IDENTIFICATION OF MUNICIPAL POLICIES THAT INFLUENCE THE DISTRIBUTION OF GREEN COVER ACROSS METROPOLITAN REGIONS

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ABSTRACT:

Nature's services provided by green cover are important to environmental conditions in cities and their ability to adapt to climate change. Researchers using geospatial technologies have dramatically increased the spatial and temporal resolution of knowledge about the distribution of tree and shrub cover in cities. Much of the current research on tree cover in cities has concentrated on individual preferences and associations between socioeconomic characteristics and environmental conditions. To complement existing research and provide planners with the practical tools they need to maintain the benefits of urban nature, this study focuses on the public policy factors that influence tree and other green cover at the lot and neighbourhood scales, concentrating on single family neighbourhoods. Green cover is classified using an object-oriented method with high spatial-resolution aerial imagery and GIS techniques. Landscape and property information were extracted from Los Angeles County Assessor Office files at a parcel scale for 20 cities in Los Angeles County. The extracted variables included lot size, floor-area ratio, residential landscape standards, tree protection ordinances, and street tree programs and were used along with average temperature and rainfall information in multiple regression models to explain the distribution and character of green cover across different neighbourhoods.

1. INTRODUCTION

The need for and benefits of green cover and especially forests within US cities has been well documented (McPherson and Rowntree, 1993; Nowak, 1993; McPherson, et al., 2005; Barbosa, et al., 2007). These benefits include, for example, increased groundwater percolation and recharge, improved air quality, increased carbon sequestration and biodiversity, reduced urban heat island impacts and energy consumption for air conditioning, and stormwater runoff reductions (Simpson and McPherson, 1996; McPherson and Simpson, 1999; Akbari, et al., 2001; Akbari, 2002; Xiao and McPherson, 2003; Carver, et al., 2004; Donovan and Butry, 2009). Researchers have investigated the green cover effects on energy use (Bengston, et al., 2004; Ewing and Rong, 2008) and aesthetics and neighbourhood character (Szold, 2005; Nasar, et al., 2007), but the consequences for ecosystem services and biodiversity have not yet been adequately described.

The green cover has been maintained by tree planting programs that often are directed at publicly owned lands such as parks or easements along streets. The potential ecosystem services and biodiversity benefits cannot be fully realized only on public land, but rather require involvement of private landowners. The largest single land use in which such actions can take place is low density residential development (Wu, et al., 2008). Although researchers have investigated various socioeconomic correlates of landscape characteristics within residential neighborhoods, theses efforts have been geographically limited (Martin, et al., 2004; Grove, et al., 2006; Troy, et al., 2007) and not yet linked to policy decisions (e.g., tree preservation ordinances, zoning and building codes) that could influence them.

There are several noteworthy trends in urban morphology and social norms that influence both the prospects for provision of ecosystem services within residential neighborhoods and the function of these neighborhoods as ecological spaces within the city, as illustrated by the following three examples.

First, the size of the average single-family dwelling has almost doubled over the past 50 years (Szold, 2005). In some regions, these houses are disparagingly called "monster homes" (Szold, 2005) or "McMansions" (Nasar, et al., 2007), because they are extended to the minimum legal setbacks and despite their size, they are occupied by fewer residents than smaller homes on average (Breunig, 2003).

Second, access to parks and green space is unequally distributed among the poor and people of color (Loukaitou-Sideris, 1995; Wolch, et al., 2005). This pattern reinforces itself because real estate prices correlate positively with surrounding green cover (Conway, et al., 2008) and urban green spaces are disproportionately found in wealthy areas (Iverson and Cook, 2000). As a consequence, green space and its ecological functions can be characterized as an outgrowth of socioeconomic characteristics that may seem to be beyond the control of planners. This creates a negative feedback loop wherein disadvantaged communities are disproportionately denied access to both urban forest amenities and natural open space.

Third, the increasing proportion of the US population that lives in cities decreases the access that the average resident has to nature in general. The human relationship with the planet's natural ecosystems increasingly depends on the lessons learned through interaction with urban nature. The experiences of nature, especially as children, are important factors leading to environmental sensitivity as adults (Tanner, 1980; Chawla, 1999). Therefore, this study investigated the factors that influence green cover and natural values within residential neighborhoods and the policies that can change them across a sample of cities in Los Angeles County, California.

2. METHODS

A series of single family neighbourhoods (SFNs) was randomly selected in 20 of the 24 cities in Los Angeles County (LAC), California with populations of at least 80,000 and used to examine the impact of the presence and character of city policies on urban tree cover (Figure 1). Four cities were excluded – Los Angeles because of its great size and diversity in terms of environmental and socio-economic conditions and Lancaster, Palmdale, and Santa Clarita because of their locations to the north of Angeles National Forest and the increased aridity that characterizes these environmental settings (Figure 2). The remaining 20 cities varied tremendously in terms of green cover and the socio-economic and environmental characteristics that have routinely been used to explain this variability.

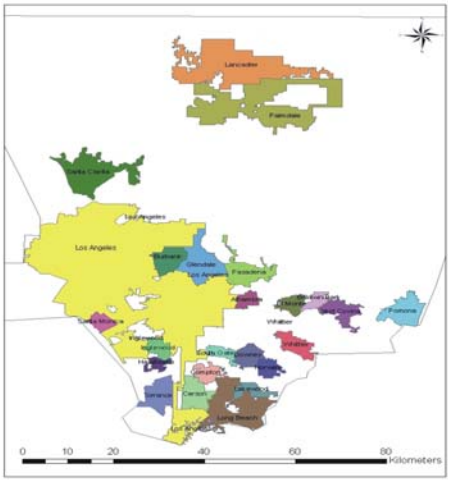

Figure 1. Cities in Los Angeles County with populations greater than 80,000.

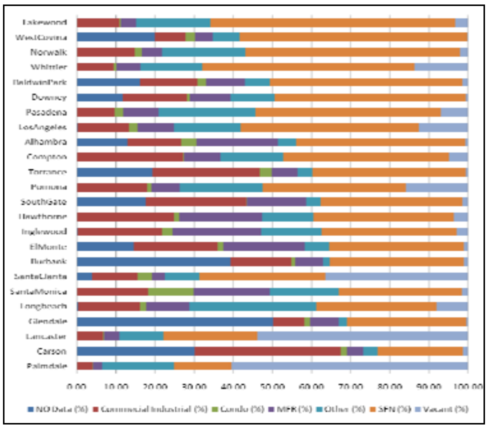

Figure 2. Land uses in the cities in Los Angeles County with populations greater than 80,000.

We selected census block groups within these cities with at least 222 SFNs and that covered at least 37% of the block group area. A total of 656 census block groups and 224,861 SFNs were selected using these criteria. The chosen SFNs covered 54.7% of the census block group areas on average.

The four subsections that follow describe how the various datasets were acquired, analyzed and interpreted.

2.1 Data acquisition and pre-processing

Green cover in the study areas was identified from 2006 color orthoimagery that was downloaded from the USGS in uncompressed, georectified, and tagged image file format (TIFF) at a spatial resolution of one foot (i.e. 0.3048 m) and saved in an ArcGIS geodatabase.

Parcel boundaries and attributes were extracted from the LAC Assessor's office and used to identify the SFNs in each city and compile house characteristics for the neighbourhoods that were chosen and used in our analysis. Figure 2 shows the ratio of land uses in each city from highest to lowest in terms of the proportion of the land area devoted to SFNs and confirms the point made earlier – that these residential areas are important given that they occupy 36% of the land area on average across the 24 cities listed here. Census information at the block group level was obtained from the US Census Bureau website and used to characterize the residents once the sample neighbourhoods were chosen.

Information about city policies with the potential to influence green cover – tree, landscape, water and zoning ordinances – was collected from city websites and phones calls to the appropriate city offices. Seven of the cities – Burbank, Glendale, Lakewood, Pasadena, Pomona, Santa Monica, and Whittier – had earned the designation "Tree City USA®" and three of these cities (Glendale, Pasadena, and Pomona) and one other (West Covina) had passed tree protection ordinances within the past 10–15 years.

2.2 Image Classification

We mosaicked and saved the images for each city as raster catalogs in a geodatabase file. We then used the object-based classification approach in Feature Analyst (Visual Learning Systems (VLS), Missoula, Montana) to digitize the green cover in the SFNs. This software uses a training dataset for which the user manually digitizes green cover and has been successfully used to classify urban land uses and land cover types (Zhou and Wang, 2007; Yuan, 2008; Miller et al., 2009).

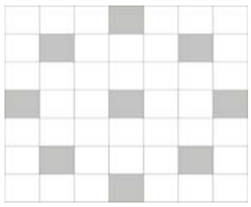

Figure 3. Bull's Eye 3 search pattern used to identify individual trees, shrubs, and other natural features.

For this study, we used the Feature Analyst with the following seven step procedure: (1) add the aerial image with true color (red, green, and blue) to ArcMap 9.3; (2) digitize the training sites; (3) set the feature type to natural feature to extract individual trees, shrubs, and other natural features; (4) set input red, green, and blue bands as reflectance; (5) set the input representation as Bull's Eye 3 (Figure 3) because this is the best model to identify natural features such as trees and shrubs; (6) set the masking tabs to select the regions of interest; and (7) set the learning options to help select parameters for aggregating areas, smoothing shapes, or filling background features. The minimum search area was specified as a 3 x 3 window (0.85 m^2) at this last step.

We then conducted an accuracy assessment using 500 random sites from the study areas (Congalton 1991), which showed that the method identified trees, shrubs and other natural features with > 90% accuracy. Figure 4 shows the classified green cover (green and orange areas combined) and the portion of this green cover that overlapped the parcels in our sample SFNs (shown in green on top of parcel with red boundaries in this graphic).

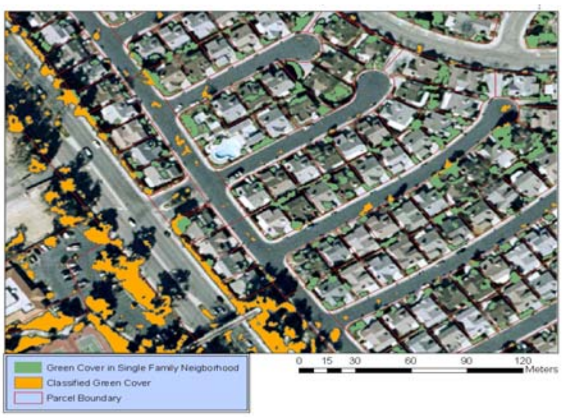

Figure 4. Green cover classification performed with Feature Analyst.

2.3 City policy analysis

For this aspect of the study we distinguished tree, landscape, water, and zoning ordinances similar to Hill et al. (2010). Our first task was to identify those cities that had earned the "Tree City USA®" designation. This program is sponsored by the Arbor Day Foundation in cooperation with the USDA Forest Service and National Association of State Foresters (Arbor Day Foundation, 2009). The many benefits of being a Tree City include creating a framework for action and education, a positive public image, and citizen pride. To earn this designation, a city must have: (1) a tree board or department; (2) a tree care ordinance: (3) a community forestry program with an annual budget of at least $2 per capita; and (4) an Arbor Day observance and proclamation. We also recorded how many years the seven cities had the "Tree City USA®" designation, and whether the cities had a public or street tree ordinance, a specific tree protection ordinance, and how many types of trees were protected by the aforementioned ordinances.

Residential areas are subject to hundreds of zoning and building regulations, but for the purposes of our study, we limited our attention to those that could affect tree canopy cover. Many of these regulations specify numerical minima and maxima, such as the minimum front, side, rear yard setbacks, maximum building height, minimum lot area, maximum lot coverage, maximum floor area ratio (FAR), and minimum floor area. Among these, we selected the minimum front, side, and rear yard setbacks as well as the minimum lot area since these indicate the spaces that can be used to plant new trees and/or maintain existing trees.

Last, we also checked whether or not the cities have a specific residential landscape ordinance or a water efficient landscape ordinance (since the latter may encourage homeowners to practice water conservation, plant specific types of native or drought resistant plants, and/or adhere to limited watering and irrigation hours) since these ordinances can also affect the level and character of the green cover present in SFNs.

2.4 Regression Modeling

We built numerous linear regression models to identify the relationship between green cover and various independent variables (representing city policies, environmental parameters, house characteristics, and occupant characteristics; Figure 5) across the 20 cities. Our study hypothesis is that green cover is related to one or more of the characteristics that are described in more detail in Appendix I.

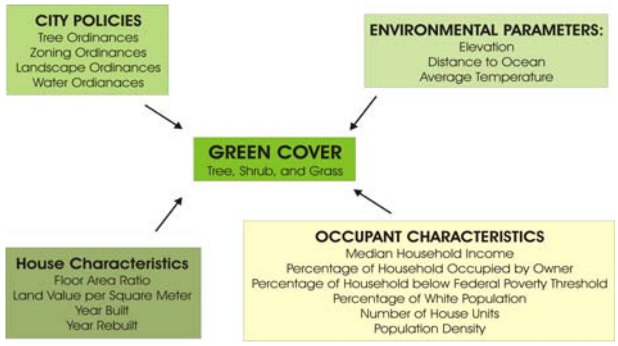

Figure 5. Variables utilized in multiple regressions.

The variables were collected at various scales (pixel, parcel, block group, city) and had to be spatially joined using ArcGIS 9.3. These variables were then checked for normality, homogeneity, multicollinearity, transformed if necessary, and the Akaike (1974) information criterion used to evaluate model performance in STATA 11. We conducted three different multi-regressions (stepwise forward and backward, and OLS) using the parcel and census block group as the unit of analysis. From the parcel analysis unit, the adjusted R-square was below 0.2, in past because we obtained over three million observations. Hence, we draw on concentrated block group areas to improve analysis. Throughout processing, we excluded insignificant variables, and finally we obtained the independent variables listed in Table 2.

3. RESULTS

Table 1 shows the percentage of SFNs and green cover in the single family neighbourhoods we examined in each city. Overall, the results in Table 1 show that the cities with the greenest SFNs are Pasadena, Santa Monica, Torrance, Norwalk, and West Covina.

These results point to the complicated set of drivers that determine green cover in residential settings. Burbank and Santa Monica, for example, have been Tree City USA® designees for 32 and 19 years, respectively without specifying a single protected tree type. In addition, Burbank is third from the bottom in terms of GC in SFNs. In contrast, Pasadena has 11 tree species as well as landmark and strategic trees that are protected in both public and private areas. West Covina, Pomona, and Glendale have five, four, and three trees protected by tree ordinances, and yet Glendale has relatively sparse GC in

SFNs (5.4%). Torrance, Norwalk and Inglewood, on the other hand, have expansive GC but lack tree policies.

City	SFN (%)	GC (%)	City	SFN (%)	GC (%)
Alhambra	55.5	6.1	Lakewood	54.5	3.6
Baldwin Park	52.6	5.4	Long Beach	56.6	5.7
Burbank	57.3	3.3	Norwalk	53.1	9.4
Carson	53.8	1.2	Pasadena	52.1	11.7
Compton	48.5	3.4	Pomona	61.9	7.5
Downey	53.8	5.3	Santa Monica	56.8	10.8
El Monte	45.9	2.3	South Gate	56.6	7.3
Glendale	55.5	5.4	Torrance	52.9	10.1
Hawthorne	57.7	4.6	West Covina	58.5	8.9
Inglewood	53.4	8.8	Whittier	54.5	4.6

Table 1. Percentage of SFNs and GC in single family neighbourhoods by city.

These kinds of contradictions also explain why we searched for additional variables (see Figure 5 for a complete list) and constructed multiple regression models linking the underlying neighbourhood characteristics and green cover. Table 2 lists the eight independent variables that were significant in explaining the variability of green cover in SFNs across the 20 cities. The level of GC in these neighbourhoods was negatively correlated with average floor area ratio (i.e. the bigger the house area, the lower the GC), number of house units (i.e. the larger number of units, the lower the GC), elevation (i.e. higher elevations correlated with less the GC), and population density (i.e. the higher the density, the lower the GC). Number of protected tree species, land values, minimum lot size, and the average percentage of households occupied by owners were positively correlated with the level of GC in SFNs.

Independent Variables	Coefficient	T - value
Protected tree species	61.887	(12.27)**
Number of house units	–2,234.31	(11.56)**
Land value per m^2	0.00093	(9.33)**
Floor area ratio	–333.574	(7.80)**
Elevation	–0.125	(6.71)**
Population density	–0.43	(4.25)**
Minimum lot size	0.001	(3.96)**
Household occupied by owner	0.34	(3.12)**
Constant	307.702	(16.06)**
Absolute value of t statistics in parentheses * significant at 5%; ** significant at 1%		

Table 2. Results of multiple regression model.

The eight variables listed in Table 2 were all significant and explained 55.5% of the variability in GC across 551 census block groups (Akaike's information criterion: 9.674, Bayesian information criterion: 1891.652). The coefficients show that the proportion of GC in a SFN is positively correlated with the number of tree ordinances, land values, lot size, zoning ordinances, and the percentages of owner occupied units – all variables that might be directly or indirectly influenced by city policies.

4. DISCUSSION AND CONCLUSIONS

Our main goal has been explore the role of city policies in determining green cover in single family neighborhoods. Several of the significant variables in our model have shown up in earlier work. For instance, Landry and Pu (2009) found that residential tree cover in the City of Tampa, Florida was correlated with the proportion of parcels regulated by tree protection ordinances, median building age, median building cover, median market value, proportion of White and Hispanic, median age of persons, housing unit density, and proportion vacant housing units. Troy et al. (2007) examined predictors of vegetative cover on private lands in Baltimore, Maryland using population density, lot coverage, and building density in low-income areas. The results significantly indicate how social stratification is related to vegetation cover. Finally, Heynen (2006) investigated the relationship between changes in median household income and changes in urban forest canopy cover in Indianapolis, Indiana.

Our results extend the earlier work because we concentrated specifically on identifying city policies that are correlated with GC extent. Two of the variables identified by Landry and Pu (2009) and Troy et al. (2007) were retained in our final model: lot coverage and the proportion of parcels regulated by tree protection ordinances.

By concentrating on attributes of SFNs that can be regulated, and in some instances, changed by city decisionmakers, we have identified a useful path for planners and regulators seeking to maintain and increase ecosystem services in residential neighborhoods. Although our models include some attributes over which managers have no control — elevation, land value, owner occupancy — others can be regulated at the planning stage of development or even changed in existing SFNs. At the planning stage, planners might consider the adverse effects of small minimum lot sizes on resulting green cover and weigh it against the benefits of affordable housing from smaller lots. Ordinances actually protecting tree species turn out to be important in maintaining green cover, consistent with previous studies (Landry and Pu 2009; Troy et al. 2007).

Floor area ratio, which can be regulated through zoning action, is also an important predictor of GC and may be the best tool that municipalities have against mansionization of existing SFNs. The ecosystem services provided by GC on generously sized parcels are quickly lost when new homes are constructed to fill the entire area within lot line setbacks. The loss of these services has an effect on society as a whole, which should provide a public interest rationale to ensure that zoning codes cap the floor area ratio allowed in SFNs. Keeping floor area ratios restrained also counterbalances the effects of larger minimum lot sizes by keeping homes at a more modest size.

Future research should quantify the magnitude of ecosystem services provided by SFNs, given their large proportion of city area shown here. It should also trace out magnitude and rate of the loss of those services to mansionization — e.g., water management, buffering against climate change, and urban biodiversity (Tratalos et al. 2007). Such losses could be described for the past and potential losses modelled for the future under various policy scenarios. But even as these research routes are pursued, the current study indicates policy options for cities desiring to maintain trees and green cover in their residential neighborhoods.

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APPENDIX I

City Policy	**Applied Ordinances**	**City Policy**	**Applied Ordinances**	
Tree Protection Ordinance	Tree City USA? (Y/N)	**Zoning Ordinance**	Front Yard Setbacks (FYS)	FYS + SYS + RYS
	Years as a Tree City USA		Side Yard Setbacks (SYS)	
	Public/ Street Protection Tree Ordinance? (Y/N)		Rear Yard Setback (RYS)	
	Specific Tree Ordinance with number of specific types of trees protected		Max Height	
	Applicable areas (public, private, both, or none)		Min Lot Area	
Landscape Ordinance	Residential Landscape Requirements (Y/N)		Min Lot Width	
Water Rates and Ordinance	Water Efficient Landscape Policy (Y/N)		Max Lot Coverage	
	Monthly Water Cost		Max FAR (Floor Area Ratio)	

US Census Block Group						
Population	Population Density	Median Household Income		Population Under Poverty Level		
White	African American	Asian	Hawaiian	American Indian	Hispanic	Other
Block Group area	Average family size	Number of house units	Number of vacant houses	Household occupied by owner	Household occupied by renter	

Parcel from Los Angeles County Assessor’s Office				
Area of Parcel	Land Value (per m^2)	Size of building	Year built	Year of rebuild

Environmental Parameters		
Elevation	Average temperature	Distance to ocean