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Research Paper

The relationship between residential yard management and neighborhood crime: An analysis from Baltimore City and County

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HIGHLIGHTS

- Front yard landscaping has an association with crime, adjusting for several control variables.
- Crime correlates negatively with yard trees, garden hoses/sprinklers, lawns, and pervious area.
- Crime is positively associated with litter, desiccated lawns, uncut lawns, among other factors.
- Results add to the evidence that crime is deterred by “cues to care”.
- They also add to the evidence that landscaping draws more “eyes on the street”.

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ABSTRACT

We analyzed the relationship between crime and indicators of residential yard management in Baltimore City and County. Data came from a survey we conducted of over one thousand front yards that included more than 40 indicators relating to lawns, trees, shrubs, beds and other features. These indicators were related to point counts of crime at the 150 m scale using a combination of ordinary least squares, spatial error, and Poisson regressions. After controlling for income, population density, block-scale tree canopy, and housing type, we found a consistently significant relationship between crime and a number of indicators of yard management. Yard-level variables that were negatively associated with crime included: the presence of yard trees, garden hoses/sprinklers, and lawns, in addition to the percentage of pervious area in a yard. Those positively associated with crime included presence of litter, desiccation of the lawn, lack of cutting of the lawn, and number of small trees in front of or adjacent to the property. While these results do not establish causality, they add evidence to a growing literature that suggests the possibility of several mechanisms by which environmental design may reduce crime: “cues to care” (the inverse of the “broken window” hypothesis) can lead to reduced crime by signaling to criminals the presence of social capital and the active involvement of neighbors in community spaces; and more appealing landscaping draws more “eyes on the street,” which in turn deters criminals.

1. Background

A growing body of literature suggests that urban environmental design has a significant impact on crime. However, the specifics of this relationship, including mechanisms and best management practices, are still poorly understood. This paper represents an attempt to address some of those gaps in the realm of residential yards.

A number of studies have focused on negative aspects of vegetation, suggesting that vegetation, particularly when low in height or dense in form, is positively associated with actual or perceived crime risk because it affords criminals concealment and a place to stash stolen goods or weapons (Fisher & Nasar, 1992; Nasar, Fisher, & Grannis, 1993). Michael, Hull, and Zahm (2001) cite anecdotes from park police about how dense vegetation is regularly used by criminals; and how automobile thieves say they use dense vegetation to shield many of their activities, including target selection, examination of stolen goods, and disposal of unwanted goods. Donovan and Prestomon (2012) found that low trees that decreased views from first floor windows on private lots in Portland, OR were associated with increased crime occurrence. Stoks (1983) found

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that dense vegetation was a common characteristic of rape sites. It is not surprising, then, that in their guide to park design, Forsyth, Musacchio, and Fitzgerald (2005) discuss the importance of eliminating concealing undergrowth in parks to make users feel safer.

While this research suggests that vegetation can be a liability in some cases, an increasingly large literature suggests that it—along with outdoor landscaping in general—can be an asset in reducing crime. Troy, Grove, and O'Neil-Dunne (2012) found that tree cover has a strong negative correlation with several types of crime, even after adjusting for a number of socio-economic, housing, and environmental control variables. Wolfe and Mennis (2012) found that vegetation abundance measured at the tract scale has a significant negative association with rates of assault, robbery and burglary. Snelgrove, Michael, Waliczek, and Zajicek (2004) found a negative association between a remotely sensed greenness index and quantity of crimes committed.

A number of potential mechanisms for why trees may reduce crime have been proposed in the literature. One explanation is that well-designed landscaping makes spending time outdoors more appealing, leading to more "eyes on the street," which in turn leads to checks on dangerous behavior (Jacobs, 1961, Kuo, 2003). More "eyes" in public spaces deter criminals by making it harder for them to go unnoticed and by leading to informal surveillance networks (Kuo & Sullivan, 2001a; Kuo & Sullivan, 2001b). Additionally, these outdoor encounters foster social networks and cohesion among neighbors (Yancey, 1971), further fueling this virtuous cycle. Sullivan and Kuo's research suggests that stronger social networks can mean a reduced likelihood of crime from within the community in the case of public housing (Sullivan & Kuo, 1996). By contrast, non-landscaped, non-vegetated areas are often perceived as "no-man's lands" that keep people away. For instance, Coley, Kuo, and Sullivan (1997) found that the amount of time residents spent in common outdoor neighborhood spaces was associated with the presence of trees and that the closer trees were to residential buildings, the more people spent time outside near them. Kuo, Sullivan, Coley, and Brunson (1998) found that while residents disliked and avoided barren common spaces typical of many unmaintained inner city parks, they liked photo-simulations of the same spaces when those photos included additional grass and trees. The "eyes on the street" theory is consistent with "opportunity theory" from criminology, which suggests that for a crime to occur, motivated offenders must encounter suitable targets and the absence of capable guardians (Cohen & Felson, 1979; Wilcox, Land, & Hunt, 2003). Additional eyes on the street mean a potentially larger number of capable guardians.

A second explanation of why vegetation might reduce crime is that it can be seen as a "territorial marker" or a "cue to care," signifying to criminals that the residents are actively involved with their surroundings (Brown & Bentley, 1993), even if they see no residents on the street. The presumption is that when looking for a place to commit a crime, a perpetrator would move on to a neighborhood where cues suggest weaker neighborhood organization and less social capital. This is consistent with the "broken window theory," which posits that neighborhoods displaying visual cues of neglect or poor maintenance experience higher crime because these cues suggest to criminals a lack of effective law enforcement, while maintained neighborhoods send the opposite cue (Wilson & Kelling, 1982).

And finally, research also suggests that green surroundings can attenuate violent behavior through psychological mechanisms. For instance, green surroundings have been found to be associated with lower levels of aggression and mental fatigue in inner city residents (Kuo & Sullivan, 2001), while they have also been found to be linked to cognitive forms of self-discipline among youth, such as impulse inhibition and delay of gratification (Taylor, Kuo, & Sullivan, 2002).

The fact that some studies support the finding that vegetation increases crime through concealment while others find it decreases crime through eyes on the street or cues to care suggests that the type or configuration of urban vegetation matters. Most of the studies finding an inverse relationship between trees and crime are not explicit about the characteristics of vegetation being studied (e.g. height, species, age). One study that is explicit about this (Kuo & Sullivan, 2001a; Kuo & Sullivan, 2001b) looked specifically at widely-spaced, high-canopy trees over grass, finding that their presence decreased crime around Chicago public housing (although that predictor only explained about 8% of the variance). The authors point out that the vegetation being studied in this case was not the type that would afford concealment; therefore the vegetation's crime-fighting characteristics outweigh its crime-inducing effects. One of the few other studies to explicitly control for vegetation type in its design is from Donovan and Prestomon (2012), which found that low trees that decreased views from first floor windows on private lots in Portland, OR were associated with increased crime occurrence, while taller trees on private lots were associated with decreased crime.

While street trees have been associated with decreased crime in general, Troy et al. (2012), using Geographically Weighted Regression, found that there is some spatial variability in the relationship between tree canopy and crime that may be explained by vegetation management. The few block groups where more trees were associated with more crime tended to contain significant areas of unmanaged, densely stocked vegetation between residences and industry, suggesting that such landscapes have few of the crime-fighting benefits of managed vegetation while at the same time offering opportunities for concealment.

Several studies that examined the after-effects of vacant lot greening yield found further support for the proposition that actively managed urban landscapes are associated with less crime. These results suggest, in addition to the presence and height of vegetation, that the design and level of intentionality of urban vegetation and its associated landscaping matter. If urban trees or landscaping reduce crime at least partly through drawing "eyes to the street," then it would seem logical that landscapes that are more attractively managed may draw more eyes to the street as well. Among the studies that support this contention, Branas et al. (2011) examined more than 4000 vacant lots that had been greened in Philadelphia. These researchers found that gun assaults and vandalism rates dropped significantly around lots that had been greened when compared to un-altered lots. The study further supports the "eyes on the street" hypothesis in that it finds that residents around greened lots report more exercise and less stress. Not surprisingly, then, increases in the number of vacant lots have been found to be associated with greater assaultive violence (Branas, Rubin, & Guo, 2012).

This review of the literature suggests that a combination of landscape design, elements, quality, and maintenance can influence crime. While residential yards are one of the most prominent components of urban nature, no research to our knowledge exists that examines the relationship between private landscape features and crime in residential areas. This study attempts to fill this gap by relating indicators of the level of yard management to crime at a fine scale. Our hypothesis is that the level of yard management is inversely correlated with crime for several reasons: a streetscape with actively managed yards signals to potential criminals the presence of social cohesion and can drive the perception that informal surveillance exists, both of which raise the risks to criminals; a well-landscaped streetscape is more likely to have residents out on the street, increasing eyes on the street and likelihood for potential agents of intervention against crime; and greener streetscapes reduce stress and aggression while increasing cognitive function, all of which can help

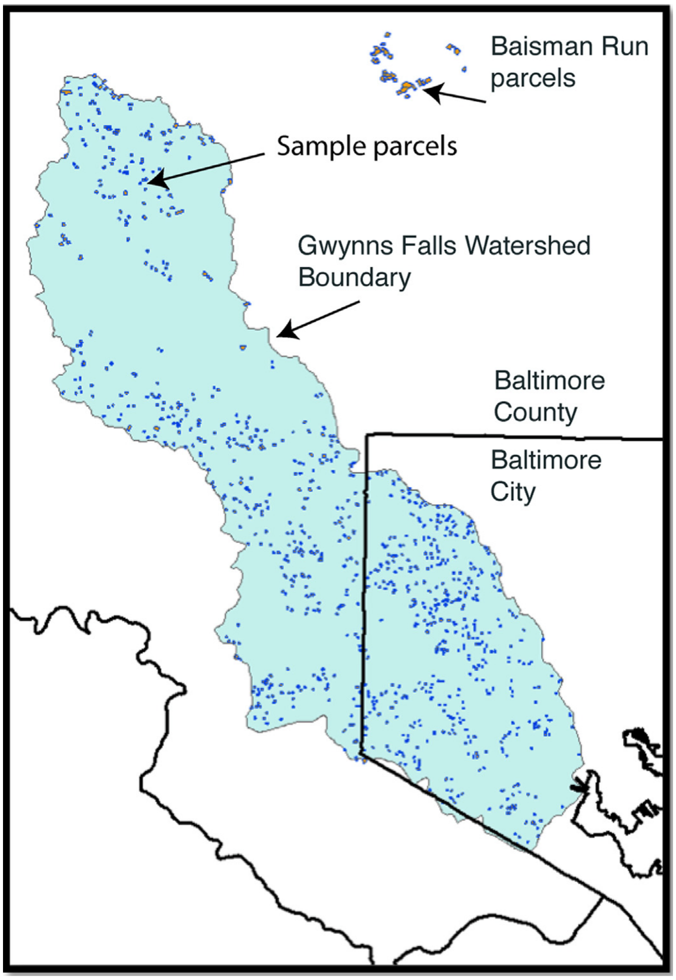

Fig. 1. Study area.

attenuate crimes driven by momentary lapses of judgment or self-control.

2. Methods

2.1. Study area

Parcels were sampled mostly from within the Gwynns Falls Watershed in Baltimore City and Baltimore County in Maryland (Fig. 1), with a small number of parcels also coming from the nearby but much less urbanized Baisman Run sub-watershed. Both watersheds, which between them contain a wide range of neighborhood crime rates – from among the highest in the nation, to near-zero – were selected because of the extensive data sets available for these watersheds, gathered through the Baltimore Ecosystem Study. Spanning approximately 43,400 acres, the Gwynns Falls watershed contains diverse land use, vegetation, and crime patterns. The southern section of the Gywnns Falls watershed is dominated by residential, commercial, and industrial areas, while the northern section of the watershed is characterized by suburban developments, forested areas, and open space. In 2004, overall vegetation cover in the watershed was 65% of the total land area, with 35% tree and shrub cover and 30% grass and herbaceous cover. Vegetation cover varies substantially between U.S. Census block groups (BG) in Gwynns Falls, ranging from less than 4% in parts of Baltimore City to more than 95% in Baltimore County. Crime is extremely variable across the watershed, with block group level rape rates ranging from zero to more than four times the national average and robbery rates ranging zero to over 16 times the national average. Nonetheless, statistics are improving. Violent crimes, which were at nearly 22,000 for Baltimore City (3% of the population) in 1993, were down to around 10,000 (1.6% of population) by 2009. Baisman Run is a 381 ha mostly forested watershed in located about 10 km north of Baltimore City which includes a number of suburban homes on large lots and has very low crime rates. It was included because it represents a housing type that is rare within Gwynns Falls.

2.2. Data and GIS analysis

Vegetation maintenance data were drawn from the 2007 Greater Baltimore Residential Land Management Survey. The survey, which was created by the authors, was drafted and field-tested in 2007. Data were collected by trained field technicians from 999 lawns in the Gwynns Falls watershed over a five-week period from June through mid-July 2007. Parcels were selected for the survey using a two-tier stratified random sampling method. Of the 999 parcels surveyed in the Gwynns Falls watershed, 500 were located in Baltimore County and 499 in Baltimore City, 100 of which were known to be vacant lots. Thirty additional lots were sampled from Baisman Run.

Minimum sampling criteria were established to determine the population to be sampled. The first criterion was to select only residential properties. Condominium and townhouse developments were eliminated because their open spaces tend to be professionally managed. Parcel fragments (i.e. small, irregularly shaped and unbuildable lots) and rental dwellings were also excluded from the sampling population. In order to reduce the chance of sampling lots with little or no front yard, parcels were eliminated from the sample if they contained less than 20% vegetation cover or failed to meet minimum size criteria (200 square meters for Baltimore County and 150 square meters for Baltimore City).

Parcels were first stratified using Claritas PRIZMTM 15 marketing clusters to categorize block groups based on population density and socioeconomic status (PRIZM, or Potential Rating Index for Zipcode Markets, is a commercially available lifestyle segmentation product made by the market research firm Nielsen-Claritas, Inc., designed to categorize neighborhoods based on purchasing preferences and social characteristics). Additionally, housing age (built before or after 1965) was used as a stratification variable in the County and abandonment status of parcels was used in Baltimore City. To select parcels, we utilized a modified proportional sample with oversampling for low population strata. For Baltimore City, we oversampled vacant properties by predetermining that there would be 400 parcels of occupied housing and 100 vacant lot parcels sampled. Using Google Earth, we eliminated vacant parcels that were inaccessible on foot. Oversampling of vacant lots was not performed for Baltimore County, as there are an insignificant number of such lots there.

The Land Management Survey focused on vegetation maintenance and yard management practices. The survey included sections on property type, street and yard trees, shrubs, lawn, and additional yard features. Data relating to occupancy and dwelling type were recorded under property type. Observations made on trees included number of trees on property, evidence of management of trees (including mulching, pruning, gator bags, and staking), and estimated overall health. When trees were present, we distinguished between those less than 6″ in diameter at breast height (DBH) and those equal to or greater than 6″ in DBH, and noted the number of "unwanted" trees. An unwanted tree was defined as a volunteer species that did not appear to have been intentionally planted or to be actively managed, based on a combination of factors, including size, invasiveness of species, location, and stocking. For shrubs, we collected data on evidence of management (mulching, edging, and pruning), overall shrub quality, and percent of shrubs classified as "unwanted." For the lawn, grooming status, signs of lack of management (bare or desiccated patches, large patches of herbaceous species within lawn, and leaf litter or fruit-drop present), and overall lawn greenness were recorded. Additional features ranging from vegetable gardens to bird feeders to litter were also noted.

Recognizing that many of these measures were somewhat subjective, the field technicians had lengthy training in survey methods and parcels were occasionally surveyed twice and analyzed for consistency. Photos were taken to document unique or unusual lawn features and management techniques.

Although front yards are often managed differently from backyards (Larsen, 2006), surveys were only conducted on the former, not only because of their visibility and role in signaling to potential criminals, but also because gaining access to backyards would have required obtaining hundreds of permissions, which would have made this study infeasible.

Crime data for Baltimore City and County came from Spotcrime (http://spotcrime.com), a service that aggregates and geocodes crime data from public record police reports, augmented by news stories and user input. Spotcrime is one of the most widely distributed Internet source of crime mapping in the United States. The crime database included records from the middle of 2007 to the end of 2010. Attributes included the date, crime type, a brief description, and the geographic coordinates. Crime types used in this analysis included robbery, burglary, theft, assault, vandalism, arson, and shooting crimes. Robbery includes the taking or attempted taking of goods from a person by force or threats, such as holdups. Burglary includes unlawful entry into a structure, such as a house or store, to commit theft or some other felony. This encompasses both "breaking and entering" and "forcible entry." Theft includes various forms of stealing not included in the previous categories. It is often synonymous with "larceny." One of the largest categories it includes is theft in or of motor vehicles. Shooting includes murder and attempted murder. Assault is a broad category that occurs crimes involving attempted or actual severe bodily harm, or use of a deadly weapon. From reading the detailed crime notes, it appeared that a number of crimes classified as "assault" involved another component such as robbery.

We chose this combination of crime based on the assumption that all have the potential to be affected by environmental design. For instance, robberies or car thefts are generally outdoors and the chance that they will be attempted in a given place very much depends on the absence of bystanders and opportunities for concealment. Burglaries also are far more likely when there are fewer "eyes on the street" and better places to hide and stash stolen goods. Nonetheless, we recognized that many of these broad crime categories would include actual criminal acts that bear no imaginable relationship to environmental design, particularly those occurring entirely indoors. Therefore we conducted a detailed review of the notes fields of the crime records in our data set and attempted to purge all those crimes that could clearly be placed indoors, or that appeared to have no connection to environmental design. This resulted in the elimination of 1422 out of over 22,000 crimes records. Among the sub-types of crimes excluded were shoplifting, indoor larceny from commercial establishments, forgery, Internet theft, and credit card misuse.

Crime data were summarized by buffering each parcel by 150 m and taking the count of crime points within the buffer. The choice of buffer radius was based on the desire to represent crime at the scale of approximately a city block face, since we hypothesize that the choice of where to perform a crime likely occurs at approximately this scale. While many of the buffers did overlap, meaning that some of the same crimes were counted toward two or more sample parcels, we do not believe this poses a problem. We recognize that crime and its determinants represent a spatial spillover phenomenon (i.e. the design of one person's yard affects crime not just in front of that house but potentially also down the block, and a crime hotspot on one block may often be associated with high crime on an adjacent block because the same people may be committing the crime). Therefore, unless observational units are spaced very far apart (which was not feasible in this study) there is no way to avoid the issue of spatial autocorrelation. However, recognizing this, we use the spatial error regression model, which accounts for autocorrelation stemming from overlapping observational units in a way that avoids the problem of inflated test statistics.

Each parcel was attributed with block group-level Census variables and data on tree canopy coverage at the scale of 150 m grid cells. Gridded tree data was used to control for block-scale tree coverage, which has been found to have a strong negative correlation with crime (Troy et al., 2012). Canopy data were derived from a combination of classifying 1-meter resolution color infrared imagery from the National Agricultural Imagery Program (NAIP) from 2007 along with surface models generated from light detection and ranging (LiDAR) data (O'Neil-Dunne, MacFadden, Royar, & Pelletier, 2012). The use of LiDAR was particularly valuable in that it allowed for the detection of trees within areas obscured by building shadows and the differentiation of canopy trees versus low woody vegetation, such as shrubs. The imagery and LiDAR were integrated into an object-based image analysis (OBIA) system in Definiens eCognition software. Once classified, data were then aggregated to a 150 m grid, whose values were spatially assigned to parcels.

Implicit in our choice of spatial scales is an important assumption about representation. While we measure landscape variables at the parcel scale, our analysis is at a slightly coarser scale due to the use of the 150 m buffer for calculating crime counts. To only look at crime counts immediately in front of a sampled parcel would lead to two problems: an insufficient number of crimes to provide adequate variation in the dependent variable; and a level of false-precision, since many of geotags are not accurate to that sub-block scale. Rather, we assume that the parcel we sample is representative of other parcels on the block in which it is a member. We feel this choice is justified and does not present any inferential problems because we found, through our informal tours of hundreds of miles of Baltimore streets, that there appeared to be a high level of consistency in landscaping across yards within any given block. Or, put differently, we found between-block heterogeneity in yards to be far greater than within-block. This phenomenon relates in part to the fact that housing in and around Baltimore was historically developed in relatively large increments with consistent designs, yielding yards with very similar sizes and configurations across a given block—in turn constraining what kind of landscaping can or cannot be done across a given block. But it also relates to contemporary socio-cultural norms that influence homeowners to landscape in ways similar to their neighbors (Robbins, 2012; Steinberg, 2006). For instance, Grove et al. (2006), Grove, Locke, and O'Neil-Dunne (2014) and Troy, Grove, O'Neil-Dunne, Pickett, and Cadenasso (2007) found empirical support for the "ecology of prestige" theory, which hypothesizes that yard management decisions tend to be influenced by household lifestyle characteristics that are often similar within a given neighborhood, and are also influenced by a desire to outwardly express membership in that lifestyle group, thereby leading to similarities in yard management among neighbors. Harris, Martin, Polsky, Denhardt, and Nehring (2013) also found in metropolitan Boston that shared emotions within a neighborhood context work to create collective yard management practices that either perpetuate a landscaping status quo or collectively launch new paradigms. In other words, we feel comfortable assuming that a sampled yard is typically representative of a larger area.

2.3. Statistical methods

Crime counts were predicted as a function of yard characteristics and surrounding tree canopy. Three statistical approaches – ordinary least squares (OLS), spatial error regression (SER), and Poisson regression – were utilized comparatively to evaluate the stability and consistency of results. OLS was used for its simplicity and ease of interpretation. SER was used to adjust for spatial autocorrelation in the dependent variable, which also yields a more conservative model. The Poisson method was used because, while it is common practice to use linear regression on dependent variables in count form, Poisson regression is more appropriate for counts.

A large number of yard variables were measured and tested. Only those significant at the 90% level or greater were included in the interests of parsimony. Table 1 lists those that were tested for significance and indicates which of those were ultimately included in the model. A number of additional variables were included to control for potential confounding, some at the parcel level and some at the block group level. Variables that were significant in our model at the block-group level were median household income, population density, and percentage of detached houses. A dummy variable for whether the property was a single family detached home was also significant. Table 2 gives summary statistics for only those variables included in the statistical models, including landscape and control variables. Median income was log-transformed due to its non-normal distribution and the fact that it was only significant when transformed. Due to the large number of variables, we also tested the use of principal components as a form of data reduction, but we found that this did not result in improved model fit or interpretability. Thus, principal component results are not presented here.

Diagnostic tests were performed on OLS regression results to investigate the spatial dependency of the dependent variable or residuals, using several differently configured neighbor weight matrices. These tests were done because strong spatial autocorrelation, particularly in the dependent variable or error term, may indicate a form of pseudo-replication, increasing the chance for type 1 error, a problem that can be overcome by using spatially adjusted regressions (Cliff & Ord, 1981). Two possible spatial regression models are available to use: spatial error and spatial lag (Anselin & Bera, 1998). We chose spatial error because while spatial lag regression treats spatial dependence as a structural and substantive component to be modeled (it assumes the existence of spillover effects in the dependent variable—that is, the value of yi influences yj which in turn influence yk and so on, such that a marginal change in observational unit can have a cascading impact on the outcome variable in many other observational units), the spatial error model instead treats spatial autocorrelation more as a nuisance to be controlled for, allowing for a more conservative model (Gleditsch, Ward, & Kristian, 2007). Our goal was not to model the spillover effect of crime (which also introduces significant difficulties in interpretation), but to control for an inflation of test statistics caused by autocorrelation. We expect both our dependent variable and our residuals to be autocorrelated given that many observations were located close to each other and given that measurements of nearby observations may represent manifestations of the same underlying spatially-dependent social or environmental processes. Often Lagrange Multiplier tests are used to make a choice between the SER and lag models. In our case these tests, in both their regular and robust forms, failed to indicate which was superior, so we based our decision of which model to use instead on the conceptual argument previously presented. The model we present used a weight matrix with a distance threshold of 150 m, the same buffer distance used for calculating crime.

A Poisson regression was run using a model-based estimator that is a hybrid between the Newton–Raphson and Fisher scoring methods and uses all the same variables (and transformations) as were used in the OLS analysis. The significance of coefficients was assessed using a Wald Chi-square hypothesis test. No spatially adjusted Poisson regression was conducted.

It should be noted that given the lack of time series data, our statistical methods are unable to assign causality, but rather only association.

3. Results

Our OLS results (Table 3) indicate that ten landscape variables were significant at the 95% confidence level with the expected signs. Parcel-level variables that were negatively associated with crime included: presence of yard trees, garden hoses/sprinklers, shrubs and lawns, in addition to the percentage of pervious area in yard. Those positively associated with crime included presence of litter, desiccation of the lawn, absence of mowing, and number of small street trees in front of the property. Gridded tree canopy was negatively associated with crime. Control variables in the model were all of the expected sign: population density was associated with more crime; median income and status as a single family home and the percentage of single family detached homes in the neighborhood were negatively associated with crime. R-squared was 0.58 in the OLS.

When this model was performed again using the spatial error regression, results were very similar. Every term retained its sign and significance except for Shrubs (which, at a p value of over .1, was dropped) and Lawn_uncut, which went from being significant at the 95% level to the 90% level ($p = 0.066$). Changes in magnitude were generally modest. All but two variables saw smaller magnitudes and the overall average percentage drop in magnitudes was approximately 18%.

When the data were analyzed using a Poisson regression, coefficients on all variables were significant at the 99% confidence level except Shrubs, which was not significant ($p = 0.64$) and so was dropped.

4. Discussion

Our results indicate that after controlling for a number of potential socio-economic or housing-related confounders, there is a strong association between indicators of urban yard management and crime at the 150 m scale. While we have no definitive way to confirm causality in this relationship, the combination of the relatively good fit of the model, our use of numerous control variables and the consistency of our results with previous empirical and theoretical literature—particularly those studies that did establish causal linkages (e.g. Branas et al., 2011)—suggest a possibility that landscaping may be one of the causes of lowered crime. However, the chain of causality is clearly complex, and it is possible that causality could also operate in the other direction, where lowered crime encourages more people to garden. Or, it may be possible that causality operates simultaneously in both directions.

In general, greater signs of intentional landscaping were associated with fewer nearby crimes while greater signs of neglect were associated with more nearby crime. Signs of intentional landscaping included the amount of pervious area, the presence of garden hoses and sprinklers, and lawn, shrubs, or yard trees. Signs of neglect included the presence of litter, desiccated grass, and uncut grass. A further sign of neglect that had not initially been expected was the number of small trees in the surrounding public right of

Table 1
List of yard-level landscape variables tested.

Elements	Measurement	Cross-tab factor	Included in model?
Street trees	Presence		Y (small)
	Number	Size class, planted vs. volunteer	
	Overall health of trees		
	% trees in poor condition		
	Presence of mulch		
	Presence of tree supports		
	Presence of gator bags		
	Evidence of pruning		
Yard trees	Presence		Y
	Number	Size class	
	Overall health of trees		
	% trees in poor condition		
	Presence of mulch		
	Presence of tree supports		
	Presence of gator bags		
	Evidence of pruning		
Hedges/shrubs	Presence		Y
	Presence of mulch		
	Evidence of edging		
	Evidence of pruning		
	Overall health of shrubs		
	% of shrubs that appear to be volunteer/unwanted		
	% of shrubs in poor health		
Lawn/beds	Presence		Y
	Evidence of cutting		Y
	Evidence of edging		
	Presence of bare patches		
	Presence of weed species		
	Presence of leaf litter/fruit drop		
	Presence by greenness level	Lush, dessicated, medium	Y (dessicated)
	% of front yard pervious		
Fence	Presence	Wooden, metal, hedge	Y
Flower boxes	Presence		
Hose/sprinkler system	Presence		Y
Potted plants	Presence		
Vegetable/rain garden	Presence		
Trellis	Presence		
Feeders, ornaments	Presence		
Play equipment	Presence		
Refuse	Presence	Garbage, Trash, Litter	Y (litter)
Patio/hardscaping	Presence		

way. An analysis of photos from yards where these small trees were present suggests that many of these are volunteer trees growing in unmanaged interface zones, or areas of transition between private yards and other land uses such as industrial or vacant parcels. Finally, tree canopy cover at the grid cell (similar in size to many blocks) scale was found to be strongly associated with lower crime, consistent with the findings of Troy et al. (2012) and Donovan and Presetemon (2012). The sign and significance of all predictors were robust to the statistical test used, with the exception of shrub presence, which was significant only at the 90% confidence level in the Poisson model, and lawn_uncut, which was significant only at the 90% confidence level for the spatial lag model.

Based on the explanation given at the end of Section 2.2, we do not believe that these results are in any way compromised by the fact that we measure crime at the 150 scale while we only sample landscaping from a single property on the block. Rather, the marginal effects should be interpreted in light of the fact that any given parcel is meant to be representative of the streetscape (at roughly the block scale) it is part of, due to the fact crime is measured at the 150 m scale and yards tended to be fairly consistent within a given block. Therefore, the marginal effects should be interpreted as showing the impact of that design element were it to be uniformly present across all parcels in that 150 m zone.

Marginal effects (Table 4) were quite striking. Among our OLS results, we found that: the presence of yard trees is associated with a drop in crime count in the 150 m radius of 3.4 (about 9% of the average count) over the period in question (approximately 3.5 years), holding all else constant; an uncut lawn is associated with an increased crime count of 3.8 (10%); litter is associated with an increase of 7.8 (21%); having a lawn is associated with a decrease of 23 (63%); a desiccated lawn is associated with an increase of 3.8 (10%); the presence of garden hoses or sprinklers is associated with a decrease of 4.7 (13%); each 10 percentage point increment of pervious area is associated with a decrease of 0.9 (2%); each 10% increase in grid-scale treecover is associated with a decrease of 5.8 (16%); each additional small street tree is associated with an increase of 17 (47%); and shrubs are associated with a drop in count of 3.6 (10%).

Our Spatial Error regression results yield similar but slightly lower interpretations of marginal effects. The big difference is that shrubs are not significant and lawn_uncut is only significant at the 90% confidence level. The other large differences in interpretation of marginal effects include: having a lawn goes from being associated with a decrease in crime count of 23 (63%), to only 11 (30%); the effect of an uncut lawn goes from 3.8 (10%) to 2.3 (6%); the effect of each additional small street tree goes from 17 (47%) to 5.8 (16%);

Table 2
List of final variables included with summary statistics.

Variable name	Description	Min	Max	Mean	Stdv
CrimeCount	Dependent variable: count of crimes (see definition in text) over a 3.5 year period in 150 m buffer around property in question	0	251	36.68	32.74
Ave_tree_cover	Average tree canopy cover for the 150 m buffer of the parcel based on 150 grid cells	3.60	69.71	24.63	8.46
Dessication	Presence of a lawn with evidence of extensive desiccation or lack or irrigation	.00	1.00	.21	.41
DetHousePct	Percentage of homes in the block group to which the parcel belongs that are detached	.00	1.00	.46	.33
GardenHoseSprinklers	Presence of garden hose or sprinkler systems in the front yard of the parcel	.00	1.00	.33	.47
Lawn	Presence or absence	.00	1.00	.97	.16
LawnUncut	Presence of lawn that appears not to have been mowed or cut recently	.00	1.00	.54	.50
Litter	Presence of litter (small-sized refuse, like gum wrappers)	.00	1.00	.19	.39
LnInc	Natural log of median household income for the block group to which the parcel belongs	8.76	12.26	10.84	.50
Popdens	Population density in persons/sq km for the block group to which the parcel belongs	81.6	19356	3049	2429
NumStreetSm	Number of small diameter (<6″ DBH)	.00	4.00	.02	.20
SFH	Whether the parcel is occupied by a single family home (1/0)	.00	1.00	.64	.48
Shrubs	Presence of shrubs	.00	1.00	.83	.38
YardPervious	Percent of front yard that is pervious (lawn, soil, plants)	.00	100.00	88.35	23.08
YardTrees	Presence of yard trees	.00	1.00	.60	.49
YrsOld	Age of house on property	13.00	71.00	50.67	12.47

Table 3
Regression results.

Parameter	Linear Regression		Spatial Error Regression		Poisson Regression	
	B	*T*-test	*B*	*Z*-value	*B*	Wald Chi-Square
(Intercept)	178.290	8.853***	167.387	7.792***	7.350	2928.524***
Avg.treecover	−0.582	−6.759***	−0.573	−6.470***	−.019	654.188***
Dess	3.833	2.217**	3.017	1.977**	.091	54.596***
DetHousePct	−15.271	−4.835***	−18.040	−5.349***	−.700	656.470***
Garden.hose.sprinklers	−4.727	−3.204***	−3.906	−3.038***	−.135	103.705***
Lawn	−23.880	−4.224***	−11.241	−2.219**	−.126	13.434***
Lawn.uncut	3.807	2.677***	2.278	1.838*	.133	124.385***
Litter	7.808	4.181***	6.209	3.770***	.126	104.822***
LnInc	−7.863	−3.958***	−8.367	−4.000***	−.253	341.247***
Num.street.sm	17.020	4.994***	5.883	1.983**	.163	104.659***
Popdens	0.002	5.416***	0.002	5.476***	.	109.887***
SFH	−11.861	−6.145***	−9.687	−5.249***	−.275	357.562***
Shrubs	−3.639	−1.816*	Dropped	NA	Dropped	NA
Yard.pervious	−0.093	−2.410**	−0.077	−2.261**	−.002	68.009***
Yard.trees	−3.455	−2.265**	−3.448	−2.620***	−.121	110.940***
Lambda			0.421	16.112***		
Model fit	*R*-squared	0.58	Pseudo *R*-squared	0.66	Deviance/DF ratio	10.417

* Significant at 90% level.
** Significant at 95% level.
*** Significant at 99% level

the effect of litter drops from 7.8 (21%) to 6.2 (17%); and the effect of garden hoses and sprinklers goes from −4.7 (13%) to −3.9 (11%).

The raw Poisson coefficients are not directly comparable to OLS or SER coefficients because the former represent the natural log of rate ratios corresponding to a one unit difference in the predictor. Nonetheless, Poisson coefficients can be exponentiated, after which they can be interpreted as rate ratios, meaning that a number greater than one corresponds to positive effect on the dependent variable and less than one corresponds with a negative effect, after which these rates can be compared to rates calculated from the OLS and SER coefficients. So, for instance, the Poisson coefficient of .126 on litter translates to an exponentiated value of 1.13, meaning that properties with litter have 1.13 times as many crimes as those without, or 13% more. By comparison the SLG coefficient on litter is 7.8, meaning that the presence of litter increases the count of crime in the 150 m buffer by a count of about 7.8, holding all else constant, which translates to about 21% more crimes relative to the average, somewhat greater than with the Poisson estimate.

Marginal effects for all landscape variables are given in percentage form in Table 4 for the three models, along with 95%

Table 4
Comparative marginal effects by model relative to average crime values.

Landscape variables	Linear regression	Spatial error regression	Poisson regression
All values for a one unit marginal change unless otherwise noted. 95% confidence intervals given in parentheses			
Avg.treecover	−15.9%/10% increase (−20.5, −11.3)	−15.6%/10% increase (−20.3, −10.8)	−18.9%/10% increase (−20.5% to −17.6%)
Dess	10.4% (1.2, 19.7)	8.2% (0.1, 16.4)	9.5% (6.67, 11.49)
Garden.hose.sprinklers	−12.9% (−20.8, −5.0)	−10.6% (−17.5, −3.8)	−12.6% (−16.08, −10.89)
Lawn	−65.1% (−95.3, −34.9)	−30.6% (−57.7, −3.6)	−11.8% (−19.35, −5.87)
Lawn.uncut	10.4% (2.8, 18.0)	6.2% (−0.4, 12.8)	14.2% (10.96, 15.64)
Litter	21.3% (11.3, 31.2)	16.9% (8.1, 25.7)	13.4% (10.17, 14.99)
Num.street.sm	46.4%(28.2, 64,6)	16.0% (0.2, 31.8)	17.7% (13.19, 19.44)
Shrubs	−9.9% (−20.6, 0.8)	NA	NA
Yard.pervious	−2.5%/10% increase (−4.6, −0.5)	−2.1%/10% increase (−3.9, −0.3)	−2.3%/10% increase (−2.9, −1.8)
Yard.trees	−9.4% (−17.6, −1.3)	−9.4% (−16.4, −2.4)	−11.4% (−14.37, −9.86)

confidence intervals, allowing for comparison of models. It indicates that marginal effects are mostly similar across models. There are only a few exceptions: Shrubs, which is dropped in SER and Poisson models due to insignificance; Lawn, which has a marginal effect of −65% in the OLS regression but drops to 31% in SER and 12% in Poisson; Litter, which drops from 21% in OLS to 17% in SER and 13% in Poisson; and Num.street.sm, which drops from 46% in OLS to 16% in SER and 18% in Poisson.

Our results, although only associative, still contribute to the growing body of evidence that the "cues to care" hypothesis may be at work. That would suggest that signs of active involvement in shared neighborhood spaces (front yards) are a sign of social capital and cohesion that might deter criminals. Part of this deterrence stems from a belief that socially cohesive neighborhoods will have more "eyes on the street" and residents will be more likely to collaboratively defend their collective territory. That indicators of neglect are positively associated with crime suggests that the "broken window" hypothesis may also be at work. Signs of neglect signal a lack of social capital, which may serve to encourage criminals. Furthermore, there can be interactions between these processes; the broken window hypothesis also suggests that indicators of neglect can lead to citizens withdrawing from their neighborhoods, thereby reducing social capital and informal surveillance, which in turn means that arresting signs of neglect can in turn foster the social capital needed to fight crime.

These explanations are consistent with the routine activity theory of crime (Cohen & Felson, 1979), which stipulates that the occurrence of crime requires three conditions to be met: a potential criminal, a potential victim, and a lack of effective authority to observe or intervene in a crime. It is also consistent with offender search theory, which suggests that potential offenders find opportunities where targets are vulnerable and guardians are few (Brantingham & Brantingham, 1993). Under these theories, if well-maintained yards and vegetation draw potential "interveners" or "guardians" onto the street, or provide the perception that residents are actively involved in their neighborhood—thus indirectly suggesting the possibility of intervention—this should reduce the probability of crime. Related to these explanations but slightly distinct is collective efficacy theory (Sampson et al., 1997), which suggests that mutual trust and social cohesion between neighbors can help lower violent crime through the informal internal controls that they engender. Under this explanation, yards and landscaping help create the attractive outdoor environment that brings people onto the street, thus fostering social capital and cohesion, which in turn suppresses criminal activity in various ways. This contention is supported by the research of Bothwell, Gindroz, and Lang (1998) who found that traditional neighborhood design (TND) streetscape elements, such as the presence of yards, groupings of trees, porches, low fences and paths, can foster outdoor neighborhood interaction and social capital formation. They attribute this not only to the more pleasant outdoor environment, but also to the self-esteem that comes from occupying an attractive-looking home and surrounding landscape. Their interviews indicated that before a major TND redesign of a public housing project, many residents felt anxious and self-conscious about being identified with their residence, while after the redesign they felt self-confident about that locational identity, yielding a greater sense of community connection.

If causality could be established, another mechanism that may be at work is that greened outdoor spaces affect the mental state of potential criminals; for instance natural environments have been found to reduce aggression (Kuo & Sullivan, 2001a; Kuo & Sullivan, 2001b) and stress-related illnesses (Grahn & Stigsdotter, 2003; Roe et al., 2013; Thompson et al., 2012), and increase cognitive functioning (Wells, 2000). Under these explanations, the presence of attractive green spaces may change the mental state of a criminal in such a way that the decision to commit a crime becomes less likely. This probably applies more to "spur of the moment" types of crimes, however, than to crimes that require more advance planning and clear volition.

4.1. *Potential management implications*

These findings contribute to a growing body of research which, taken together, has implications for managers. To date, when police departments have worked with local communities to reduce crime, they have tended to focus on block watches and neighborhood patrols, with relatively little attention given to environmental design and maintenance. But it seems increasingly likely that communities and individual homeowners can have significant impacts on crime rates through landscape design and maintenance but that not all greening is the same in terms of its effects on crime. While it has been established that some configurations of vegetation facilitate crime and others deter it, much still remains to be learned about what the optimal "recipe" might be for urban vegetation. Furthermore it is not clear that the costs of macro-scale crime-deterring environmental design would necessarily justify the benefits without subsequent research to quantify both columns of this ledger.

Regardless, this research suggests a need to think systematically about the different functional roles of urban vegetation to deter crime, particularly in the residential "civic landscape" that exists between the street and front of a house. This landscape is a combination of public and private ownership that is often a mix of street trees, sidewalk, and lawn that includes grass, shrubs, and trees. In this residential civic landscape, both structural and symbolic factors are important to reduce crime. While much still remains to be determined about the ideal design of this civic landscape, this and previous studies suggest some potential guidelines that might yield results. In terms of structure, lower trees, shrubs, and foundation plantings could be pruned to reduce concealment opportunities. In terms of symbolic "cues to care", vegetation should be well-maintained: trees and shrubs pruned and grass cut. Empty tree pits should be re-planted with new trees. Clumps of small and dense volunteer vegetation in unmanaged spaces should be thinned, pruned or removed, depending on the context. The role of species composition, however, remains unknown and could be the topic of future research. Another area for future research is addressing how environmental design can be used to simultaneously maximize public safety and other ecosystem services, such as stormwater mitigation, air quality improvement, and building envelope shading.

At the neighborhood scale, greening and maintenance of vegetation could be a topic for raising community awareness and organizing to reduce crime. Community organizing around neighborhood safety and greening suggests an opportunity for collaboration and coordination between city agencies: specifically departments of police and parks and recreation. This collaboration could include identifying areas where assistance is most needed, community organizing, providing technical assistance, training, and materials to enhance greening and maintenance in high-crime areas. Two potential collateral benefits to this community organizing and action would be to enhance social capital within the neighborhood and social capital between the neighborhood and police. These two changes in social capital may increase the likelihood that residents would report crimes when they observed criminal behavior.

5. Conclusion

Research results show that there is a significant association between crime at the 150 m scale and the environmental design components of front yards and their surroundings, after controlling for income, population density, and housing type. Specifically, we find that indicators of yard management, from cut lawns to presence of yard trees, are inversely associated with crime, while indicators of neglect, such as litter or desiccation, are positively associated with crime. Before specific management recommendations are formalized, further research should be conducted to address causality through either time series data or intensive before-after-control-impact analyses (BACI) of greening and/or community level maintenance programs.

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