Assessing the social impacts on urban street trees through the built environment in West Oakland, CA

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ABSTRACT

Urban areas involve a complex interplay of social, natural, and physical systems, and finding ways to address and understand the urban street tree dynamics within urban areas is a difficult task for urban foresters. To maximize the benefits of the urban forest, and uncover ways that an urban area's social structure affects the physical and urban environments, new strategies for exploring these systems must be developed and tested. In this study I address social forces on the built environment and explore if similar social preferences affect the survival and dynamics of street trees in West Oakland, CA. Household and block-level analysis made it possible to assess the small-scale heterogeneity of maintenance due to residents' perception of their environment, their lifestyle choices, and their territoriality. After analysis of many factors, I found an unusually low mortality rate, as well as linkages between trees, land use, and front yard green space, and between trash level, property maintenance, and front yard green space. These linkages suggest a connection between resident's level of care on their own land and on their block, part of their lifestyle choice. However, a larger study size and perhaps longer timescale would be needed to link tree mortality to these factors.

KEYWORDS

urban forestry, tree mortality, land use, urban ecology, lifestyle

INTRODUCTION

‘Urban areas’ are defined as all cities, towns, and suburbs—all places where people live in dense populations. While few environments world-wide have escaped human influence, in urban areas humans have fundamentally altered and engineered the environment to accommodate for human activity, creating a ‘built environment’. This term may suggest that “natural” systems have been superseded in cities, and although an area’s transformation from natural to urban invariably involves reducing vegetation and disrupting natural processes, ecological processes still persist in urban ecosystems (Dow 2000). The purpose of this study is to explore how the structure of the urban environment affects the function and dynamics of urban street trees, a part of a city’s larger urban forest and an example of a natural process within a city’s complex social and physical structure.

Though urban areas have the same general factors (low vegetation/high built landscape, high population density), urban ecosystems are remarkably complex and vary dramatically over a variety of spatial and temporal scales (Grove and Burch 1997). Recent efforts have combined practices in ecology and social science with landscape analysis of spatial heterogeneity to study urban ecosystems and the changing, dynamic forces that shape them. This “urban ecology” approach aims to understand the interconnectivity between spatial heterogeneity and biophysical and socioeconomic processes, the hierarchy and subtleties of human influence as well as the forces that affect human behavior, and the consequences for physical and natural systems (Grove and Burch 1997). Applying this approach to the urban forest necessitates knowledge on the ecological response of trees in urban areas, which means assessing the social factors that influence and change the physical environment and how the physical and social systems affect tree health directly and indirectly.

An urban forest consists of all public and private trees within an urban area. Much like the study of cities themselves with urban ecology, the study of trees within cities, called ‘urban forestry’, is a relatively new and multidisciplinary approach. Urban trees can provide many benefits to society, but cities provide a harsh growing environment for trees for many reasons, such as: limited space for growth, excess pollution, soil compaction, nutrient deficiency, limited water, and damage through vandalism and other human action (Nowak et al. 1990). Urban foresters work to understand what affects urban tree survival and overcome obstacles to tree growth to maximize the many benefits of urban trees. Urban trees can improve air and water quality, offset the formation of urban heat islands, improve human health, create aesthetically pleasing environments, increase property values, create a stronger sense of community and connection to nature and others, and empower communities, among other social and quality-of-life benefits (Dwyer et al. 2000, Dwyer et al. 1992, Kuo 2003). However the sociocultural/socioeconomic forces within an urban area mean that distribution of critical resources is not equitable, and the urban forest is no different (Pickett et al. 2001). Gaining a better understanding of the social and physical factors that affect tree health is critical for urban foresters to efficiently and effectively manage the urban forest resource.

Urban forests display spatial heterogeneity within and between cities, neighborhoods, and even households (Picket et al. 2001). This heterogeneity is in large part due to differing social contexts, and differences among the groups responsible for management (Picket et al. 2001, Dow 2000). Since the majority of the urban forest is owned and managed by urban residents (Dwyer et al. 2000), looking at the physical and social environment on a small scale may be most useful for deciphering the social impact on urban trees. Social scientists have used concepts of social hierarchies (wealth, power, status, knowledge, and territory) to study how societies become differentiated, and these socioeconomic ideas have been used to explain heterogeneity in urban vegetation cover (Grove and Burch 1997). For example, population density, socioeconomic status, and level of community involvement in planting have all been shown to affect tree health and mortality (Grove et al. 2006, Sklar & Ames 1985). Human preferences and actions shape both the urban forest and the built environment, and yet no known studies relate the two systems. If assessing the built environment of a community provides real insight into the social preferences that also determine the health of the urban forest, it could provide urban forest management agencies with a cost-effective and relatively easy to collect method for predicting the forces affecting the urban forest and planning to maximize the health and benefits of the urban forest.

The characteristics of the built environment represent the history of social transformation by concentrated and diverse human activities (Dow 2000) . A key feature of the built environment is that it is not static, but changes based on the aggregate input of its past and present societies. At the same time, the way that people choose to use land and create the built environment affects people's perceptions about that space, which can affect their level of management and investment in the urban forest and built environment. The structure of the built environment can affect urban trees in a number of ways; for example narrow sidewalks, overhead wires, and driveways can all limit tree placement and growth. The ways people choose to use land (e.g. residential, industrial, commercial) affects the area's built structure, and land-use has been shown to affect tree mortality (Nowak et al. 2004). This is likely because an area's land-use type will also affect who is responsible for the area's management and the level of investment in the area (Dwyer 2000, Dow 2000). Martin et al. (2004) and Grove et al. (2006) have proposed the "luxury effect" and "lifestyle behavior" as possible explanations for the connection between vegetation and socioeconomic status, in which an individual or household with wealth use vegetation to convey its wealth ("luxury") or will manage its vegetation based on its desire to outwardly portray and uphold the esteem of the community and its social status (lifestyle). Grove et al. (2006) concluded that lifestyle behavior (including socioeconomic status) predicts maintenance on private lands as well as in the public rights-of-way which include trees, in which case a household's investment in its home and yard is would reflect its investment in its adjacent street trees. Lastly, the theory of "defensible space" suggests that the built environment plays a large part in residents' ability to regulate everyday public behavior and physical conditions within their neighborhood, called "informal social control" (Perkins et al. 1990). Low levels of informal control are associated with deterioration of the physical environment and inclivities (symbols of social disorder) such as litter, unkempt housing, or vandalism, while *territoriality*, or feelings of ownership for a resident's community space, involve physical markers such as maintaining/beautifying the block, signaling control and management of the community (Perkins et al. 1990). Kuo (2003) also suggests that trees play a pivitol part in instilling a sense of territoriality in urban residents by increasing neighbor-level social interaction. These types of influences should be more apparent on a small scale, so I employ a block-level analysis of the various built environment elements and the urban forest in West Oakland, CA.

West Oakland is an inner-city area with high levels of poverty, crime, and pollution. In 2000, it had 39% of the population living under the poverty line, compared with 11% for Alameda County as a whole (U.S. Census Beaurau 2006-2008). Pollution from bordering highways, local industry, and the Port of Oakland pose significant environmental and health risks to residents. The study site has a population of 1,586, with a largely black (64%) and minority population (US Census). Historically, low-income and minority inner-city neighborhoods have few public amenities such as a healthy urban forest, and West Oakland is no exception (Johnson & Shimada 2005). For disadvantaged neighborhoods such as West Oakland, urban forestry has the potential to mitigate poor conditions and improve quality of life. Recent urban forestry groups such as Urban Releaf in West Oakland have recognized the potential for urban forestry to expand its goals to include community revitalization, and despite accomplishments by urban foresters, financial support for urban forestry remains disproportionately low compared to its potential contribution to mitigating urban problems (Kuchelmeister and Braatz 1993). This, along with Dow's (2000) recommendation that understanding of the urban ecosystem requires continued development of new approaches, prompted this study's analysis of social factors through their physical representations in the built environment. In it I hope to distinguish factors in the built environment which have significance to urban street tree dynamics.

METHODS

Study site

The site is a 543.8 km^2 area in West Oakland, CA, bordered by are Peralta Ave., 35 St., Chestnut St., and West Grand Ave. I assessed each side blocks separately on a number of factors pertaining to the physical environment, both transient and permanent, and the urban forest resource.

Tree factors

I gathered tree abundance for each block, or the number of trees per block, as well as the number of empty tree pits per block (with no planted tree) and number of potential new pits per block. Potential new pits are areas on a sidewalk where there is currently concrete, but there could be a tree pit. There are guidelines for placement of street trees that dictate space be provided between trees, for city signs, and at a block's corner. For potential new tree pits, finding the actual distances required by the city involve time-consuming measurements and geometric calculations for each specific site. We used a less formal method recommended by UC Berkeley Urban Forestry and Landscape Architecture professor Joe McBride, stipulating ~10 feet between trees and in front of signposts, and ~15 feet space at block corners.

For 2009 tree mortality, I assessed each street tree and categorized trees without any leaves or bulbs as dead. I used 2008 tree abundance data collected by Lara Roman (U.C. Berkely) to calculate the tree mortality rate using

Block average annual mortality = 1-x $x = N_1/N_0$

N_1 = # of trees in 2009 that were recorded in 2008 N_0= # of trees in 2008

Stocking level is the ratio of live trees on a block versus the maximum number of trees that the block could structurally allow. It was calculated by dividing the tree abundance by the abundance, number of new pits, and number of existing pits, or all the places a tree could potentially be located. It defines a block's "carrying capacity" for street trees versus it's actual number of trees.

Structure

Driveways represent places where trees cannot be planted, so the number of driveways was noted for every block. To control for street length, I converted this to number of driveways per meter. Overhead wires were also noted, as they can inhibit street tree growth because they may require heavy pruning, which is detrimental to tree health.

A street's spatial dimensions reflect how it may be used. Larger streets and sidewalks may have more car and foot traffic, likely increasing levels of pollution and vandalism which makes growing conditions for trees more difficult. On the other hand, larger sidewalks may allow for more room for street trees which may improve survivorship in trees. I classified each block as Arterial (major thouroughfare) or Local (small, residential) based on distinctions in Google Maps. I measured each street's length and width using Google Earth, and sidewalk width in the field.

Land classification and usage

Differences in land use correspond with differences in the level and type of surrounding activity, and differences in the amount of attention and care a tree will receive. For example, a study by Nowak (2004) found that trees with adjacent transportation, commercial, or industrial land-use had high mortality rates, likely because due to these land uses having lower maintenance levels and higher levels of activity. Lower-density residential land uses, on the other hand, had low mortality, which he contributed to lower levels of activity and higher levels of residents' tree stewardship. To gauge the influence of land-use in West Oakland, I classified each property on a block as one of 9 land-use categories outlined in Table 1. For properties that qualified as 'Other', I described the property in my notes. After classifying each property in the field, we stepped back and estimated the percent of the block's length that each type occupies. With this I classified each block according its dominant land use type. If there was difficulty judging the percent of each type in the field, or if our estimates classified two land uses as equal to split the dominance, I revisited the block in Google Earth and measured the properties to find which type ultimately takes up more space on the block. In addition, in analysis Single-family residential—attached was combined with Single-family residential–detached, because it was dominant for only one block. Land type 'Other' was combined with Recreation because it was also only dominant for one block and review of field notes revealed it was dominated by a community garden.

Table 1. Defining land-use types used in study.

Land-use type	Example/description
Single-family residential detached	Free-standing home, on its own lot
Single-family residential attached	Townhouses, attached at one or both sides to othe single-family residences
Multi-family residential	Apartments, duplexes
Commercial	Corner store, car repair shop, restaurant
Industrial	Trucking, shipping, warehouses
Institutional	School, church
Recreational	Neighborhood park
Vacant lot	Uninhabited lot
Other	None of the above

Average property maintenance rating

The amount of effort a household/property owner puts into caring for and maintaining their house/property may parallel its effort it puts towards caring for its adjacent street trees. I assessed the block's property maintenance effort by rating each property's level of maintenance based on the categories in Table 2, then averaged these ratings for the block.

Table 2. House maintenance rating guide.

Maintenance rating	Guide for Rating
1	vacant / abandoned: boarded up windows/building, severely overgrown vegetation, structural cracks, rampant paint/exterior cracks, and/or large accumulation of trash
2	poorly maintained: building in need of substantial repair (cracks in walls, painting needed, etc.) with heavyly overgrown vegetation and/or accumulation of trash
3	fairly well to very well maintained: building in fair condition, some repairs may be needed (paint chips, cracks), moderately maintained vegetation, little trash

Trash/litter rating

Higher levels of trash on a street are not only bad for tree survivorship due to their pollution and the tendency for trash to accumulate in the lowered tree pits, but also because it may indicate a generally low maintenance effort which could translate to tree maintenance efforts. I assessed the level of litter on a block using the rating system in Table 3**.**

Table 3. Trash/litter rating guide.

Trash Rating	**Guide for Rating**
1	large amounts of litter in front of >30% of buildings and/or large piles of trash on street or sidewalk
2	litter in front of >30% of buildings and/or medium piles of trash on street or sidewalk
3	small amount of litter, in front of <30% of buildings
4	no litter / negligible litter

Front yard green space

Households and properties that maintain front yard green spaces (e.g. lawns, gardens, trees, vegetation) may do so because they value greenery or its social status, which may influence their values towards adjacent street trees and increase likelihood of stewardship. I evaluated whether each property on a block had the potential for front yard green space (area where green space could be between building and sidewalk/public property), and if those with potential front yard green space had actual front yard green space. I converted this to the ‘realized’ front yard green space, or the percentage of the block’s properties with the potential for green space that actually have it.

Gates

Fences, gated entryways (gated doors and gated deck areas), and gated windows all may indicate a property's feeling of insecurity or fear, which tends to draw people inside and make residents less inclined to care for outdoor urban street trees (Perkins et al. 1990). Conversely, fences may be an indicator of household territoriality, which could indicate residents' feeling of ownership of the area, a factor which has been shown to increase care for properties and vegetation (Perkins et al. 1990). I counted the number of households/properties with gated yards (fences), windows, and entryways, then converted these numbers to the percentage of properties on the block with gated features.

Analysis

Factors recorded were subject to chi-square analysis via contingency tables as well as ANOVA using R and R commander (R Development Core Team 2009, Fox et al. 2009). Significant p-values and chi-squared values were reported.

RESULTS

General

An summary of the means and Standard Deviations (SDs) of factors noted and analyze in Table 4. In the study area, there was a total of 305 live trees, 67 existing tree pits, and 353 potential new tree pits.

Table 4. General summary of factors noted.

Variable	Mean	SD
Sidewalk width (m)	2.34	0.72
Street length (m)	123.1	28.8
Street width (m)	12.48	2.65
Tree abundance	2.67	3.5
Block's existing tree pits	0.59	1.60
Potential new pits	3.12	3.50
Tree stocking level (%)	39.4	35.2
% properties with potential front yard green space	86.54	27.6
% properties with front yard green space	51.12	37.6
% properties with potential + realized green space	58.3	37.3

% properties with gated front yard	49.93	34.53
% properties with gated entryway	39.99	34.46
% properties with gated windows	24.55	25.21
Tree survival rate (%) (n=71; N/A=42)	96.2	0.1044915
Tree mortality rate (%)	3.8	0.105
Trash/Litter Rating	3.16	0.93
Ave. property maintenance rating	2.66	0.42
Land Use (%)		
SFR detached	17.61	24.58
SFR attached	0.97	7.79
MFR	22.65	27.42
Comm	8.41	18.53
Ind	36.64	41.56
Inst	3.05	13.42
Rec	2.65	16.15
Vac Lot	4.78	16.95
Other	3.23	10.69
Driveways/m	4.97	3.73

Mortality

For the 2008-2009 year, the entire study area's tree population had a mortality rate of 3.8%. This includes 71 blocks and 306 trees, while 42 blocks had no trees. There was, however, a net loss of only one tree due to a 2.9% planting rate.

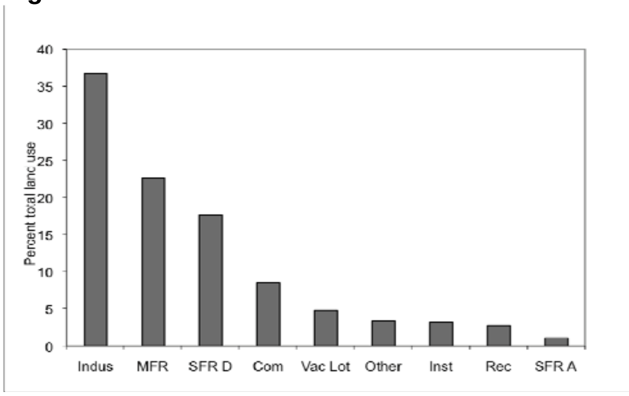
Structure

Overhead wires were present on 92.0% of blocks, or all but nine blocks (8.0%). They were not found to be significant with any factor analyzed.

12.4% of the blocks were Arterial and 87.6% were local. I found that blocks on arterial streets were more likely to have gated entryways compared to local blocks (p=0.01339). Arterial blocks also have more driveways per meter than local blocks (p=0.04427). Street length and width, and sidewalk width were not, however, found to be statistically significant in any analyses applied.

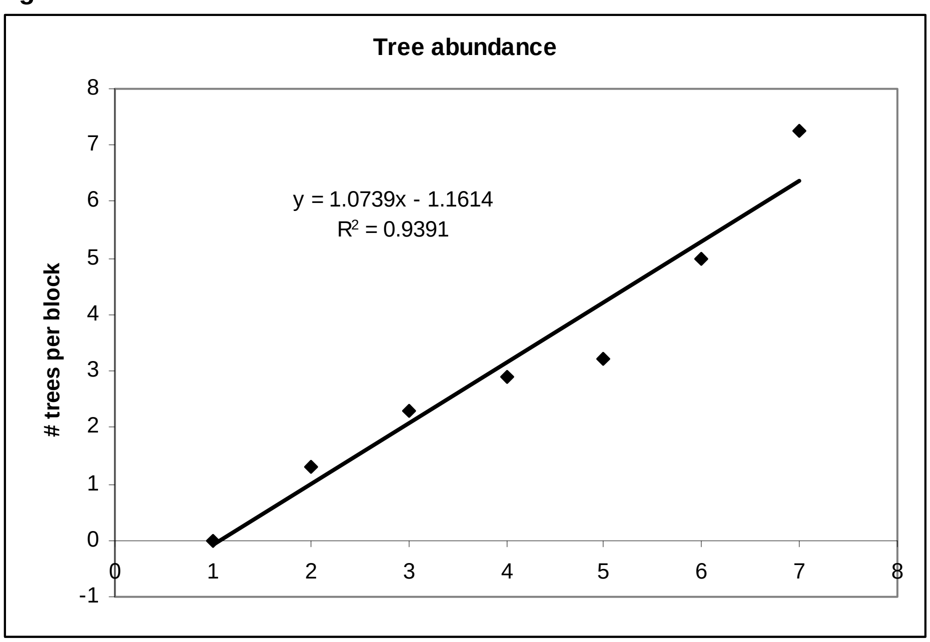
Land Classification and Usage

Figure 1. Total land use.



A breakdown of total land usage can be seen in Figure 1. Land use had an effect on tree abundance ($p<0.05$). Blocks that were had mostly Recreational land-use had the highest tree abundance. Blocks dominated by Multi-family residential, Single-family residential (attached and detatched), and Institutional land uses had higher tree abundances than blocks dominated by Industrial, Commercial, and Vacant Lot land uses (Figure 2). However, land use was not found to significantly affect tree mortality or tree stocking level.

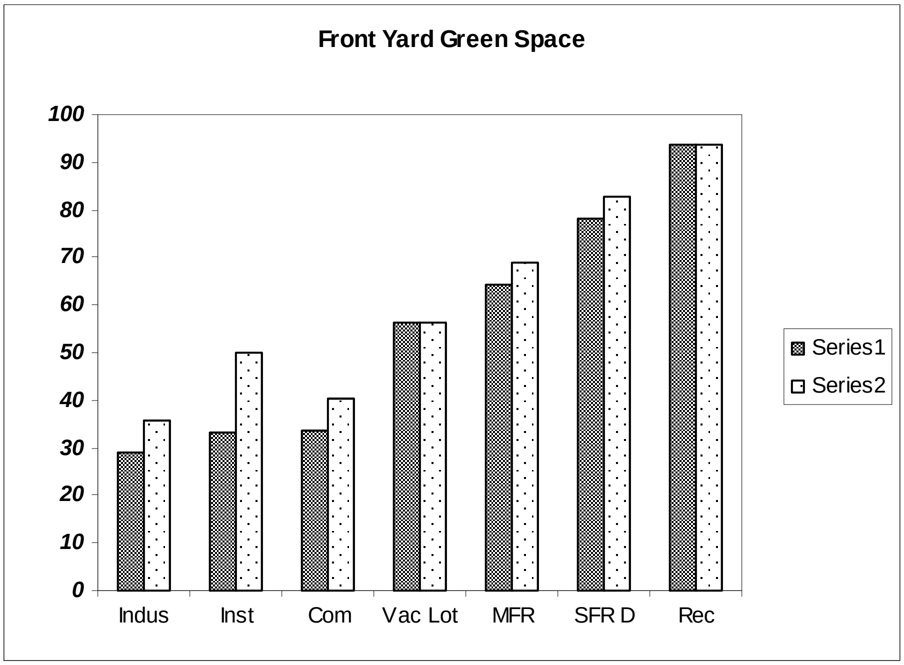
Figure 2. Tree abundance and land use.



1=Vacant lot, 2=Commercial, 3=Industrial, 4=Multi-family residential, 5=Single-family Residential, 6=Institutional, 7=Recreational

Different land use was also significant in percentage of realized front yard green space, that is, the percentage of properties that could and do have front yard green space ($p<0.01$). Industrial and commercial blocks have the lowest percentage of realized front yard green space, while Recreational, Single-family residential, and Multi-family residential have the highest amount of realized front yard green space, as seen in Figure 3 and Table 5. Chi-squared tests and other ANOVA analyses did not return significant results.

Figure 3. Percent of each land-use type with front yard green space and realized front yard green space



Series 1= Percent of properties with front yard green space. Series 2= Percent realized green space

Table 5. Land-use and front yard green space

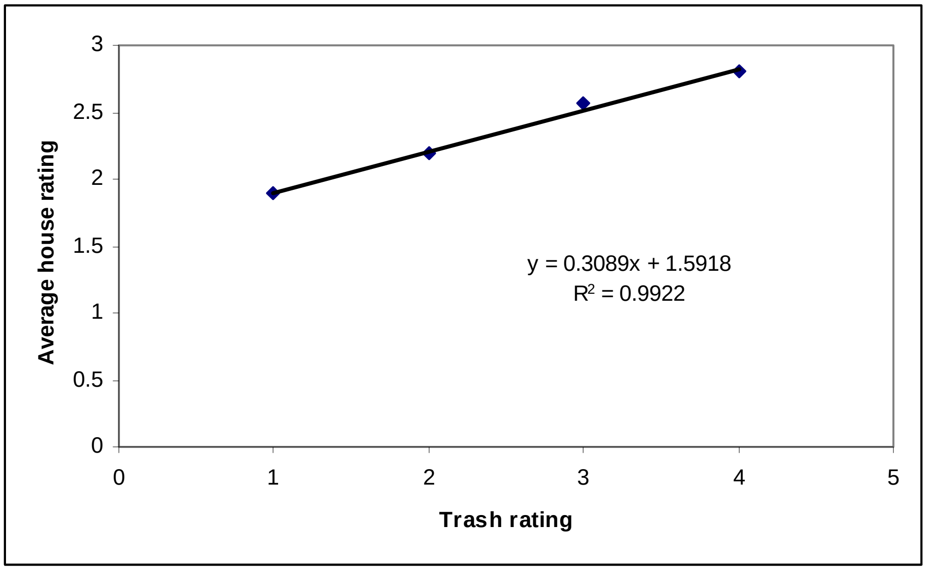
Land-use type	n	% with front yard green space	Sign*	% with realized front yard green space	Sign*
Ind	42	33.3	ab	35.8	a
Comm	10	33.7	ac	40.4	ac
MFR	27	64.1	bc	69.0	bc
SFR	23	78.3	b	82.9	b
Inst	3	29.0	a	50.0	ab
Rec	4	93.8	b	93.8	bc
Vac lot	4	56.3	ab	56.3	ab
p-value			p<0.001		p<0.001

Land-uses with different letters are statistically different. Name abbreviations: Ind=Industrial, Comm=Commercial, MFR=Multi-family residential, SFR=Single-family residential, Inst=Institutional, Rec=Recreational, Vac Lot=Vacant lot.

Trash/litter rating

Trash/litter rating is significant to a block's average property rating ($p<0.01$). Blocks with a higher (better) litter rating tended to have properties that were better maintained, and fewer vacant properties (Figure 4, Table 6). Blocks with lower trash/litter levels also tended to have fewer properties with front yard green space, and blocks with a rating of four (least litter) had the highest number of properties with front yard green space ($p<0.05$).

Figure 4. Trash/litter rating versus household rating.



Note: trash ratings 1-4 represent categories, while house rating represents continuous numbers.

Table 6. Litter Rating versus house maintenance and # properties with front yard greenspace

Litter Rating	n	Average house maintenance	Sign	Properties with front yard green space	Sign
One	10	1.9	ab	1.333333	ab
Two	11	2.2	ab	4.181818	ab
Three	43	2.6	b	2.590909	b
Four	49	2.8	a	5.122449	a
p-value			p<0.001		p=0.025

DISCUSSION

Tree health and survival in the urban ecosystem is a complex and little-understood subject, making the complexity and varied input of the social system on urban trees is difficult to address. An unusually low mortality was observed (3.8%), which may be due to low sample size as well as the longer timescale in which trees respond. Land use and trash/litter rating both were correlated with differences in the urban structure and the level of green space and trees.

Annual survival (96.2%) was higher than other studies studying tree survival like Nowak et al. (1990) (82%), and Thompson et al. (2004) (91%), but these studies were concerned with newly planted street tress, which Nowak et al. suggest may have a higher susceptibility to urban stressors and mortality. This indicates that the observed rate is reasonable, but previous evidence that socioeconomic status negatively affects tree survival, as well as previous studies in Oakland by Nowak et al. (1990) and Morici (2008) with higher mortality rates in Oakland (12% and 8.2% for study area), suggest that the observed mortality rate (3.8%) is particularly low. This low mortality rate may just be a reflection of the time scale that trees operate on; the effects of urban stressors take time to show their effects, which may mean that more long-term monitoring would provide a more accurate view of mortality rate. In addition, the sample size may have been too small to detect significant differences in mortality.

Arterial streets were significantly related to a higher percentage of gated entryways and more driveways per meter. However, this did not relate to street tree abundance, stocking level, or trees mortality in any significant way. This may mean that number of driveways or density of driveways is not useful in assessing the likelihood of a reduced number of trees. The higher level of gated entryways (e.g. doors) on Arterial streets could relate to a heightened fear of crime or intrusion on often-traveled blocks, but this is only speculation. A larger sample size would give a better idea of the range of Arterial street structure, and determine if this structure has higher gate features throughout.

Land use affected tree abundance and front yard green space. The low values for both percentage front yard green space as well as realized front yard green space for Industrial and Commercial blocks, and high percentages in Single-family residential, Multi-family residential, and Recreational, suggest that Industrial and Commercial properties do not put as much effort into maintaining their urban street trees. It also suggests that the urban forest heterogeneity is not just due to spatial availability differences between land-use types, because while Industrial and Commercial areas may have less space for trees, they are also less able to fill potential green space. Land use was significantly associated with the abundance of trees per block. Vacant lots, Commercial, and Industrial again exhibit low amount of green, this time through low tree abundance. Recreational, Institutional, and Residential land-use types had significantly higher abundances, suggesting that these land-use types have people whose preferences and actions favor street trees more. It's interesting that mortality rate, which has been shown to vary with land use (Nowak et al. 1990), was not statistically related to land use in this study. However, this study shows that people's preferences and actions differ between land-use types, which creates differences in the number of trees and the amount of total green space on a block.

The amount of trash on a block was related to the property maintenance level of properties on the block. This reflects the idea put forth from Perkins et al.(1990) about territoriality and informal social control. The coupling of amount of trash on a block and more dilapidated and vacant houses reflects a lack of sense of ownership and stewardship of the block. Perkins et al.(1990) accredits low informal social control to the breakdown of the physical environment, as well as inclivities such as trash and unmaintained/vacant houses. Blocks with higher trash levels also had fewer properties with front yard green space. This furthers the idea that a 'lifestyle behavior' model, as Grove et al. (2006) put forth, may be a critical factor while looking at block-level ecological relationships between systems: people's efforts in their individual households and front yards reflected a greater block-level trend of low maintenance, as seen by high levels of trash. It's difficult to say whether general block-level disarray affected people's perceptions and their maintenance levels, or if low household maintainence levels lowered block-level perceptions to lead to block-level lower property and trash/litter ratings. In any case, though Grove et al. (2006) and this study supposed that a consistent pattern of lacking management on private and public areas, such as absence of front yard green space and the presence of high amounts of litter seen in this study, would predict level of management for urban street trees as well, trash/litter rating did not produce significant results when compared with tree mortality, abundance, stocking level, or land-use types.

There are a number of considerations and limitations in this study to address. First of all, the initial structure of the study aimed to study ways the built environment could predict social actions that would also affect the natural factor of urban street trees. The absence of any linking factor between tree factors and built environment factors, besides land-use type, suggest that the methods of this study are not adequate to assess the urban, social, and built environment in a useful way. Alternatively, this could be due to the low sample size, or the need for a more complex, multivariate statistical analysis. Grove et al. (2006) points out that a model that has more variables, such as the present study, may not produce significant results based on traditional fit models because of the inherent increase in 'flexibility' of a model with more variables. If this is true, then a more complex statistical approach is necessary to uncover the influences of built environment systems on urban tree density and mortality. On the other hand, the failure of the model to connect the built environment to tree mortality and dynamics beyond land use may indicate that the quantitative analysis employed to uncover complex social influences on the built environment and urban trees may be inadequate as an approach, and social science methods of surveying to gauge residents' real preferences is necessary to identify social forces that affect the urban forest.

While this study did find some evidence for 'lifestyle behavior' and 'territoriality' indicators in the built environment, in public and on private land, more research is needed to understand the multiple anthropogenic changes on urban environments and urban forests. To do this, a larger study would be necessary to get a satisfactory number of blocks for each land-use category, as well as enough blocks to reveal mortality differences. This may require a longer timeframe than one year. Using a wider scope may be necessary to uncover complex social cues, and methods such as more detailed tree inventory data as well as surveys may give urban foresters a better idea of these social and ecological forces in an urban forest. The need for effective measures to maximize the urban forest resource is increasing as the level of urbanization world-wide increases, as urban trees may become a pivotal component in mitigating the environmental and social repercussions of cities (Picket et al. 2001). As McPherson (2006) says, "if a new conservation ethic is to emerge, it will come forth from our cities as the product of encounters with nature where people live".

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