

Research Paper

Resident-led vacant lot greening and crime: Do ownership and visual condition-care matter?

Sara Hadavi^{a,*}, Alessandro Rigolon^b, Paul H. Gobster^c, William P. Stewart^d^a Department of Landscape Architecture and Regional & Community Planning, Kansas State University, Manhattan, KS 66506, USA^b Department of City and Metropolitan Planning, The University of Utah, Salt Lake City, UT 84112, USA^c USDA Forest Service, Northern Research Station, Evanston, IL 60201, USA^d Department of Recreation, Sport and Tourism, University of Illinois at Urbana-Champaign, Champaign, IL 61820, USA

HIGHLIGHTS

- Block-level analysis was used to examine the impact of Large Lot Program on crime.
- Difference in differences analyses showed significant crime reduction over time.
- Resident-owner-based vacant land-reuse initiatives improve neighborhood safety.
- Visual quality of lots reduce crime as resident ownership across blocks expands.
- The impacts of the program on crime vary depending on crime types.

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ABSTRACT

In many cities, high land vacancy has contributed to negative outcomes including visual blight, loss of sense of community and safety, and high crime rates. Although studies show that vacant lot greening programs reduce crime rates in high-vacancy areas, little is known about the impacts of resident-owner-based vacant lot repurposing initiatives on crime. We evaluated the impacts of one such initiative, the Chicago Large Lot Program, on crime reduction. Through this program, qualified property owners could purchase one or two nearby city-owned vacant lots for one dollar each. Focusing on two study sites on the South and West sides of Chicago, we performed difference-in-differences analyses to examine whether blocks with at least one purchased 'large lot' ($n = 234$) showed greater reductions in various types of crime compared to matched control blocks without large lots ($n = 702$) in the years following program implementation (2015–2018). We found that, starting in the second year of implementation, the program contributed to significant reductions in overall crime density as well as a few types of crime. We also found that visual condition and care of purchased lots was associated with reduced crime density in one of our study sites where the percentage of purchased lots and mean condition-care rating were more than twice as much as those of the other site. Our findings support the usefulness of vacant land repurposing programs that transfer ownership to residents, and suggest that greening activities encouraged by these programs help improve neighborhood safety and quality of life.

1. Introduction

About 17% of the land in US cities is considered vacant or abandoned (Newman, Bowman, Jung Lee, & Kim, 2016). Urban vacancy in the US is one of the consequences of substantial industrial decline, federally subsidized suburbanization, and inner-city disinvestment in medium

and large cities starting from the mid-twentieth century (Dewar & Thomas, 2013). High vacancy rates in cities and neighborhoods create conditions that result in a host of related socio-economic problems for their residents (Accordino & Johnson, 2000; Han, 2014). Among these conditions, signs of physical disorder such as vandalism and untended vegetation that follow vacancy can reduce residents' sense of safety and

* Corresponding author.

E-mail addresses: sarahadavi@ksu.edu (S. Hadavi), alessandro.rigolon@utah.edu (A. Rigolon), paul.gobster@usda.gov (P.H. Gobster), wstewart@illinois.edu (W.P. Stewart).<https://doi.org/10.1016/j.landurbplan.2021.104096>

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heighten stress in carrying out everyday activities, and at broader social levels can contribute to the loss of neighborhood social cohesion and sense of place (Nayak, 2003; N. Sampson et al., 2017; R.J. Sampson & Raudenbush, 1999). While these individual and community health and well-being outcomes are serious in and of themselves, signs of abandonment and neglect also encourage criminal activities that further reduce neighborhood resilience and quality of life (Chaix, 2009; Cohen et al., 2003).

In response to these problems, several U.S. cities have implemented vacant lot greening programs in high-vacancy areas (Schilling & Logan, 2008) such as the LandCare Program in Philadelphia, PA (Macdonald, Nguyen, Jensen, & Branas, 2021) and the Land Bank Clean & Green Program in Flint, MI (Sadler & Pruett, 2017). A growing research literature has examined the effectiveness of green space in reducing crime, and a recent systematic review (Shepley et al., 2019) identifies a number of key factors affecting this relationship, including green space program and policy interventions that help re-enfranchise communities, and mediating variables that influence health and well-being. (e.g., Auchincloss et al., 2019; Kondo, Andreyeva, South, MacDonald, & Branas, 2018). Building upon this body of evidence, a related literature has specifically examined how urban greening initiatives can help reduce problems associated with urban vacancy (Branas et al., 2018; Kondo et al., 2016). Findings show that community cohesion and sense of place are enhanced when signs of occupancy and care of repurposed vacant lots replace signs of neglect (Alaimo, Reischl, & Allen, 2010; Nassauer & Raskin, 2014). Further, occupancy and care in repurposed vacant land can have positive social effects extending beyond the boundaries of individual lots (Krusky et al., 2015), helping rebuild the community fabric of high-vacancy residential areas (Lawson, 2004).

As noted, various vacant lot greening and re-use strategies have been proposed and implemented to address the negative consequences of urban vacancy (Schilling & Logan, 2008). Of these, programs initiated by cities and nonprofit organizations have led to crime reductions (Garvin, Cannuscio, & Branas, 2013; Kondo, Hohl, Han, & Branas, 2016; Schilling & Logan, 2008). However, little is known about whether programs that transfer ownership of vacant lots to residents, who then become the stewards of those lots, also contribute to decreasing crime. Furthermore, research has yet to examine the extent to which the *quality* of greened vacant lots (their level of condition and care) predicts changes in crime at a scale as small as a block.

The purpose of this study is to evaluate whether a resident-owner-based vacant lot re-use initiative, the Chicago Large Lot Program, has contributed to lower crime rates in high-vacancy neighborhoods of Chicago's South and West sides. Specifically, we examined whether the transfer of ownership of vacant lots to neighborhood residents contributed to a long-term crime reduction in city blocks with these repurposed lots compared to blocks without such lots (Aim 1). We also studied whether improvements in the visual condition and care of greened 'large lots' (lots purchased under the Chicago Large Lot Program) were associated with reductions in reported crime incidents over time (Aim 2). Building upon place-based theories and crime-related analytical frameworks (Fowler & Mangione, 1982), and by virtue of selecting a fine spatial scale of analysis, our work links resident-owner-based vacant land reuse programs to crime rates in high-vacancy neighborhoods. In so doing, our study offers useful applications to policy and planning by showing the effectiveness of programs that engage resident-owners in marginalized communities in improving safety and neighborhood quality of life.

2. Background and research questions

2.1. Place-based approaches to crime prevention

Until the late 1960s, most crime prevention strategies in the U.S. focused on offenders and their motivations, which to critics neither successfully explained crime nor informed policy (Kelling & Coles,

1996). Later in the 1960s, new research suggested that physical design of places, and people's related behavioral responses, influenced crime levels (Fowler & Mangione, 1982; Jacobs, 1992). In the 1970s, the emphasis shifted from offenders and their motivations to potential victims and characteristics of their environments (Bursik & Grasmick, 1999; Lewis & Salem, 1981). The shift to a place-based strategy was framed as 'community crime prevention' and led to initiatives such as the Hartford Crime Prevention Program (Lewis & Salem, 1981).

Place-based strategies to crime prevention emphasize the need for citizen involvement. Such strategies intentionally bring various activities to outdoor spaces to have more 'eyes on the street' (Clarke, 1983; Jacobs, 1992), and seek to change neighborhood built environments into 'defensible spaces' (Jacobs, 1992; Newman, 1972). Extending the defensible space framework, 'routine activities theory' (Cohen & Felson, 2010) posits that when everyday activities of people in a space have a certain pattern, opportunities to commit crimes increase because patterns allow criminals to predict when factors align for their best advantage. These factors are associated with perceptions of neighborhood disorder. As a related framework, 'social disorganization theory' (Kubrin & Weitzer, 2003) suggests that visible signs of physical and social disorder signal a lack of social control, leading to higher crime rate.

Place-based crime prevention strategies also integrate factors related to visible signs of social control. 'Broken windows theory' (Sampson & Raudenbush, 2004; Wilson & Kelling, 1982) emphasizes that even minor signs of physical disorder such as litter and graffiti if unaddressed can trigger a downward spiral of urban decay that encourages crime. Physical disorder characteristics are easily noticed in high-vacancy areas and discourage neighborhood social interaction (Hinkle & Yang, 2014). The perception of physical disorder results in psychological distress, perceived powerlessness (Mitchell & LaGory, 2002; Ross, 2000), fear of crime (Perkins, Meeks, & Taylor, 1992), and decreased neighborhood satisfaction (Hadavi, Kaplan, & Hunter, 2018; Hur & Nasar, 2014). The opposite of physical disorder characteristics are those that visibly indicate human presence and care for the landscape. Such characteristics, referred to as 'cues to care,' imply neighborhood norms that watch and protect, and have the potential to reduce criminal activities (Nassauer, 1995; Nassauer & Raskin, 2014).

Several studies have identified landscape characteristics related to care and maintenance that show promise as part of community crime reduction and prevention strategies. For instance, Troy, Grove, & O'Neil-Dunne, 2012 found that neighborhoods with greater tree canopy had lower levels of crime. This and other studies suggest that well-maintained vegetation may reduce crime as it is seen as a 'territorial marker' indicating to prospective criminals that the environment is being actively cared for by the residents even if they see no one on the street (Nassauer, 1995; Troy et al., 2012). Further, Troy, Nunery, & Grove, 2016 found that crime was negatively associated with cues to care such as yard trees, mown lawns, and sprinklers, and positively associated with signs of disorder such as litter and dry or unmown lawns. These place-based studies of crime prevention provide a useful context to apply to issues of urban vacancy and greening strategies in residential areas.

2.2. Vacant lot greening/reuse strategies and crime

An important part of place-based crime prevention approaches involves engaging residents in outdoor activities that bring life to their neighborhoods (Clarke, 1983). Neighborhood greening is one such activity in which residents' sense of place, safety, and security may be improved (Garvin et al., 2013). Recent studies show that different greening approaches may vary in their influence on different types of crime. For example, traditional city- or organization-led 'clean and green' strategies (Schilling & Logan, 2008) reduced some types of crime such as burglaries, while community-engaged programs that mostly involved community gardens had greater impacts on violent crime

reduction (Kondo et al., 2016). These greening initiatives align with 'busy streets theory' (Aiyer, Zimmerman, Morrel-Samuels, & Reischl, 2015) that connects individual beliefs and social processes with residents' collective action and implications for community empowerment.

There is an increasing consensus that community-engaged greening programs such as lot cleanups and community gardening afford solutions to vacant lot maintenance while also helping to reduce or prevent crime (Heinze et al., 2018). Other vacant lot greening strategies that involve the transfer of city-owned vacant land to nearby property owners, such as the Large Lot Program in Chicago, have not received much attention regarding their potential impacts on crime reduction. In these resident-owner-based programs, private ownership of vacant lots is seen as a tool for revitalizing and stabilizing neighborhoods (Authors, 2020 masked for review). Considering previous research focused on programs led by cities or nonprofits (e.g., Branas et al., 2011; Kondo et al., 2016), programs that transfer lot ownership to residents may have similar effects on crime reduction. Resident-owner-led activities might help reduce signs of neglect and disorder, bringing in more 'cues to care', as well as drawing more 'eyes on the street' and breaking the 'routine activities' patterns on residential blocks. A recent study of the Large Lot Program (Stern & Lester, 2021) found significant impact of this program on overall crime rate one year after program implementation. It is important to dig deeper into the program outcomes and examine the impacts of both ownership and resident-led improvements to the visual quality of lots on various types of crime across multiple years to assess longer-term impacts of the program.

2.3. The block level as a behavior setting for the study of crime

Some studies on the relationship between vacant lot greening and crime have utilized relatively large spatial units such as US census tracts or neighborhood levels (Garvin et al., 2013; Tita, Petras, & Greenbaum, 2006), whereas others have examined crime at microscale such as lots or buildings (e.g., Branas et al., 2016; Kajeepeta et al., 2020). Large units of analysis can have low internal homogeneity with respect to crime occurrences and associated social and environmental characteristics, making it difficult to understand and predict how and why crimes might occur. Smaller units of analysis are likely to be more homogeneous than larger units, and thus may be preferable (Oberwittler & Wikström, 2009; Weisburd, Groff, & Yang, 2012). But most microscale studies on greening and crime rely upon smoothing techniques such as kernel density (e.g., Branas et al., 2016; Kajeepeta et al., 2020; Kondo et al., 2016) to estimate probable crime densities extending up to several blocks around lots or buildings, and thus might not accurately represent the behavior settings where crimes occur. A behavior setting is defined as the part of the environment that 'an individual, at a particular moment in time, can access with his or her senses, including any media present' (Oberwittler & Wikström, 2009, p. 36). Therefore, choosing the appropriate spatial scale is a key issue in crime studies (Malleson, Steenbeek, Andresen, & Koukoulas, 2019).

When studying spatially-influenced human behaviors such as acts of crime, residential blocks are the behavior settings where most environment-behavior interactions take place and are observed (Perkins, Florin, Rich, Wandersman, & Chavis, 1990). 'Situational action theory' emphasizes the importance of geographic scale, and specifies that behaviors such as acts of crime are an outcome of how people perceive their behavioral alternatives when faced with characteristics of their behavior settings (Wikström, 2014). Units of analysis at the block level would be conceptually appropriate because they align with the relevant behavior setting for criminal activity. Drawing on these advantages, in this study we focus on the block level with adjusted boundaries of traditional city blocks (See Section 3.3.1) to address how repurposing vacant lots is associated with crime. Additionally, Chicago and other cities report crime incidents at the block level due to privacy reasons. Therefore, choosing blocks as the unit of analysis has the advantage of using the actual number of crime incidents in our analyses,

precluding the need to estimate the likelihood of crime incidents in the unit of analysis.

3. Research questions

Building upon place-based theoretical frameworks and the literature on vacant land greening strategies, we examined the potential impacts of the Chicago Large Lot Program on crime reduction in the four years following its implementation. Specifically, we studied whether large lot ownership and resident-led investments in care resulting from program implementation have played a role in crime reduction in the subsequent years. The following aims and questions guided our analyses. Concerning ownership, we examined the blocks with large lots in the broader context surrounding them to answer two questions (Aim 1):

Question 1.1. To what extent does the ownership of large lots on residential blocks impact the density of highly frequent crime types over time?

Question 1.2. Does the ownership of large lots impact specific types of crime (e.g., property crime, violent crime, and drug abuse) more than others over time?

Concerning owners' investments in care of their large lots, we examined visual condition and care as a predictor of crime using a single, seven-point rating scale called condition-care scale (See details in the Methods section) to answer two questions (Aim 2):

Question 2.1. To what extent is the level of condition-care associated with crime density over time in blocks with large lots?

Question 2.2. Is large lot condition-care associated with reduction of specific types of crime over time?

4. Methods

4.1. Large lot Program

The Large Lot Program is an outgrowth of a 2011 Green Healthy Neighborhoods planning effort enacted by the City of Chicago in collaboration with local community groups and organizations (City of Chicago, 2014a). As a revitalization and population stabilization strategy for high-vacancy neighborhoods on Chicago's South and West sides, the program transfers city-owned vacant lots on residential blocks to neighborhood residents for the goals of creating wealth in the community and giving residents greater local control of land, reducing municipal maintenance and tax burden, and increasing safety and building community (City of Chicago, 2014b). Qualified property owners can purchase one or two lots on their block or the adjacent block, each for one dollar. Large lot owners must pay property taxes and maintain the lots to a minimum standard. Acceptable uses for the purchased large lots include developing green space such as yards, gardens, and play areas, as well as shared community gardens, parking areas or garages, and even new residential buildings, though it was expected that most owners would use the lots for green space uses, at least in the early years after purchase. Large lot owners can sell the properties five years after purchase. The Program was adopted by the City in 2014 and qualified property owners applied for the lots on the program's website (Large Lot Program, Nd.). The first batch of large lots was transferred to successful applicants in early 2015.

4.2. Study area

The study area includes 2064 blocks within two sites; 1748 blocks in Greater Englewood and 316 blocks in East Garfield Park (Table 1, Fig. 1). In early 2015, 261 large lots were purchased in Greater Englewood and 150 in East Garfield Park (total of 411 large lots). The study area thus includes a total of 2064 residential blocks with 234 blocks having at least one purchased large lot (*treated* blocks) and 1830 blocks without large lots (*nontreated* blocks). Based on data from the Cook County Assessor, approximately 69% of the new large lot owners lived

Table 1
Characteristics of the two study sites.

Characteristic	Greater Englewood	East Garfield Park
Area (mi ²) *	14.528	2.734
% vacant land (mean) ***	15.38%	14.98%
% vacant housing units (mean) **	27.18%	18.44%
Number of blocks*	1748	316
Number of large lots*	261	150
Mean condition-care rating in four years (PSM)	32.78	84.58
% blocks with large lots	9.78%	19.94%
Number of households***	32,300	6,923
Population density (PPSM) **	6505	7555
% African-American population (mean) **	85.87%	85.23%
% population over 25 with higher education (mean) **	11.72%	15.97%
Median household Income**	\$23,596	\$29,068

* City of Chicago Data Portal (Nd.), 2016; ** American Community Survey, 2016; *** Chicago Metropolitan Agency for Planning, 2013.

on the same block, suggesting that the majority of improvements to the treated blocks are made by resident-owners.

4.3. Data and measurement

4.3.1. Unit of analysis

Because lot conditions are visible from the streets and crime incidents are recorded on the centerline of those streets, we drew polygons using ArcMap (version 10.8) that defined blocks as comprised of all lots facing both sides of the length of a given street segment between two street intersections. As shown in Fig. 2, we have slid the frame around the traditional blocks to left or right for half of a block width to adjust the block boundaries. Using these re-defined blocks as the unit of analysis makes it possible to create a model that reflects perceptual and visual changes such as cues to care and allows for examining the influence of visual changes on acts of crime at the block level. This modification provides improvements on independence of block observations as compared to traditional street blocks. This definition conforms to analyses elsewhere (e.g., Maroko, Weiss Riley, Reed, & Malcolm, 2014; Mooney et al., 2014) and avoids overlap between blocks in accounting for crime incidents.

4.3.2. Dependent variable: Crime density

We obtained crime data from the City of Chicago Data Portal (Nd.). Since changes in the appearance of the lots were associated with growing seasons, we considered the observations for each year from April to the following March (e.g., April 2014 to March 2015), covering one year before the lot purchases in early 2015 as baseline, and four years afterwards (2014–2019). Table S1 presents total crime frequencies across these years.

We examined the frequency of each category of public crime defined by the Uniform Crime Reporting program (UCR) obtained from the Chicago Police Department (Nd.) in our study sites between 2014 and 2019 and selected the most frequently occurring public crime types in the study area. These included 10 types of index crimes, 4 types of non-index crimes, and miscellaneous non-index offenses (Table 2; Fig. 3). According to the Chicago Police Department, index crimes consist of ten categories of crime selected by the Federal Bureau of Investigations (FBI) because of their seriousness and frequency of occurrence. The high-frequency index crimes included in our study are property crimes (burglary, larceny, motor vehicle theft, and arson), and both gun- and non-gun-related violent crimes (homicide 1st and 2nd degree, criminal sexual assault, robbery, aggravated assault, and aggravated battery). High-frequency non-index crimes consist of vandalism, drug abuse, simple assault, simple battery, and miscellaneous non-index offenses considered as crimes against society including criminal trespassing,

public peace violation, and narcotics possession.

Using X-Y coordinates in ArcMap, we geolocated all crime incidents in the two study sites. Because crime data are reported by the City at the block level and plotted at the centerline of a street segment, we tabulated the number of each type of crime incident within each block for each year. But given the variability of block sizes, we calculated the number of crimes per square mile and used this standardized measure of block-level crime density as our dependent variable for each crime type and each year.

4.3.3. Independent variables: Presence of large lots and visual quality

The City of Chicago (2014b) provided data about the location of large lots sold in early 2015. We used those large lot locations to classify blocks into treated ($n = 234$) and nontreated ($n = 1830$) blocks, and matched each treated block with three nontreated ones ($n = 702$) as control blocks based on socio-demographic characteristics (see below) to address the research questions on large lot ownership (Q.1.1 and Q.1.2).

To address the research questions on the visual quality of large lots (Q.2.1 and Q.2.2), we used the *condition-care scale* as our main independent variable of interest. We developed the scale based upon previous visual landscape assessment and neighborhood auditing tools (e.g., Dewar et al., 2013; Krusky et al., 2015) and report the details in an earlier paper (Authors, 2020 masked for review). The tool incorporates elements of physical disorder and cues to care into a single rating scale ranging from -1 (mismanaged lots showing vandalism, safety hazards, serious erosion, and other undesirable conditions) to $+5$ (extensive gardens and numerous other social, aesthetic or recreational cues to care). Virtual and field-based assessments showed strong intra- and inter-rater scale reliability, and independent measures of lot condition and care from parallel visual and social assessments support the scale's validity (Authors, 2020 masked for review; See Appendix A for sample large lot changes, and Appendix B for scale descriptions).

The large lots were visually assessed using this tool the year before purchase (2014), the year of purchase (2015), and within first and third years after purchase (2016 and 2018), and a condition-care rating was assigned to each large lot for each year. For each of these four time periods, the total of condition-care ratings within each treated block was divided by the area of the block (in square miles) to compute an area-normalized condition-care rating for each treated block. These normalized ratings were used to address our second set of research questions (Q.2.1 and Q.2.2). As shown in Table 1, the two study sites have different percentages of treated blocks and mean condition-care ratings per square mile three years after lot purchases.

4.3.4. Control variables

Socio-demographics. We obtained median household income, percentage of African-American population, and percentage of 25-year-old residents and older population with higher education at the census block group level from the American Community Survey (2016; five-year estimates) and transferred these data to our blocks using ArcMap. As presented in Table 1, low-income African-American residents, with less than 16 percent having a college degree, is the dominant profile in both study sites.

Vacancy. We calculated the percentage of vacant lots within each block using data from the Chicago Metropolitan Agency for Planning (CMAP, 2013). Using data from the American Community Survey (2016), we then computed the percentage of vacant housing units in each block. Table 1 shows relatively large amounts of vacant land and vacant housing units in each study site.

Adjacencies. The proximity of different land uses affects the flow of outsiders into and out of residential blocks, which may in turn affect crime (Boessen & Hipp, 2015; Branas et al., 2011; Lorenc et al., 2012; Macdonald, Nguyen, Jensen, & Branas, 2021). To control for land use adjacency, we obtained land use data from CMAP, selecting these land use types based on relevant studies (e.g., Branas et al., 2011; Stucky &

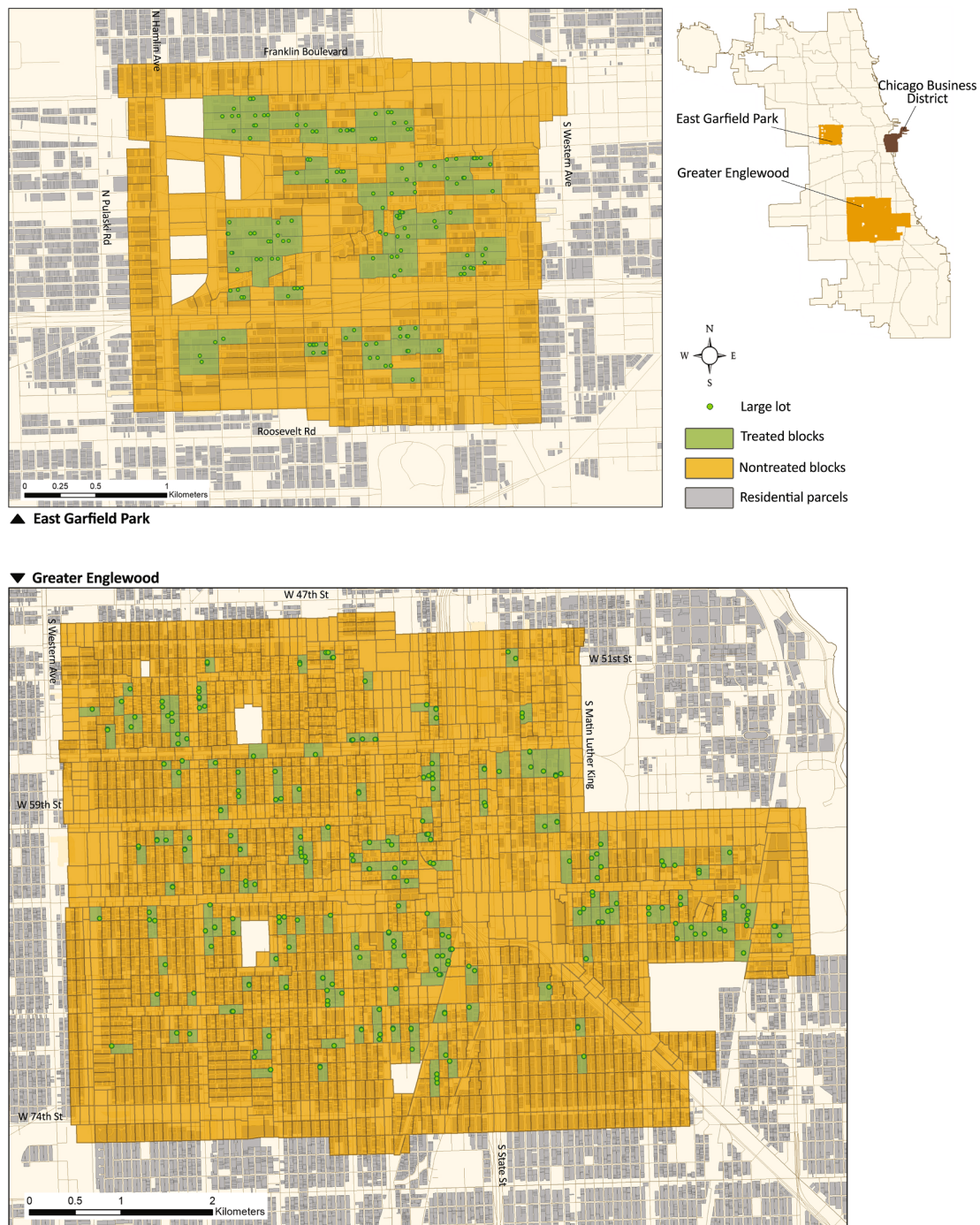


Fig. 1. Study area with treated* and non-treated blocks and large lot locations.

* The number of treated blocks in this study (234) is different from that of our previous studies ($n = 252$) due to the different block boundaries we defined in this study.

Ottensmann, 2009): open and recreation space, educational facilities, governmental administration services (police, fire, civil defense), religious facilities, and roadway and transportation. Such land uses, depending on who they attract, have the potential to create various 'opportunity structures' consisting of potential victims (e.g., school-children), motivated offenders, and existence or absence of guardians who could interfere such as police (Stucky & Ottensmann, 2009). The selected land uses were coded as dichotomous variables, with land use considered adjacent to the block if it was within 100 m (half of the length of a typical Chicago block).

4.4. Data analysis

We used mixed-effect models to address our research questions, first checking for potential spatial autocorrelation for the crime data and matching treated blocks with control blocks. Spatial analyses and lag value calculations were conducted in GeoDa (version 1.14.0; Anselin et al., 2010), and all statistical analyses were conducted in R (version 4.0).

To check for potential spatial dependence of crime density, we ran diagnostic Moran's I tests in ArcMap using row-standardization. Also, since all block arrangements were contiguity-based, we used the Queen's neighborhood method, which defines contiguity based on

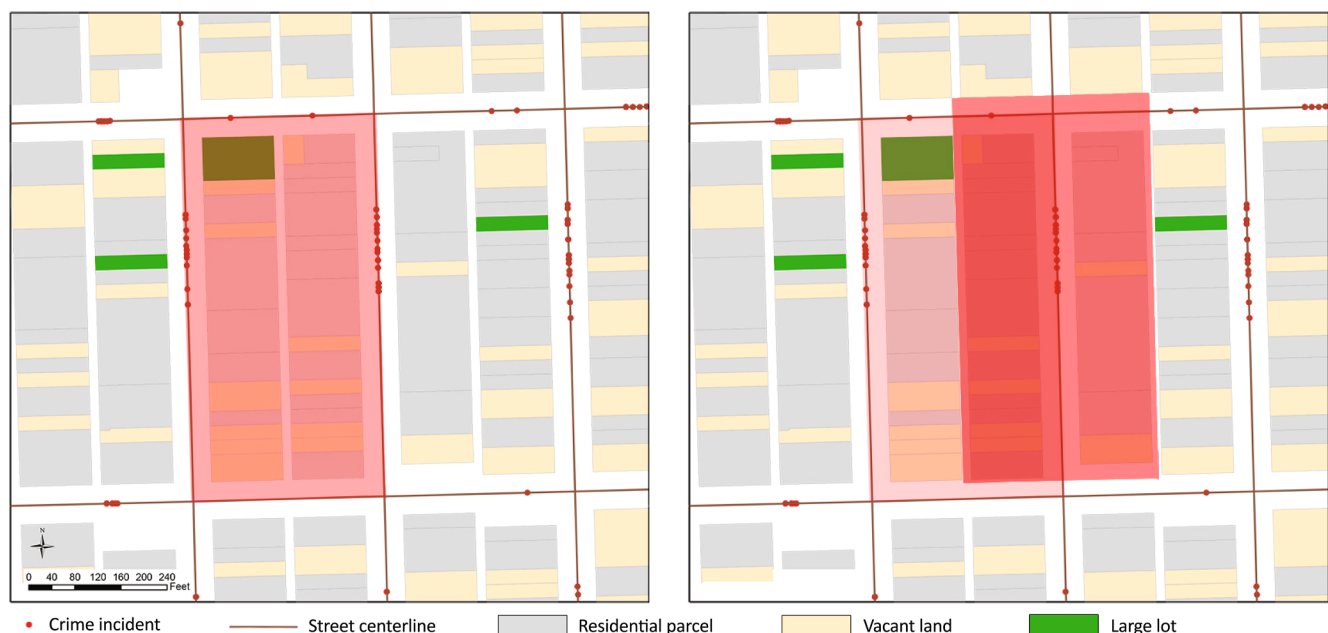


Fig. 2. Shifting the polygons representing standard street blocks (left) to represent block faces and street segments as behavior settings with crime incidents falling inside of the block polygon rather than falling on edges (right). 2064 polygons drawn as presented on the right, covered the entire study sites.

Table 2

Crime categories investigated in the study.*

Major crime categories		Crime types
Index crimes	Property crimes	Burglary Larceny Motor vehicle theft Arson
	Violent crimes (Gun-/non-gun-related)	Homicide 1st degree Homicide 2nd degree Criminal sexual assault Robbery Aggravated assault Aggravated battery
Non-index crimes	Other non-index crimes	Vandalism Drug abuse Simple assault Simple battery
	Misc. non-index offenses	e.g., criminal trespassing, public peace violation and narcotics

* The crime types/categories presented in bold are those used in our analysis

either a common vertex or a common edge (Sim & Miller, 2016). In GeoDa, we ran OLS and in addition to Moran's I, we checked other diagnostics for spatial dependence including Robust LM (lag) and Robust LM (error). Because of significant autocorrelation in our crime dataset (See Table S2), we accounted for this error by using spatial lag models (Browning, Dietz, & Feinberg, 2004; Buonanno, Montolio, & Vanin, 2009; Sohn, Yoon, & Lee, 2018) in GeoDa. The comparisons of R^2 -squared, log likelihood, and Akaike information criterion confirmed the spatial lag model to be a better fit (See Table S3 and Anselin, 2010). We chose the spatial lag model rather than the spatial error model to be able to calculate the lag values. GeoDa allowed us to use lag values to calculate spatially-lagged crime density variables based on inverse distance weighting (modified values based on autocorrelation) for each year in each block and use them as adjusted dependent variables in our regression models.

4.4.1. The impact of ownership of large lots on crime density over time (Questions 1.1 and 1.2)

In this analysis, we used a matched sample of control blocks to minimize differences between the treated and nontreated blocks, reduce

the risk of non-parallel trends (Ryan, Kontopantelis, Linden, & Burgess, 2019), and increase the reliability of our comparisons. Using the Propensity Score Matching (PSM) approach with the nearest neighbor method (closest propensity score) in R's *matchit* package, we matched each treated block ($n = 234$) with three selected nontreated blocks (3:1 ratio, $n = 702$). A three-to-one matching ratio is widely used in similar research (e.g., Branas et al., 2016; Ellen, Laco, & Sharygin, 2013; Kondo, Hohl, Han, & Branas, 2016). We used a 300-foot (~91 m) buffer around the treated blocks to make sure the selected control blocks were not adjacent to treated blocks. The control variables used for matching included the percentage of vacancy (both vacant land and vacant housing units), median household income, percentage of African-American population, percentage of population over 25 with higher education, and the study site (Greater Englewood versus East Garfield Park). We ran Welch two-sample t -tests to check whether each of these control factors differed between treated and control blocks (See Table S5). No statistically significant differences were found between treated and control blocks. Therefore, our sample for this analysis consisted of 936 blocks (234 treated blocks + 3 * 234 control blocks).

Difference-in-differences regressions. To determine whether the

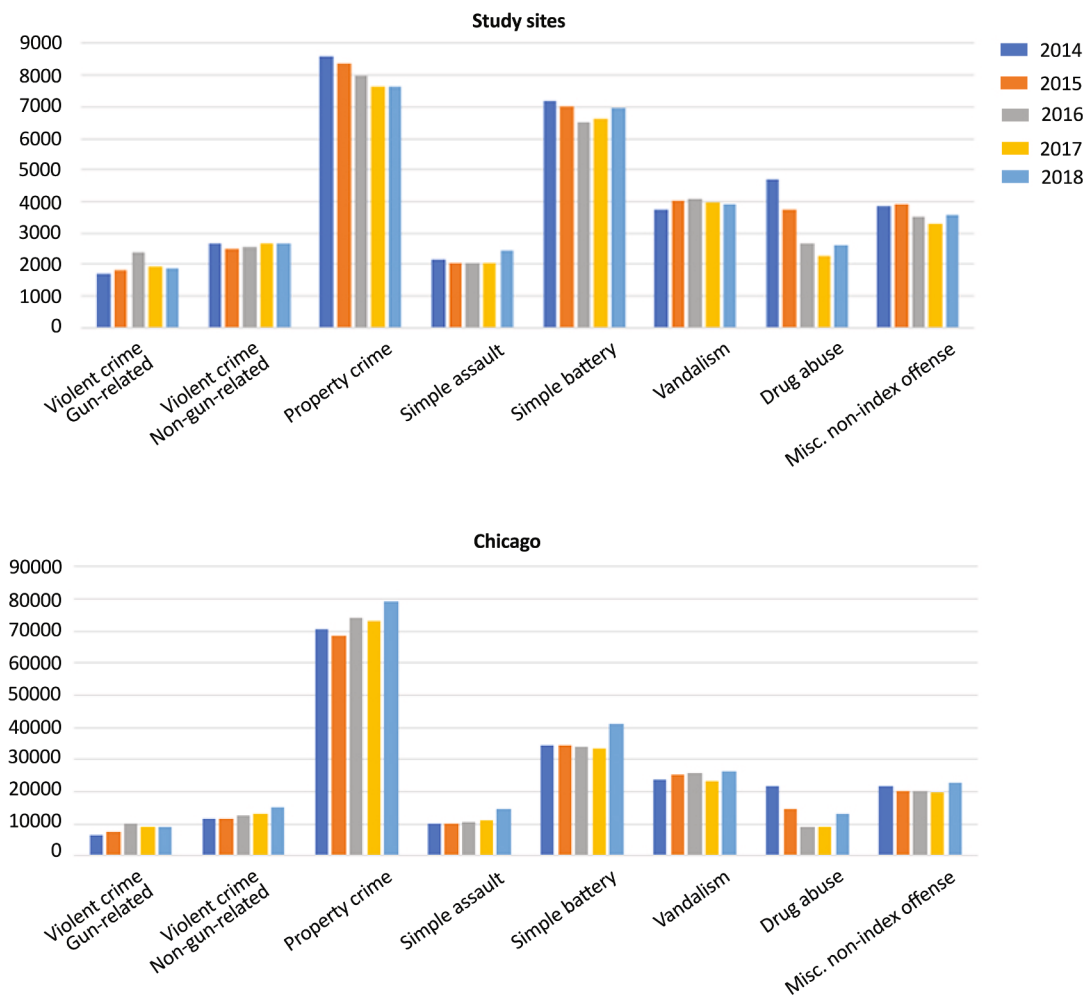


Fig. 3. Crime frequencies by type in the study sites (top) and all Chicago residential areas (bottom) from 2014 to 2018.

presence of large lots contributed to lower crime in blocks over time, we ran a difference-in-differences analysis that accounted for differences in crime over the years (before and after the sales) and between treated and control blocks. Using the *lme4* and *lmerTest* packages in R, we applied mixed-effects models to predict crime density for aggregated crime types as well as for each separate crime category. We created a panel dataset of treated and control blocks ($n = 936$) with five time observations: one year before the treatment (2014) as the reference condition (Time = 0) and the four successive years (2015, 2016, 2017, and 2018) as Time = 1, Time = 2, Time = 3 and Time = 4. In each model, we used the treatment (the presence of a large lot), time dummy variables, and the control variables as fixed effects.

Our fixed-effect variables of interest were interaction terms between time periods and treatment, which are four dummy variables (Treatment = 1 multiplied by Time = 1 to 4). These four terms represent the pre-treatment differences in crime density between treated and control blocks with the post-treatment differences at four different points in time (the year of treatment and 3 consecutive years after the treatment). The block ID was used as the grouping factor (random-effect intercepts). The estimated models used maximum likelihood ratio, and the *t*-tests used Satterwaite's method. We then used *emmeans* package to create plots of the difference-in-differences terms.

4.4.2. The association between the level of condition-care and crime density over time in blocks with large lots (Questions 2.1 and 2.2)

To examine associations between condition-care ratings and crime density within treated blocks, we performed another set of mixed-effects

models for aggregated crimes as well as for separate crime categories using the same R packages. We created a panel dataset of treated blocks ($n = 234$) with four time observations, including one year before the intervention (2014) as the reference condition (T = 0), the year of intervention (2015) as Time = 1, and one and three years afterwards (2016 and 2018) as Time = 2 and Time = 3, respectively (condition-care data for 2017 were not available). In each model, the condition-care rating was examined as the fixed effect together with its interaction terms with time.

Given the considerable differences between the condition-care ratings of the two study sites (Greater Englewood and East Garfield Park), we also examined the interaction terms between condition-care and study sites. We controlled for socio-demographics, adjacencies, and vacancy as fixed effects, and the block ID served as the grouping factor. We then conducted simple slope post-hoc pairwise tests using R's *interactions* package to further examine the effect of interaction terms between a continuous variable (condition-care per square mile) and dichotomous terms considered as potential moderators (time and study site).

5. Results

5.1. To what extent does the ownership of large lots on residential blocks impact the density of highly frequent crime types over time? (Question 1.1).

As shown in Table 3, ownership of large lots on blocks had a

Table 3

Mixed-effect regression predicting crime density for all crimes: Difference-in-differences model.*

	Intercept	Estimated coefficient	97.5% Conf. int.	t value	p value
		1545.4748	403.004–2587.899	2.654	
Time	Time 1 (2015)	–165.5469	–270.194 – –60.898	–3.101	0.001
	Time 2 (2016)	–378.5483	–483.143 – –273.954	–7.095	0.000
	Time 3 (2017)	–512.2652	–616.948 – –407.583	–9.594	0.000
	Time 4 (2018)	–529.8544	–634.576 – –425.130	–9.919	0.000
Lot purchase	Treatment	979.9313	631.790–1328.081	5.521	0.000
Interactions (DID terms)	Time 1 × Treatment				ns ^a
	Time 2 × Treatment	–229.4959	–438.754 – –20.238	–2.150	0.031
	Time 3 × Treatment	–394.6772	–603.979 – –185.375	–3.697	0.000
	Time 4 × Treatment	–386.8490	–596.173 – –177.528	–3.623	0.000
Demographics	Median income	–20.8356	–34.183 – –7.487	–3.063	0.002
	African American pop. (%)	36.9941	26.328–47.660	6.805	0.000
	Pop. over 25 with higher ed. (%)	–16.7633	–33.865–0.339	–1.923	0.054
Vacancy	Vacant land (%)	–28.5688	–38.833 – –18.304	–5.461	0.000
	Vacant housing (%)				ns
Land use adjacencies	Roadway and transportation	–473.8724	–768.649 – –179.082	–3.154	0.001
	Religious facilities	755.2506	439.342–1071.174	4.690	0.000
	Open/recreational space				ns
	Governmental administration services				ns
	Educational facilities (K-12 and post-secondary)				ns
Study site	East Garfield Park	1627.8038	1266.62–1988.94	8.843	0.000

a: Not significant.

* Akaike Information Criterion (AIC) = 80937.3. Marginal R^2 = 0.197. n = 939.

significant impact on lowering crime density starting in Time 2 (year 2016). There was also a statistically significant main effect of large lot ownership ($p < 0.001$). Although the first interaction term did not show significance (Treatment * Time 1), all the three successive interaction terms had statistically significant coefficients ($p < 0.05$ for Treatment * Time 2 and $p < 0.001$ for Treatment * Times 3 and 4). Fig. 4a shows that crime density had a steeper decline in treated blocks than in the control ones. Looking at the control variables, there was a significant negative association between median income and crime density, and a positive association between the percentage of African-American population and crime. There was also a negative marginally significant association ($p = 0.054$) between the population with higher education and crime, and the percentage of vacant land showed a significant negative association with crime density ($p < 0.001$). Further, adjacency to roadway and transportation as well as religious facilities contributed to crime density in negative and positive ways, respectively.

5.2. Does the ownership of large lots impact specific types of crime (e.g., property crime, violent crime, and drug abuse) more than others over time? (Question 1.2).

We found some significant or marginally significant interaction terms for five crime categories (Table 4). There were also statistically significant main effects of large lot ownership on these crime categories, while no significant interaction terms were found between time and treatment for simple battery, vandalism, and gun-related violent crime. Fig. 4b to 4f depict the joint effects of time and treatment for each of these five crime categories. For drug abuse, large lot ownership showed statistically significant main effects in crime reduction. However, only the interaction term between treatment and the last time period (2018) showed significance at the 0.05 level with a negative sign, reflecting a greater reduction in drug abuse crimes for treated blocks compared to control blocks (see Fig. 4c). For non-gun-related violent crimes, there was a marginally significant ($p = 0.06$) interaction term two years after intervention (Time 3) with a negative sign, lending support to a stronger reduction in those crimes for treated blocks (see Fig. 4d). The regression for simple assault showed marginal significance with negative interaction terms for Time 1 ($p = 0.09$) and Time 4 ($p = 0.06$), suggesting more reduction of these crimes in treated blocks than in control blocks in each of these years. The regression also showed smaller increases in simple assaults between 2014 and 2018 for treated blocks than control blocks

(Fig. 4e).

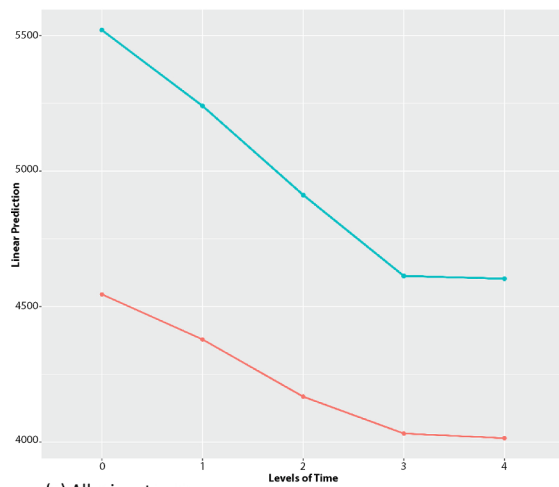
For property crime, there was a marginally significant ($p = 0.09$) negative interaction term between Time 3 and treatment (Fig. 4f). Finally, the regression for non-index miscellaneous offenses showed that, starting in Time 2 (2016), all the interaction terms between time and treatment were significant ($p < 0.05$ or lower). This suggests that large lot ownership contributed to a stronger reduction in non-index offenses starting one year after lot purchase in treated blocks compared to the control blocks (Fig. 4b).

Comparisons of the estimated marginal means between treated and control blocks over time (See Table S6) showed that aggregated crimes decreased about 4.9% more in treated than control blocks between 2014 and 2018, which means on average about 1.24% more crime reduction per year in treated than control blocks in the entire study period. Reduction of drug abuse in treated blocks during this period was 6.3% more than that of control blocks, which means, on average, drug abuse decreased by 1.58% more per year in treated than in control blocks. Non-index offenses also showed about 12.58% more reduction in treated blocks as compared to control blocks between 2014 and 2018, meaning that on average, this type of crime decreased by 3.21% more per year in treated than control blocks.

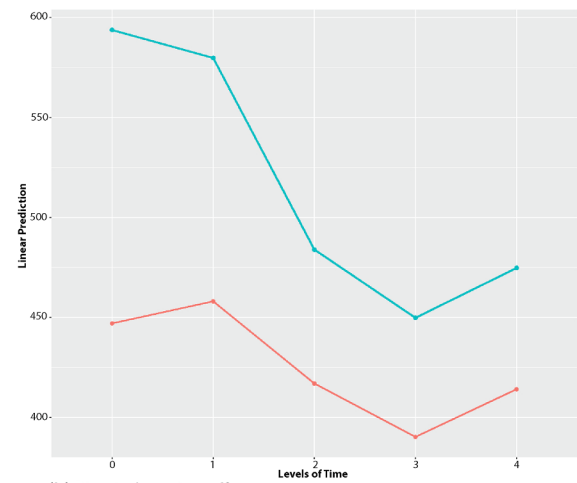
5.3. To what extent is the level of condition-care associated with reduction of different types of crime density over time in blocks with large lots? (Questions 2.1 and 2.2).

Mixed-effects models (Table 5) showed that the condition-care rating was not associated with either aggregated crimes (Question 2.1) or individual crime categories (Question 2.2, data not shown). The interaction terms between time and condition-care rating were not significant either. However, the interaction term between the condition-care rating and a dummy variable describing blocks in East Garfield Park was negatively associated with both aggregated crimes and drug abuse ($p < 0.001$) as shown in Table 5.

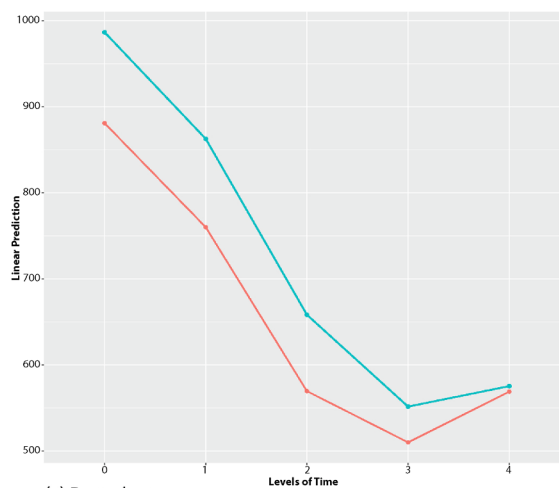
Importantly, the post-hoc simple slope analysis for those interaction terms (See Table S4) showed marginally significant negative associations between the level of condition-care and both aggregated crimes ($p = 0.07$) and drug abuse ($p = 0.06$) in East Garfield Park but not in Greater Englewood, suggesting that neighborhood context might moderate the impact of condition and care on crime.



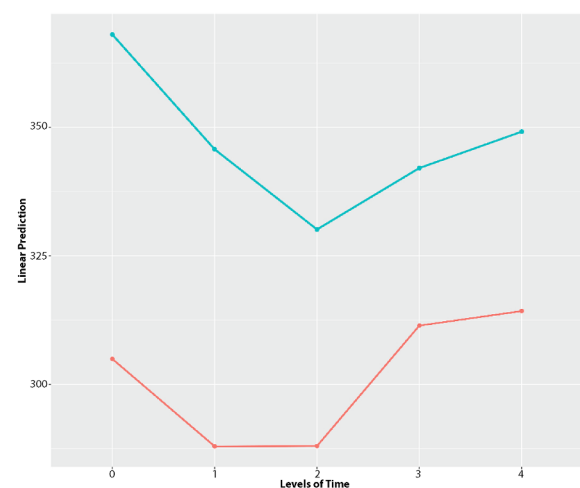
(a) All crime types



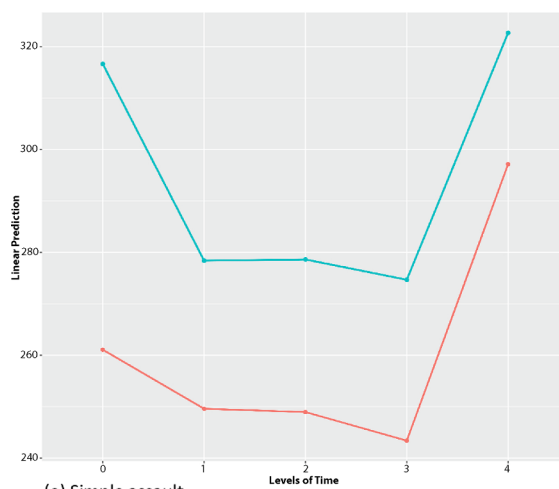
(b) Non-index misc. offenses



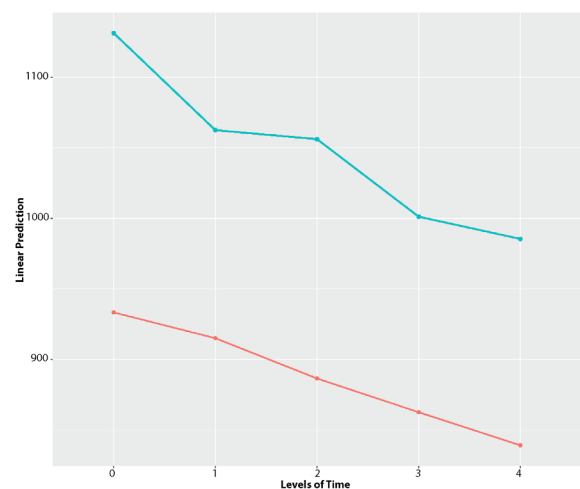
(c) Drug abuse



(d) Non-gun-related violent crime



(e) Simple assault



(f) Property crime

Nontreated blocks —●—
Treated blocks —●—

Fig. 4. Comparisons of estimated marginal means between treated and nontreated blocks as a function of joint effects of time and treatment

Table 4

Mixed-effect regressions predicting crime density for each crime category: Difference-in-differences models.

		Non-Index misc. offenses		Drug abuse		Non-gun-related violent crimes		Simple assault		Property crimes	
		Estimate	t value	Estimate	t value	Estimate	t value	Estimate	t value	Estimate	t value
	Intercept	200.775	2.750 ($p = 0.0060$)		ns ^a	159.628	3.196 ($p = 0.0014$)	89.142	2.162 ($p = 0.0308$)	510.011	4.273 ($p = 0.000$)
Time	Time 1 (2015)		ns	-121.415	-5.261 ($p = 0.000$)	-17.277	-1.939 ($p = 0.0525$)		ns		ns
	Time 2 (2016)	-30.079	-2.198 ($p = 0.0280$)	-311.836	-13.517 ($p = 0.000$)	-17.357	-1.949 ($p = 0.0513$)		ns	-47.227	-2.664 ($p = 0.0077$)
	Time 3 (2017)	-56.452	-4.122 ($p = 0.000$)	-371.420	-16.089 ($p = 0.000$)		ns	-17.577	-2.175 ($p = 0.0297$)	-70.260	-3.960 ($p = 0.000$)
	Time 4 (2018)	-32.667	-2.384 ($p = 0.0171$)	-311.996	-13.508 ($p = 0.000$)		ns	36.196	4.476 ($p = 0.000$)	-93.609	-5.274 ($p = 0.000$)
Large lot ownership	Treatment	147.370	5.497 ($p = 0.000$)	106.054	2.236 ($p = 0.0254$)	63.244	3.517 ($p = 0.0004$)	55.844	3.621 ($p = 0.000$)	199.623	4.946 ($p = 0.000$)
Interactions (DID terms)	Time 1 × Treatment		ns		ns		ns	-26.945	-1.667 ($p = 0.0955$)		ns
	Time 2 × Treatment	-79.675	-2.910 ($p = 0.0036$)		ns		ns		ns		ns
	Time 3 × Treatment	-87.460	-3.194 ($p = 0.000$)		ns	-32.462	-1.822 ($p = 0.0685$)		ns	-59.778	-1.685 ($p = 0.0920$)
	Time 4 × Treatment	-86.317	-3.152 ($p = 0.0016$)	-99.347	-2.152 ($p = 0.0314$)		ns	-30.151	-1.865 ($p = 0.0622$)		ns
Demographics	Median income	-1.740	-2.053 ($p = 0.0404$)		ns	-2.086	-3.593 ($p = 0.0003$)	-1.374	-2.870 ($p = 0.0041$)	-3.102	-2.231 ($p = 0.0259$)
	% Afro-American pop. % Over 25 with higher ed.	3.712	5.478 ($p = 0.000$)	4.876	3.938 ($p = 0.000$)	2.479	5.344 ($p = 0.000$)	2.205	5.766 ($p = 0.000$)	6.728	6.056 ($p = 0.000$)
Vacancy	% Vacant land	-3.661	-5.611 ($p = 0.000$)	-2.171	-1.822 ($p = 0.0688$)	-2.214	-4.957 ($p = 0.000$)	-1.737	-4.716 ($p = 0.000$)	-5.942	-5.556 ($p = 0.000$)
	% Vacant housing units		ns	3.352	2.011 ($p = 0.0446$)		ns		ns		ns
Land use adjacencies	Roadway and transportation	-56.672	-3.024 ($p = 0.0025$)	-103.658	-3.028 ($p = 0.0025$)	-43.751	-3.410 ($p = 0.0006$)	-21.399	-2.023 ($p = 0.0433$)	-83.835	-2.729 ($p = 0.0064$)
	Religious facilities	81.524	4.059 ($p = 0.000$)		ns	80.081	5.824 ($p = 0.000$)	53.637	4.732 ($p = 0.000$)	166.627	5.061 ($p = 0.000$)
	Open/recreational space		ns	61.942	1.775 ($p = 0.0762$)		ns		ns		ns
	Governmental administration services		ns	84.063	1.780 ^a ($p = 0.0753$)		ns		ns		ns
Study site	Educational facilities (K-12 and post-secondary)		ns		ns		ns		ns		ns
	East Garfield Park	104.282	4.540 ($p = 0.000$)	751.487	17.910 ($p = 0.000$)	70.623	4.491 ($p = 0.000$)	51.590	3.980 ($p = 0.000$)	65.313	1.735 ($p = 0.0830$)
AIC		66848.2		71887.2		62921.1		61829.1		69713.1	
Marginal R ²		0.097		0.249		0.099		0.090		0.112	

*Confidence Interval: 97.5%. n = 939. a: Not significant.

6. Discussion

We examined a resident-owner-based approach to repurposing vacant lots through the Chicago Large Lot Program and its effects on crime in high-vacancy neighborhoods. Improving safety has been part of the goals of this initiative (City of Chicago, 2014a), and we found evidence for the effectiveness of the program in terms of reducing crime

density over time. This study showed that (1) ownership of large lots on blocks had a significant impact on lowering crime density starting one year after lot purchase; (2) visual condition and care of purchased lots was associated with reduced crime density in one of our study sites where the percentage of purchased lots and mean condition-care rating were more than twice as much as those of the other site; and (3) various crime types were impacted differently by ownership and condition-care

Table 5

Mixed-effects regressions to predict crime density for treated blocks: Condition-care rating is the main independent variable of interest.*

		Aggregated crimes		Drug abuse	
		Estimate	t value	Estimate	t value
Time	Intercept	3318.637	3.042(p = 0.0026)		ns ^a
	Time 1 (2015)	−282.534	−2.614 (p = 0.0091)	−128.086	−2.889 (p = 0.0039)
	Time 2 (2016)	−599.575	−5.267 (p = 0.000)	−331.157	−7.177 (p = 0.000)
	Time 3 (2018)	−911.423	−8.130 (p = 0.000)	−414.651	−9.094 (p = 0.000)
Visual condition	Condition-care score		ns		ns
	Study site	2508.763	6.833(p = 0.000)	929.907	9.192(p = 0.000)
Interaction ^b	East Garfield Park (EGP)				
	Condition-care score × EGP	−0.597	−2.007 (p = 0.0450)	−0.254	−2.380 (p = 0.0175)
Demographics	Median income		ns		ns
	% Afro-American pop.	22.659	2.354(p = 0.0194)		ns
	% Over 25 with higher ed.		ns	−8.256	−1.832 (p = 0.0681)
	% Vacant land	−48.442	−3.431 (p = 0.0007)		ns
Vacancy	% Vacant housing units		ns	9.803	2.216(p = 0.0277)
AIC		16474.3		14603.2	
Marginal R ²		0.209		0.238	

* Confidence Interval: 97.5%. n = 234. a. Not significant. b. Post-hoc simple slope analyses show that the slope of the condition-care score is approaching significance and is negative ($p = 0.07$ for all crimes and $p = 0.06$ for drug abuse) for East Garfield Park but not for Greater Englewood (see Table S4 in the Supplementary materials).

level. These findings highlight how a resident-led greening strategy based on the transfer of vacant lands to local property owners and their improved condition and care is an effective way to boost neighborhood safety and quality of life by reducing crime incidents.

6.1. Ownership matters and has long-term effects

One of the highlights of our findings is that residents' ownership of vacant lots has a significant and sustained impact on overall crime density. Given that crime prevention was not identified as the most important purpose of this program, the extent of our findings that demonstrate a strong connection between resident-owner-led greening and crime reduction is remarkable. These findings confirm the results of a recent study on the Large Lot Program regarding the role of ownership in crime reduction (Stern & Lester, 2021) and extend that work by examining several types of crime, multiple years of crime data, and the visual quality of purchased lots.

An important takeaway from this study is related to ownership and the scope of time. While no significant effect appears in the first year after large lot purchase, considerable reductions in crime emerge in the second year along several crime types and they continue in subsequent years of study. This pattern of effects suggests that the impacts of resident-owner-led programs on crime reduction require time to take root and sustain themselves over the long term. This is quite different

from most policing strategies aimed at weeding-out crime that may achieve quick success but depend on a continued high level of input in personnel and other resources. Further studies are needed to examine policing strategies in these neighborhoods and whether the residents involved in large lot greening also had higher levels of collective efficacy or community engagement with the police department to help increase safety in their neighborhood. Resident-owner-led programs for repurposing vacant land could be a cost-effective way of longer-term, sustained crime prevention, to help reclaim and revitalize urban neighborhoods beset by negative outcomes of urban vacancy.

6.2. Visual condition-care matters depending on the neighborhood context

Our findings that condition-care is associated with crime in one study site raise a question on the importance of the *extent* of visual improvements in the neighborhoods. Comparing the two study sites, 10% of the blocks in Greater Englewood have improved visual quality through the Large Lot Program, while 20% of the blocks have improved visual quality in East Garfield Park. Further, the mean condition-care rating of the treated blocks in East Garfield Park is 2.5 times higher than that of Greater Englewood (Table 1). An explanation for these differences in the relationship between condition-care and crime could be linked to a threshold of visual cues to care in residential blocks. In other words, when the stewardship efforts of individual large lot owners reach a critical mass, they may create enough of a positive visual impact in the overall perceived level of condition-care of a block to make a difference. Such an explanation supports previous findings about reducing signs of disorder through enhanced 'cues to care' contributing to crime reduction and leading to neighborhood cohesion and more desirable sense of place (Alaimo, Reischl, & Allen, 2010; Nassauer & Raskin, 2014). Thus, another takeaway from our work suggests that for the visual quality of the blocks to contribute to crime reduction, the expansion of resident ownership of vacant lots across the blocks is necessary.

Our findings also align with the idea that the *process* of neighborhood stewardship fostered by residential ownership of vacant lots may play a role in crime reduction by encouraging residents to be outside taking care of their lots. This is in line with previous findings concerning more 'eyes on the street' (e.g., Clarke, 1983) together with breaking 'routine activities' (Cohen & Felson, 2010) through acts of care that contribute to lower crime on blocks with purchased large lots.

6.3. The impacts on crime vary depending on crime types

We found that ownership and level of condition-care of large lots impacted crime types in different ways. When examining the role of ownership, among the several observed crime categories, non-index offenses (e.g., criminal trespassing, public peace violation, and narcotics possession) was the only category to be significantly impacted by large lot ownership across all years after the year of lot purchase. This is an important outcome of the Large Lot Program, given that high-frequency occurrence of non-index offenses in residential neighborhoods may negatively impact the perception of safety and neighborhood satisfaction among residents.

Drug abuse was another crime type that showed significant reduction due to the Large Lot Program but did so only in the fourth year of ownership. When examining the role of condition-care, however, drug abuse responded differently across the two study sites and was significantly impacted where the mean condition-care ratings of the blocks were more than twice as much as that of the other site. Large lots are outdoor spaces where resident-owners may spend more time taking care of their properties, which might deter potential offenders from committing crimes. Our study supports previous work showing that drug abuse takes place mostly in areas that have low levels of "eyes on the street" such as in blocks with substantial blight and housing vacancy (Skobba, Osinubi, & Tinsley, 2020) and less visual cues to care, away from religious facilities (Mason et al., 2009).

6.4. Limitations

We acknowledge that crime is a multifaceted phenomenon and some possible confounding factors were not accounted for in this study. We also acknowledge that there may be some non-visible factors playing roles that our condition-care scale did not address. Additionally, we did not control for potential ongoing policing activities in the study sites across the observation years that might have affected the number of crime incidents in certain blocks. Another factor that was not accounted for in our study relates to absentee owners. A recent study (Stern & Lester, 2021) suggests that local owners may have greater impact on crime reduction compared to absentees. Further, the nature of crime-report data could serve as a limitation to many studies including ours. Reported crime data is generally dependent on residents' or witnesses' recognizing and reporting crime to the police, who then respond in ways that create a report (Messer, Kaufman, Dole, Savitz, & Laraia, 2006). In this sense, the social process of crime reporting reduces the verity of crime databases as representational of the actual crimes committed. For example, if in a block with high percentage of vacant land there are few reported crime incidents, it might be due to fewer people watching outdoors to witness and report the crimes.

7. Conclusion

Our findings suggest that a vacant land re-use policy that is based on resident-ownership and its consequent resident-owner-led care and utilization of the vacant lots has significant impact on crime reduction in high-vacancy neighborhoods. The resident-owner-based initiative examined in this study, shows that positive impact of such initiatives to neighborhood safety may not be visible immediately at the beginning, but their substantial impact will emerge and sustain over time. Our study further suggests that expanding the amount of lot sales might reinforce change through improved visual condition and care of those lots that lead to less crime. Unlike many community-based greening programs that may need continued financial support from municipalities in order to be sustained, resident-owner-based programs can be self-sustaining drivers of change that lead to improved neighborhood safety and quality of life. These programs offer planners and policymakers cost-effective and self-sustaining solutions to pressing issues caused by urban vacancy.

CRedit authorship contribution statement

Sara Hadavi: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Validation, Visualization, Writing - original draft. **Alessandro Rigolon:** Conceptualization, Formal analysis, Methodology, Validation, Visualization, Writing - review & editing. **Paul H. Gobster:** Conceptualization, Methodology, Validation, Writing - review & editing. **William P. Stewart:** Conceptualization, Funding acquisition, Methodology, Project administration, Supervision, Writing - review & editing.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.landurbplan.2021.104096>.

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