking place and wanted to test the specific associations during the greening season itself.

Independent variables. Given the research question examined, the independent variable of interest is cumulative greening for the neighbourhood parcel. We conducted kernel density analyses to derive a cumulative greening score (in raster format) for 2006–2014. Working from the assumption that greening associations are relatively local and that maintaining a property may influence crime levels within the distance of approximately one block, we employed a search radius of 500 feet (as used in Sadler et al., 2017). In total, we calculated nine scores, which were inclusive (e.g. the 2006 score included 2005; 2007 score included 2005 and 2006; the 2008 score included 2005, 2006 and 2007; and so on, with the final score for 2014 including all the years). We used cumulative scores because we assume a longer-term association with places that have consistent greening over several years. We then joined the cumulative greening scores for each year to the corresponding year's crime density score. For example, the 2007 cumulative greening score (which included 2005–2007 greening inclusive) was joined to the 2007 crime density score, the 2008 cumulative greening score (which included 2005–2008 greening inclusive) was joined to the 2008 crime density score, and so on.

Control variables. Prior research documents a relationship between residential racial composition, socioeconomy, built environment and crime (Brown et al., 2009; Macdonald, 2015; Sampson and Raudenbush, 1999; Sampson et al., 1997). As a result, we appended to parcels six control variables: (1) socioeconomic distress, (2) percent black, (3) parcel status, (4) neighbourhood housing condition, (5) land mix, and (6) city-wide population. The first measures consider

socioeconomic conditions, the second measure racial composition, and variables 3–5 consider the built environment. Finally, citywide population captures fluctuations in the Flint population. This is particularly important in the city of Flint because the city has experienced vast residential outmigration during the past 20 years. Indeed, from 2006 to 2014 the city population went from approximately 116,000 residents to 99,000 residents. We use block group level statistics from the US Census to capture socioeconomic conditions, and City of Flint data to capture built environment and citywide population.

We measure socioeconomic distress with an index of variables adapted from past research on Flint (Hanna-Attisha et al., 2016; Sadler et al., 2013) and social disorganisation (Sampson et al., 1997). Socioeconomic distress includes an unweighted *z*-score sum of rates of: (1) low educational attainment measured as the proportion of residents 25 years and older with no high school diploma; (2) lone parenthood measured as the proportion of single-parent families; (3) low income measured as the average income of people 25 years and older; and (4) unemployment measured as the employment population ratio of residents 25 years and older. In this index, higher scores indicate more socioeconomic distress, while lower (negative) scores indicate less distress. Percent black captures the percentage of black residents within the block group.

Built environmental data from the City of Flint (2012, 2016) include parcel status, neighbourhood-housing condition and land use mix. Parcel status captures whether the parcel is vacant or occupied. We measure neighbourhood average housing condition by averaging the conditions of every house in the block. We obtained data for this measure from a housing survey conducted by the city of Flint in 2012 (City of Flint, 2012). As part of the survey, a trained rater from the GCLBA coded the conditions of every house in the city and assigned houses one of four ratings based on the condition of the house: good, fair, poor or structurally deficient. We used these scores to create the neighbourhood (block-level) average condition score. Land use mix is an entropy index defined by the mix of residential, commercial and industrial land use. It is defined as:

$$LUM = (-1) * \left[\left(\frac{R}{a}\right) \ln\left(\frac{R}{a}\right) + \left(\frac{C}{a}\right) \ln\left(\frac{C}{a}\right) + \left(\frac{I}{a}\right) \ln\left(\frac{I}{a}\right) \right] / (\ln(n3)) \quad (1)$$

where a is the total acreage of a land use within a moving window from any point on the map, R is residential acreage, C is commercial acreage, I is industrial acreage and $n3$ signifies the total number of land uses present in the window (which in this case is 500 feet). We converted each variable to a categorical scale for stratification of regression analyses, with the categories shown in Table 1.

Analysis

The unit of analysis to which we assigned all variables is the residential parcel, with observations for each year in the data set inclusive. We examined 51,263 total parcels (representing all residential properties in the city) and assigned to each parcel the characteristics of the larger unit in which it resides. We then ran two separate sets of analyses – one for violent crimes and one for property crimes. The primary analytic technique employed was linear regression with two key modifications: (1) controlling for spatial dependencies between points, and (2) allowing for (potentially non-linear) temporal trends in the association between cumulative greening and crime density. To accommodate those modifications, generalised additive models

Table 1. Summary of variables.

Category	Variable	Scale	Categories
Social	Distress	Census block group	Quintiles of *z*-score sums
	Percent black	Census block group	Quintiles of *z*-score sums
Built Environment	Parcel status – vacant (Yes, No)	Parcel	Yes/No
	Neighbourhood housing condition	Block	1–1.24; 1.25–1.49; 1.5–1.99; 2–2.49; 2.5 +
	Land use mix	Census block group	Quintiles

(GAMs) were employed. Specifically, within a single model, we modelled crime density at time (year) t and parcel location (in UTM coordinates) s as:

$$Y_t(s) = X(s) \cdot \beta + G_t(s) \cdot \alpha(t) + P(t) \cdot \gamma + \phi(s) + \theta(t) + \varepsilon \quad (2)$$

β is used to control for non-time-varying covariates (socioeconomic distress, percent black, parcel status, housing condition and land mix), denoted by $X(s)$; these coefficients are interpreted the same way as coefficients from a linear regression model. The primary parameter of interest is $\alpha(t)$; the time-varying coefficient for cumulative greening score at location s and time t, $G_t(s)$, is interpreted the same as a usual regression coefficient but varies (potentially non-linearly) as a function of time. Therefore, in this way, it may be viewed as a (non-linear) generalisation of an interaction between greening and time. We examine nine different time points (i.e. 2006–2014). Within this framework, testing for a time-varying association between greening and crime amounts to testing the null hypothesis that $\alpha(t)$ is a constant function, $H_0 : \alpha(t) = \alpha$.

To get a properly adjusted estimate of the association between greening and each crime type, we controlled for neighbourhood socioeconomic distress, percentage of black residents in the neighbourhood, parcel status, neighbourhood housing condition and land use mix in all models. City-wide population (by year), $P(t)$, was also included in an attempt to control for the changing population size in Flint, in the absence of time-varying population-size data at the block level (which in ACS Census Data is unreliable at best).

The function $\phi(s)$ is used to model spatial trends in the data and removes any spatial signal from the residuals in a fashion analogous to spatial random associations. Previous research has modelled spatial dependence in this way (see Goldstick et al., 2015). Controlling spatial dependency in this way treats space continuously rather than assuming arbitrary areal units (e.g. neighbourhoods defined by census block groups) with fixed correlation within units and none across units. The temporal trend is captured by $\theta(t)$, which models any residual secular temporal trends not captured by the greening variable (e.g. declining crime counts due to uniform population loss). All functional parameters in this model – $\alpha(t), \theta(t), \phi(s)$ – are modelled using thin-plate splines, with smoothness chosen within the fitting procedure by generalised cross-validation, which allows data-driven (rather than pre-specified) determination of the shape of the regression function. All other regression coefficients were fixed (i.e. time-invariant).

Findings

Table 2 presents descriptive statistics and unadjusted correlations between each

Table 2. Descriptive statistics (N = 461,367).

Variable	M/% (SD)	Violent	Property
Distress	2.4 (3.2)	0.33 (0.32, 0.33)	0.06 (0.06, (0.06)
Percent black	0.54 (0.40)	0.12 (0.12, 0.12)	−0.04 (−0.04, −0.04)
Parcel status vacant	10205 (19.9%)	0.02 (0.02, 0.02)	−0.10 (−0.10, −0.10)
Neighbourhood housing condition	1.7 (0.6)	0.26 (0.26, 0.26)	0.07 (0.06, 0.07)
Land use mix	−0.63 (0.00)	−0.25 (−0.25, −0.25)	−0.23 (−0.23, −0.23)
Cumulative greening (2006)	0.26 (0.97)	0.02 (0.01, 0.03)	−0.06 (−0.07, −0.05)
Cumulative greening (2007)	0.47 (1.59)	0.05 (0.04, 0.06)	−0.01 (−0.02, 0.00)
Cumulative greening (2008)	0.59 (2.00)	0.01 (−0.00, 0.02)	−0.08 (−0.08, −0.07)
Cumulative greening (2009)	0.82 (2.50)	0.02 (0.01, 0.03)	−0.07 (−0.08, −0.06)
Cumulative greening (2010)	1.21 (3.37)	−0.00 (−0.01, 0.00)	−0.17 (−0.17, −0.16)
Cumulative greening (2011)	1.65 (4.30)	−0.06 (−0.07, −0.05)	−0.12 (−0.12, −0.11)
Cumulative greening (2012)	2.06 (5.22)	−0.11 (−0.12, −0.11)	−0.17 (−0.18, −0.16)
Cumulative greening (2013)	2.53 (6.21)	−0.04 (−0.05, −0.03)	−0.19 (−0.20, −0.18)
Cumulative greening (2014)	3.33 (7.45)	−0.07 (−0.08, −0.06)	−0.12 (−0.13, −0.12)

Notes: Entries in the left column are mean/SD for quantitative variables and percentages for counts. Columns 2–4 show unadjusted correlations of each variable with violent and property crimes, respectively. For the rows specific to a single year the sample size is 51,263 parcels.

variable and crime density. Percent black is correlated with more violent crime and had a small but statistically significant association with property crime. Vacant parcels had lower rates of property crime and a small positive association with violent crime. Neighbourhood distress showed positive associations with both violent and property crimes, with the larger association being with violent crime; a similar trend was seen with housing condition. Land use mix was positively associated with property and violent crime. Cumulative greening values increased annually from 2006 to 2014. The associations between greening and property crime were increasingly negative over time; a similar trend was observed with regard to violent crime.

Violent crime

We show the non-time-varying regression coefficients in the model for violent crime in Table 3, and the time-varying associations of cumulative greening with violent crime in Figure 2. The unsmoothed estimates (i.e. fitting a separate coefficient for each year) of the time-varying relationship between greening and violent crime are also superimposed on Figure 2. The smooth time-varying association yields give a more interpretable trajectory than the large year-to-year fluctuation seen in the unsmoothed estimates. The adjusted association of cumulative greening begins near zero (with the point-wise confidence interval clearly covering zero) and quickly declines thereafter. After the second year (2007), the association is significantly negative (the confidence interval is entirely below zero) and continues to decline. The association appears to move back toward zero after year six (2012). The time-varying association was statistically significant ($p < 0.001$). Overall, this trajectory suggests that the association of greening with violent crime is increasingly strong over time, possibly because of a delayed onset of the positive associations of greening (see Figure 2). The diminishing effect in later years may be due to the continued expansion of the programme and the positive mechanisms that reduce crime not immediately taking hold in those new neighbourhoods. Structural conditions also emerged as significant in this

Table 3. Non-time varying regression coefficients relating to crime. (N = 461,367; 51,263 parcels measured at nine time points).

Variable	Violent crime	Property crime
Population (in 1000s)	−0.71 (0.07)	5.53 (0.00)
Distress	3.22 (0.05)	0.48 (0.06)
Percent black	21.38 (0.76)	46.62 (1.12)
Parcel status (vacant)	−7.57 (0.20)	−14.21 (0.29)
Neighbourhood housing condition	9.37 (0.20)	7.09 (0.29)
Land use mix	−49.8 (0.46)	−76.78 (0.68)

Notes: Entries are regression coefficients with standard errors in parentheses. All coefficients are significant at $p < 0.001$.

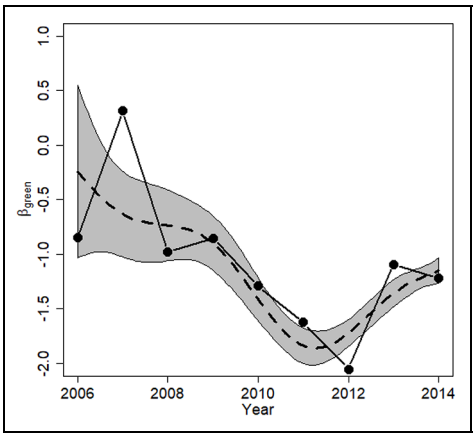

Figure 2. Time-varying associations of cumulative greening on violent crime (N = 461,367; 51,263 parcels measured at nine time points).

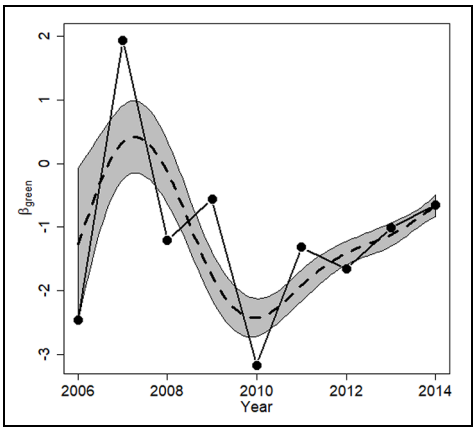

Figure 3. Time-varying associations of cumulative greening on property crime (N = 461,367; 51,263 parcels measured at nine time points).

model (see Table 3). Specifically, parcels in areas with higher numbers of vacant lots experienced fewer violent crimes, while those in areas with a higher percentage of black residents, greater socioeconomic distress and structures in neighbourhoods with poorer housing conditions experienced more violence crime. Finally, mixed land use is related to less violent crime.

Property crime

Table 3 shows the coefficients of the non-time-varying covariates of property crime. The adjusted association between cumulative greening and property crime (Figure 3) starts out significantly negative (the upper end of the confidence interval is below zero) before crossing zero and becoming positive in year 2, null in year 3 and significantly positive thereafter. The time-varying association was statistically significant ($p < 0.001$). Overall, this coefficient trajectory shows that greening is generally negatively associated with property crime, but we also found some fluctuation in the earlier years. Analogous to the violent crime figure, the unsmoothed trajectory estimate (i.e. fitting separate coefficients for each year) was superimposed on Figure 3 to display the utility of smoothing over the

year-to-year fluctuation. Of note, in both Figures 2 and 3 we notice that a constant coefficient estimate (i.e. a global estimate that does not vary across time) would likely substantially underestimate the association between greening and crime in the later years of the trajectory. Similar to the violent crime model, all the structural variables emerged as significant, although some exhibited distinct relationships. Specifically, neighbourhood percent black, socioeconomic distress and housing condition also had positive significant associations with property crime, with increases in black residents, socioeconomic distress and poor housing being associated with more property crime.

Discussion

Researchers have reported that greening initiatives can serve as a crime control/prevention mechanism in crime-ridden neighbourhoods. Testing this proposition with robust analytic techniques, this study adds to this body of research by examining the relationship between greening efforts (as a form of CDPDR) and crime while controlling for structural conditions and accounting for time-dynamic associations. The findings suggest that greening is increasingly negatively associated with crime over time after controlling for neighbourhood-level structural variables. These associations did fluctuate, however, with some years showing a non-significant association. These fluctuations may be due to the introduction of new lots during some years. The C&G programme grew significantly during the study, from 440 treated properties in 2005 to 3146 in 2014. Although the addition of new parcels is accounted for in the cumulative greening scores, the association in some areas may be muddied or not strong enough to capture since some properties were not involved with the programme long enough to demonstrate an association. Despite these fluctuations, evidence from this study indicates that reducing physical disorders via greening can be an effective tool for crime prevention and control in communities. Indeed, areas with more years of greening are equated with stronger negative relationships with crime rates.

Theoretically, these findings give further support to the positive associations of reducing disorder with crime. The findings also suggest that it is important to consider time when examining the associations of these types of initiatives. Although not examined here, greening efforts in Flint appear to have increased levels of collective efficacy (Sadler and Pruett, 2015), which in turn can explain positive associations with regard to the two distinct crime types. Drawing on prior research, participation in CDPDR efforts such as greening may enhance collective efficacy by increasing the density of close social ties and improving a community's organisation infrastructure, thereby countering the negative association of structural disadvantage and serving as an effective tool for crime prevention and control.

In addition to serving as a catalyst for the emergence of collective efficacy, one can surmise that the reduction of physical disorder via greening also served as a form of 'fixing broken windows' and, thus, increased informal social control in the treated neighbourhoods. The beautification strategies may have served as a deterrent to would-be offenders, by encouraging residents and non-residents alike to step outside in these neighbourhoods, engage with one another and consequently provide guardianship (Aiyer et al., 2015) in these areas. Because of increased ownership of spaces for legitimate use and heightened levels of guardianship, offenders may be increasingly averse to committing crime in these communities.

At the city level, these findings are encouraging given Flint's ongoing challenges with crime. Flint has endured rapid and

substantial population losses, a trend that unfortunately is projected to continue. Indeed, the Genesee County Metropolitan Planning Commission (2015) estimates that Flint's population will decline to 90,854 by 2020 and 79,365 by 2040. This population decline is particularly striking in a city that had over 200,000 residents in the 1960s. Inevitably, accompanying such a sustained outward migration of people will be an increase in the prevalence of vacant and abandoned housing as well as lower tax revenue that will further constrain the city's capacity to deliver public services and tend to these properties. As a result, the implementation of similar community-driven strategies throughout the city can serve to alleviate these issues. These findings also have implications for other similar legacy cities. Cities experiencing the negative effects of economic decline have a critical need to develop policies to effectively address the steadily increasing supply of neglected properties in order to prevent the spread of urban blight and crime, and to do so with as little reliance on formal authorities as possible.

This study finds more evidence for longer-term relationships between greening and crime than has been observed in prior research (even after controlling for structural conditions). This finding, however, should be considered within the context of the study's limitations. Many of the control variables were not available at the same scale, or timeframe, as the outcome variable, which makes it difficult to derive fully adjusted estimates of the greening associations. Although, to the extent it was possible, we used data from as near to the middle of the time period as possible, gaps in data collection and existence limited our ability to do so. It is possible that having time-varying data would allow us to see more clearly how these variables may influence the relationship between greening and crime but it is impossible to determine what these may be given the multitude of potential changes in time-varying data. As one example, based on the fact that crime has differing relationships with variables such as distress, vacancy and housing condition (whose change rates tend to coincide), the extent to which they varied over time would not necessarily introduce bias into the estimate. Or, taken another way, if distress and housing condition change outpaced vacancy in one neighbourhood, but vacancy outpaced the others in another neighbourhood, we might see inverse relationships between these neighbourhoods.

This study also examined the association between crime and a CDPDR initiative in a city that has had a unique experience over the past few decades. As a result, the generalisability of these findings is largely limited to select urban cities throughout the country that have experienced similar problems associated with deindustrialisation (e.g. Detroit, Michigan; Cleveland, Ohio; Gary, Indiana; Pittsburgh, Pennsylvania; St Louis, Missouri). Future research should replicate the methods presented here in order to ascertain the generalisability of the findings.

Although prior research suggests that the crime associations evidenced here were a product of collective efficacy, this study did not directly test for these measures. Future research examining residents' perceptions of disorder, fear, collective efficacy, neighbourhood satisfaction and similar dimensions could assist in understanding the causal patterns of the 'greening' association. Researchers should also examine the association of greening with neighbourhood guardianship (via informal social control) and whether the higher traffic in these communities and the accompanying beautification effort serve as a deterrent to would-be offenders. Relatedly, research in this area should also consider displacement and diffusion of benefits. It would be noteworthy to know whether offenders desisted from crime, or

simply moved their criminal activities to other neighbourhoods or whether tactical displacement occurred, with offenders simply shifting their preferred methods for engaging in crime. Logically, such efforts would appear to be mutually reinforcing but understanding how to plan, implement and sustain collective efforts to simultaneously build collective efficacy, decrease crime opportunities *and* generate actual greening outcomes is needed if academics are to translate research into measurable outcomes.

Finally, scholars should also examine the association of other CDPDR strategies. This study only tested a programme focused on greening and beautification but other types of community-driven efforts would fit under this broader category of strategies (e.g. graffiti removal, community gardens and improving streetscapes) that could have implications for community building and crime. Indeed, the finding of the sustained associations of greening supports the promise of these upstream strategies. Combining criminological prevention techniques, often aimed at immediate risks, with longer-term public health prevention tactics at high-risk places appears to hold promise for translating short-term crime reduction into long-term and sustainable community-building strategies.

Funding

This work was supported by Bureau of Justice Assistance, US Department of Justice (2014-AJ-BX-0011), and the Michigan Youth Violence Prevention Center funded by the Center for Disease Control (U01CE002698).

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References

Aiyer SM, Zimmerman MA, Morrel-Samuels S, et al. (2015) From broken windows to busy streets: A community empowerment perspective. *Health Education & Behavior* 42(2): 137–147.

Alaimo K, Reischl TM and Allen JO (2010) Community gardening, neighborhood meetings, and social capital. *Journal of Community Psychology* 38(4): 497–514.

Branas CC, Cheney RA, MacDonald JM, et al. (2011) A difference-in-differences analysis of health, safety, and greening vacant urban space. *American Journal of Epidemiology* 174(11): 1296–1306.

Branas CC, South E, Kondo MC, et al. (2018) Citywide cluster randomized trial to restore blighted vacant land and its effects on violence, crime, and fear. *Proceedings of the National Academy of Sciences* 115(12): 2946–2951.

Brown SC, Mason CA, Lombard JL, et al. (2009) The relationship of built environment to perceived social support and psychological distress in Hispanic elders: The role of 'eyes on the street'. *Journals of Gerontology* 64(2): 234–246.

Burley BA (2018) Green infrastructure and violence: Do new street trees mitigate violent crime? *Health and Place* 54: 43–49.

City of Flint Department of Planning and Development (2012) *Housing Condition Survey*. City of Flint, Department of Planning and Development (producer). Flint, MI.

City of Flint Department of Planning and Development (2016) *Built Environment Data*. City of Flint, Department of Planning and Development (producer). Flint, MI.

ESRI (2015) *ArcGIS Desktop: Release 10.3*. Redlands, CA: Environmental Systems Research Institute.

Garvin EC, Cannuscio CC and Branas CC (2013) Greening vacant lots to reduce violent crime: A randomized controlled trial. *Injury Prevention* 19(3): 198–203.

Genesee County Land Bank (2015) Clean and green program description. Available at: http://www.thelandbank.org/downloads/program_description_2015.pdf (accessed 1 May 2018).

Genesee County Metropolitan Planning Commission (2015) *Draft: 2045 Population Projections Methodology Report*. Flint, MI: Genesee County Metropolitan Planning Commission.

Available at: http://gcmpc.org/wp-content/uploads/2015/11/12_3_15.pdf (accessed 1 May 2018).

Goldstick JE, Lipton RI, Carter P, et al. (2015) The effect of neighborhood context on the relationship between substance misuse and weapons aggression in urban adolescents seeking ED care. *Substance Use & Misuse* 50(5): 674–684.

Hanna-Attisha M, LaChance J, Sadler RC, et al. (2016) Elevated blood lead levels in children associated with the Flint drinking water crisis: A spatial analysis of risk and public health response. *American Jounal of Public Health* 106(2): 283–290.

Heinze JE, Krusky-Morey A, Vagi KJ, et al. (2018) Busy streets theory: The effects of community-engaged greening on violence. *American Journal of Community Psychology* 62(1–2): 101–109.

Jacobs J (1961) *The Death and Life of American Cities*. New York: Random House.

Kondo MC, Hohl B, Han S, et al. (2016) Effects of greening and community reuse of vacant lots on crime. *Urban Studies* 53(15): 3279–3295.

Kondo MC, Morrison C, Jacoby SF, et al. (2018) Blight abatement of vacant land and crime in New Orleans. *Public Health Reports* 133(6): 650–657.

Kuo FE and Sullivan WC (2001a) Environment and crime in the inner city: Does vegetation reduce crime? *Environment and Behavior* 33(3): 343–367.

Kuo FE and Sullivan WC (2001b) Aggression and violence in the inner city: Effects of environment via mental fatigue. *Environment and Behavior* 33(4): 543–571.

Locke DH, Han S, Kondo MC, et al. (2017) Did community greening reduce crime? Evidence from New Haven, CT, 1996–2007. *Landscape and Urban Planning* 161: 72–79.

McCabe A (2014) Community gardens to fight urban youth crime and stabilize neighborhoods. *International Journal of Child Health and Human Development* 7(3): 223–237.

MacDonald J (2015) Community design and crime: The impact of housing and the built environment. *Crime and Justice* 44(1): 333–383.

Markowitz FE, Bellair PE, Liska AE, et al. (2001) Extending social disorganization theory: Modeling the relationships between cohesion, disorder, and fear. *Criminology* 39(2): 293–319.

Minnesota Population Center (2011) *National Historical Geographic Information System: Version 2.0*. Minneapolis, MN: University of Minnesota.

Moyer R, MacDonald JM, Ridgeway G, et al. (2019) Effect of remediating blighted vacant land on shootings: A citywide cluster randomized trial. *American Journal of Public Health* 109(1): 140–144.

Rountree PW, Land KC and Miethe TD (1994) Macro–micro integration in the study of victimization: A hierarchical logistic model analysis across Seattle neighborhoods. *Criminology* 32(3): 387–414.

Sadler RC and Lafreniere DJ (2017) Racist housing practices as a precursor to uneven neighborhood change in a post-industrial city. *Housing Studies* 32(2): 186–208.

Sadler RC and Pruett NK (2015) Mitigating blight and building community pride in a legacy city: Lessons learned from a land bank's clean and green programme. *Community Development Journal* 52(4): 591–610.

Sadler RC, Gilliland JA and Arku G (2013) Community development and the influence of new food retail sources on the price and availability of nutritious food. *Journal of Urban Affairs* 35(4): 471–491.

Sadler RC, Pizarro JM, Turchan B, et al. (2017) Exploring the spatial–temporal relationship between a community greening program and neighborhood rates of crime. *Applied Geography* 83: 13–26.

Sampson RJ and Raudenbush SW (1999) Systematic social observation of public spaces: A new look at disorder in urban neighborhoods. *American Journal of Sociology* 105(3): 603–651.

Sampson RJ, Raudenbush SW and Earls F (1997) Neighborhoods and violent crime: A multilevel study of collective efficacy. *Science* 277(5328): 918–924.

Skogan WG (1990) *Disorder and Decline: Crime and the Spiral of Decay in American Neighborhoods*. Berkeley, CA: University of California Press.

Snelgrove A, Michael J, Waliczek T, et al. (2004) Urban greening and criminal behavior: A geographic information system perspective. *HortTechnology* 14(1): 48–51.

US Census Bureau (2015) *Population in the United States*. Available at: https://www.google.com/publicdata/explore?ds=kf7tgg1uo9ude_&met_y=population&idim=place:2629000:0107000&hl=en&dl=en#!ctype=l&strail=false&bcs=d&nselm=h&met_y=population&scale_y=lin&ind_y=false&rdim=country& idim=place:2629000&ifdim=country&hl=en_US&dl=en&ind=false (accessed 1 May 2018).

US Census Bureau (2016a) *ACS Demographic and Housing Estimates: Flint, Michigan*. U.S. Census Bureau, 2010–2014 American Community Survey 5-Year Estimates. Available at: http://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml (accessed 1 May 2018).

US Census Bureau (2016b) *Selected Economic Characteristics: Flint, Michigan*. U.S. Census Bureau, 2010–2014 American Community Survey 5-Year Estimates. Available at: http://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml (accessed 1 May 2018).

US Census Bureau (2016c) *Selected Economic Characteristics: Michigan*. U.S. Census Bureau, 2010–2014 American Community Survey 5-Year Estimates. Available at: http://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml (accessed 1 May 2018).

US Census Bureau (2016d) *Selected Economic Characteristics: United States*. U.S. Census Bureau, 2010–2014 American Community Survey 5-Year Estimates. Available at: http://factfinder.census.gov/faces/nav/jsf/pages/community_facts.xhtml (accessed 1 May 2018).

Wilson JQ and Kelling GL (1982) The police and neighborhood safety: Broken windows. *Atlantic Monthly* 127(2): 29–38.

Wolfe MK and Mennis J (2012) Does vegetation encourage or suppress urban crime? Evidence from Philadelphia, PA. *Landscape and Urban Planning* 108(2–4): 112–122.