

Data and Methods Comparing Social Structure and Vegetation Structure of Urban Neighborhoods in Baltimore, Maryland

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Recent advances in remote sensing and the adoption of geographic information systems (GIS) have greatly increased the availability of high-resolution spatial and attribute data for examining the relationship between social and vegetation structure in urban areas. There are several motivations for understanding this relationship. First, the United States has experienced a significant increase in the extent of urbanized land. Second, urban foresters increasingly recognize their need for data about urban forestry types, owners and property regimes, and associated social goods, benefits, and services. Third, previous research has focused primarily on the distribution of vegetation cover or diversity. However, little is known about (1) whether vegetation structure varies among urban neighborhoods and (2) whether the motivations, pathways, and capacities for vegetation management vary among households and communities. In this article, we describe novel data and methods from Baltimore, MD, and the Baltimore Ecosystem Study (BES) to address these two questions.

Keywords Baltimore, landcover, LTER, remote-sensing, social structure, urban ecology, vegetation

This article presents new kinds of data and methods for examining the relationship between social and vegetation structure in urban areas. There are several motivations for employing these data and developing these methods. First, with a 34% increase in the amount of urbanized land in the United States between 1982 and 1997 (NRCS 1999) and the amount of developed land projected to increase from 5.2% to 9.2% by 2025 (Alig and Kline 2004), understanding and forecasting the social dynamics of urban vegetation in general will become increasingly important to society and its metropolitan regions (Nowak et al. 2001; Dwyer et al. 2002; Dwyer and McCaffrey 2004). Second, urban foresters increasingly recognize that urban forestry requires knowledge and data about urban forestry types, owners and property regimes, and associated social goods, benefits, and services (Lohr et al. 2004; Grove et al. 2005; Grove et al. in press). Finally, previous research on the relationship between social structure and vegetation has focused primarily on the distribution of vegetation cover (Whitney and Adams 1980; Palmer 1984; Grove 1996; Jensen et al. 2005) or species diversity (Whitney and Adams 1980; Hope et al. 2003; Martin et al. 2004). While the extent of vegetation cover may be significant to urban ecosystem processes, the structure of that vegetation cover in terms of large and small trees, shrubs, and herbaceous layers may also be important. However, little is known about (1) whether vegetation structure varies among urban neighborhoods and (2) whether the motivations, pathways, and capacities for vegetation management vary among households and communities. In this article, we describe data and methods from Baltimore, MD, that may be used to address these two questions.

Background

Studies related to the first question, the association between social and vegetation structure in urban neighborhoods, have often been limited by small samples of field observation data (Whitney and Adams 1980; Palmer 1984; Hope et al. 2003; Jensen et al. 2005; Martin et al. 2004) or moderate-resolution remotely sensed data (Vogt et al. 2002). Regional vegetation cover data have typically been derived from 30-m resolution Landsat Thematic Mapper (TM) satellite imagery. Socioeconomic analyses have normally been conducted at the U.S. Census Tract level, which includes approximately 2500–8000 persons, or a U.S. Census Block Group, which contains between 200 and 400 households.

Unfortunately, the resolution of these data makes it difficult to dissect and characterize the fine-grain vegetation and social heterogeneity that often prevails in densely settled areas. This heterogeneity has both a spatial and attribute component. For instance, to discriminate between vegetation on private property, public rights-of-way (PROW), and riparian areas requires high-resolution (1-m) remotely sensed data for vegetation, cadastral data for roads and parcels, and topographic data for streams and riparian boundaries. And to distinguish among different vegetation types or social groups requires high-resolution categorical data.

Recent advances in remote sensing and the widespread adoption of geographic information systems (GIS) by federal, state, and local governments have greatly increased the availability of high-resolution spatial and attribute data. Vegetation can be derived from high-resolution imagery and combined with digital parcel data, which includes property boundaries for each parcel, to distinguish among vegetation on private property, public rights-of-way (PROW), and riparian areas (Robbins and Birkenholtz 2003; Grove et al. in press). For example, Figure 1 compares different ways vegetation can be partitioned using high-resolution remotely sensed imagery and parcel boundaries, in contrast to moderate-resolution data from Landsat and U. S. Census Block Groups.

Social scientists can also increase the categorical resolution of their social area analyses (Bell and Newby 1976; Johnston 1976; Murdie 1976; Hamm 1982; Grove and Burch 1997) through the novel application of market research data and methods (Holbrook 1995; Lang et al. 1997; Weiss 2000). This can improve the characterization of social groups, building from indices of population density, ethnicity, or socioeconomic status to more complex characterizations. For instance, the Claritas, Inc., PRIZM (Potential Rating Index for Zipcode Markets) categorization system uses factor analysis and U.S. Census data about housing, household education, income, occupation, race/ancestry, and family composition to classify urban, suburban, and rural neighborhoods into categorical group measures (Lang et al. 1997; Claritas 1999). The PRIZM categorization system has three levels of resolution: 5, 15, or 62 categories. The 5-group categorization is the coarsest resolution and is arrayed along an axis of urbanization. Disaggregating from 5 to 15 categories adds a second axis: socioeconomic status. The 62-group version is the highest categorical resolution and expands the socioeconomic status axis into a lifestyle categorization with components including household composition, mobility, ethnicity, and housing characteristics (Claritas 1999).

Researchers in the Baltimore Ecosystem Study (BES) have taken advantage of these advances in spatial and categorical data resolution to study variations in social structure and vegetation cover. Grove et al. (in press) used these data and a

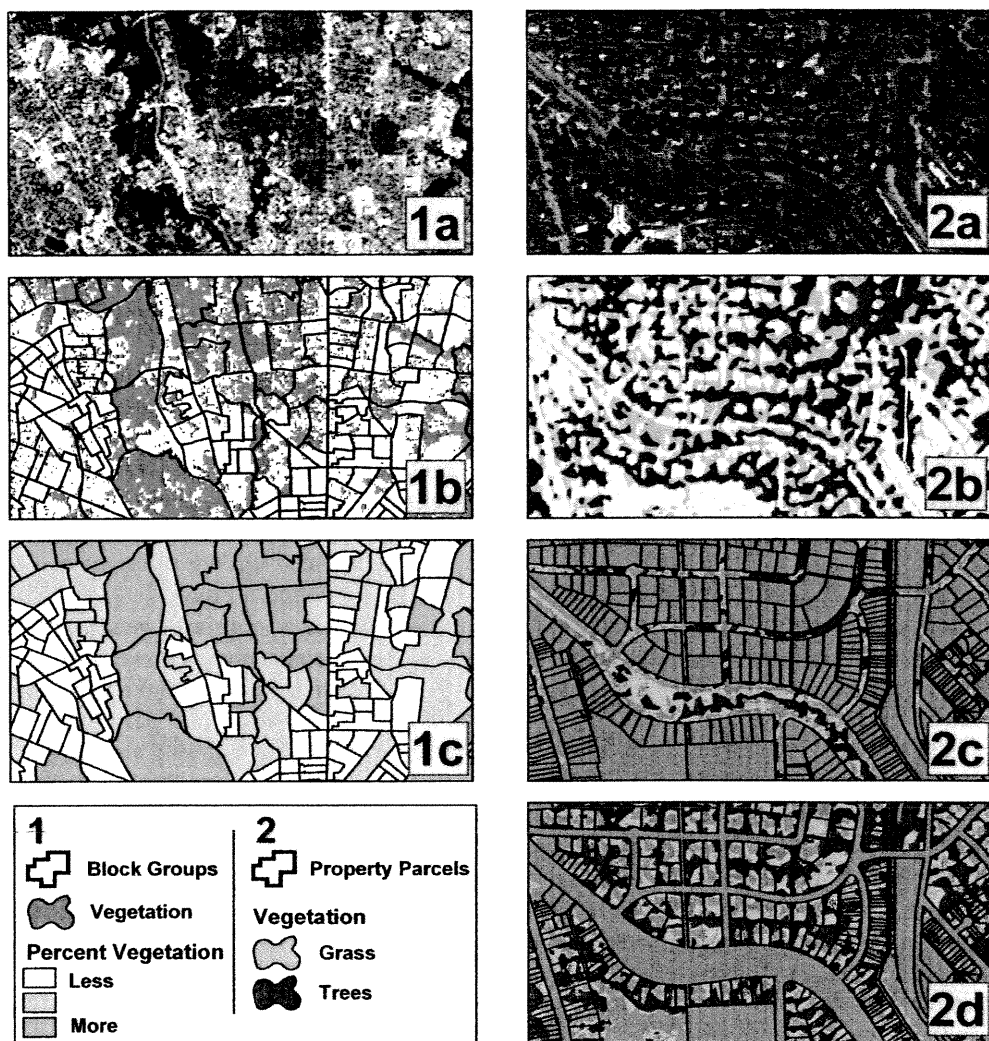


Figure 1. Comparison of relatively coarse-scale (1:100,000) and fine-scale (1:10,000) vegetation analysis that can be performed using (1) Landsat and (2) IKONOS derived vegetation data.

multimodel inferential approach (Burnham and Anderson 2002) to assess the ability of categorical measures of population density, socioeconomic status, and lifestyle behavior to predict the distribution of vegetation cover. Grove et al. found that variations in vegetation cover in riparian areas were not adequately explained by any of the three measures, while lifestyle behavior categories were the best predictor of vegetation cover on private lands. Surprisingly, lifestyle behavior was also the best predictor of vegetation cover on PROW lands. Vegetation cover on private lands was also found to relate quadratically to median housing age, increasing positively until approximately 40 years and then declining.

Troy et al. (in press) built on these data and analyses of vegetation cover by adding building footprint data for the city of Baltimore and generating measures of “potential stewardship” and “realized stewardship.” Potential stewardship referred

to the amount of private land, excluding water, which did not have built structures on it, and therefore had potential for greening. Realized stewardship referred to the proportion of potential stewardship land on which vegetation was present already. Troy et al. found that the combination of socioeconomic status and quadratic housing age was the best predictor of variation in *potential stewardship*. This suggests that older housing stock, which tends to be denser, with higher lot coverage, and occupied by lower income residents in Baltimore, had less room for planting. However, the combination of lifestyle behavior and housing age was the best predictor of variation in *realized stewardship*. This suggests that income and education are insufficient to explain why people plant when they have room to do so. Rather, some combination of housing age and neighborhood-level lifestyle factors accounted for these differences. Again, predicted realized stewardship increased with housing age until about 44 years and then declined, suggesting that it peaks in moderately old neighborhoods.

Advances in remotely sensed data have also contributed to a novel landcover classification system developed specifically for urban systems: HERCULES (High Ecological Resolution Classification for Urban Land and Environmental Systems). This classification is hierarchical and uses high-resolution satellite or aerial imagery to characterize the fine-grained heterogeneity of urban areas in terms of vegetation and built cover and structure, and presence of massed pavement. The features used in constructing this new landcover classification scheme are included because they are hypothesized to affect biophysical functions such as hydrologic and thermal fluxes (Cadenasso et al. in press).

The term *resolution* in HERCULES refers to the fineness of the classes themselves. There are three distinct categories at the coarsest (most aggregated) level of this classification: (1) coarse textured vegetation with a closed canopy, (2) mixed textured vegetation with an open canopy and no built structures, and (3) some built structures. Within the first category of closed canopy coarse vegetation, areas are further discriminated based on crown size. Classes within the second category are discriminated based on the presence of pavement, bare soil, and the proportion of coarse and fine textured vegetation. The third category encompasses much of the urban system and varies relative to three dimensions: (1) the type and density of structure, (2) the texture and proportion of vegetation, and (3) the extent of impervious and bare surfaces. There is a fourth, complex class that includes elements such as interstate highways, golf courses, and cemeteries.

Our second question, whether motivations, pathways, and capacities for vegetation management vary among households and communities, builds on the first. While our first question focuses on potential associations between social and vegetation structure, our second question centers on processes related to neighborhood-level management of vegetation structure. In question 2 we use the same data and methods from question 1 to assess how much, if anything, we can learn about management motivations, pathways, and capacities. The answer to this second question may caution researchers and practitioners not to confound the ability to measure the association between social and vegetation structure at a high resolution with identifying and measuring the interactions among those structures.

Problem

In this article, we assess whether new kinds of data and methods—remote sensing, digital parcel and building data, social area analysis, and landcover

classification—are adequate to address whether (1) vegetation structure varies among urban neighborhoods, and (2) motivations, pathways, and capacities for vegetation management vary among households and communities. Question 1 focuses on the association between high-resolution categorical data of social and vegetation structure by building on recent studies of vegetation cover in the BES (Grove et al. in press; Troy et al. in press). A new contribution in this analysis is the use of a high-resolution landcover database: HERCULES. Question 2 assesses whether social processes related to the management of vegetation structure can be identified and measured using the same data and methods for characterizing social and vegetation structure from Question 1. Based on these results, we examine some theoretical insights that emerge and empirical steps to pursue.

Methods

Site Description

Urban ecosystems are strikingly heterogeneous and scale dependent (Grimm et al. 2000; Pickett et al. 2001). Baltimore, MD (southwest corner: 39° 11'31" N, 76° 42'38" W; northeast corner: 39° 22'30" N, 76° 31'42" W), has experienced extensive demographic and economic changes over the past 50 years, with the city's population declining from nearly 1.2 million in the 1950s (Burch and Grove 1993) to its current level of 614,000 people (Geolytics 2000). At the same time, the Baltimore Metropolitan Region has had one of the highest rates of deforestation in the northeastern United States because of urban sprawl (Horton 1987). Located in the deciduous forest biome, on the banks of the Chesapeake Bay, the largest estuary in the United States, Baltimore City is drained by three major streams and a direct harbor watershed.

Baltimore City comprises 276 neighborhoods. In 2000, the city of Baltimore had 258,518 households and 300,477 household building units, with an average of 2.5 persons per household (Geolytics 2000). The city includes a variety of housing types, of which 14.8% are single-family detached units, 28.4% are multifamily units (Geolytics 2000), and 63.3% are townhomes (Maryland 2003). Baltimore County, which surrounds most of the city, had 300,020 households and 313,734 household building units, with an average of 4.2 persons per household (Geolytics 2000). The county includes a variety of housing types, of which 54.2% are single-family detached units, 21.0% are multifamily units (Geolytics 2000), and 63.3% are townhomes (Maryland 2003).

This research is based on four study sites in Baltimore City and Baltimore County: Watershed 263 (3.7 km²), Rognel Heights (18.8 km²), Glyndon (18.8 km²), and McDonogh (18.8 km²) (Figure 2). These sites are used because of the extensive long-term social and biophysical data that have been developed through the BES (<http://www.beslter.org>), a long-term ecological research (LTER) project supported by the National Science Foundation. Table 1 summarizes differences in housing type, age, and ownership for the study areas.

Data

Categorization of Neighborhoods: Lifestyle Behavior

Neighborhood measures of lifestyle behavior are based on the Claritas, Inc., PRIZM (Potential Rating Index for Zipcode Markets) categorization system, which was

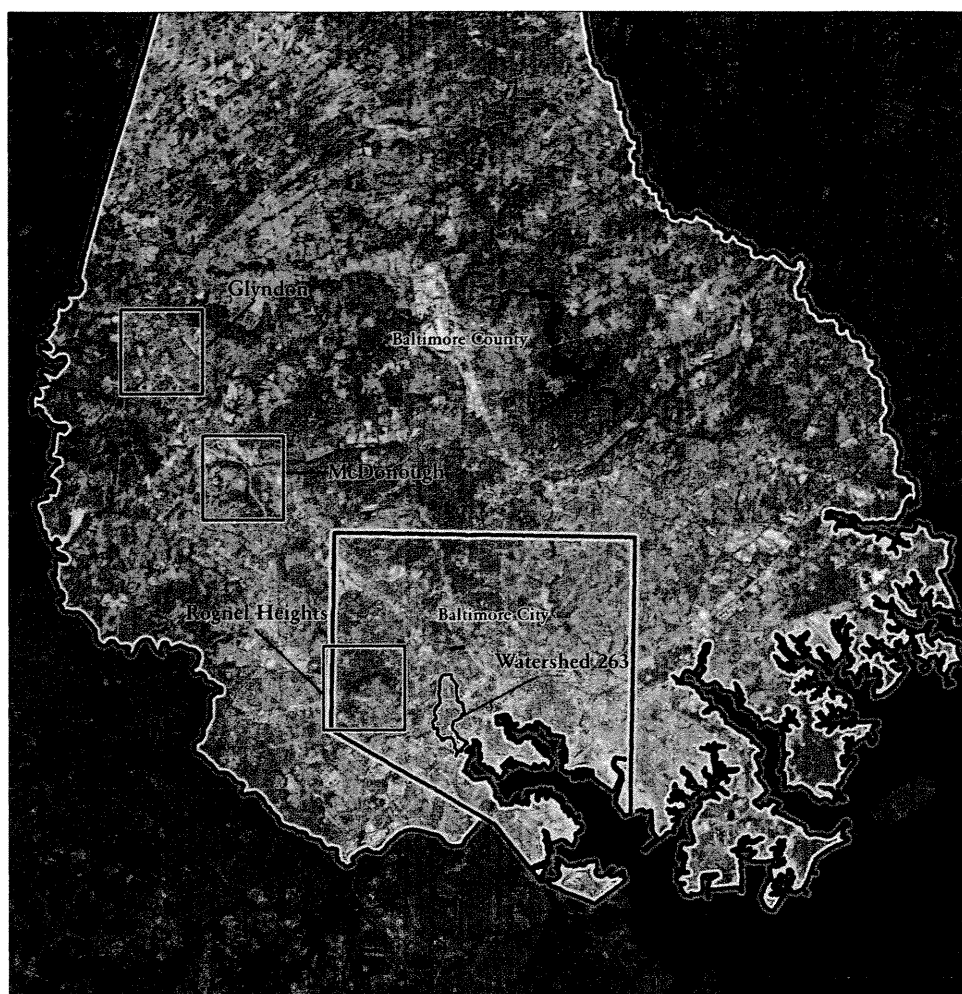


Figure 2. Study areas: Watershed 263, Rognel Heights, Glyndon, and McDonogh.

developed by demographers and sociologists for market research (Weiss 1988; Weiss 2000; Holbrook 2001) and includes 62 lifestyle categories. PRIZM has been used in several studies of urban vegetation cover, including Martin et al. (2004), Grove et al. (in press), and Troy et al. (in press).

A GIS data layer of PRIZM categories was created for Baltimore City and County by joining U.S. Census Block Group boundaries data from the Geographic Data Technology (GDT) Dynamap Census data with a PRIZM classification for each U.S. Census Block Group from the Claritas 2003 database (<http://www.claritas.com>). Each U.S. Census Block Group was assigned a PRIZM category. The GDT Census boundaries were used instead of the U.S. Census Bureau and Claritas boundaries because of their higher positional accuracy when compared with 1:12,000 scale IKONOS imagery. In the four study areas, the two dominant PRIZM categories in McDonogh were 3 and 12; in Glyndon were 15 and 18; in Rognel Heights were 30 and 45; and in Watershed 263 were 45 and 47. Table 2 provides

Table 1. Summary social characteristics of study areas

Variable	Study area			
	W263	RH	GLYN	MCD
Households	13,910	31,235	14,421	16,108
Household building units	19,212	34,005	14,958	16,964
Average persons per household	2.8	2.6	2.7	2.5
Single-family detached units (%)	4.7%	16.5%	59.1%	44.3%
Multifamily attached units (%)	31.5%	26.0%	16.0%	33.2%
Townhomes (%)	43.3%	78.8%	28.5%	32.3%
Mean housing age (years)	91	68	25	23
Newest house age (years)	5	<1	<1	<1
Oldest house age (years)	159	213	218	252
Homeowner (%)	34.9%	59.2%	78.0%	69.4%
Renter (%)	65.1%	39.5%	22.0%	30.6%
Median residence time (years)	6.5	11.1	7.6	5.7

summary social characteristics for the PRIZM categories from the four study areas (Geolytics 2000; Maryland 2003).

Median House Age

Median house age data at the block group level were obtained from the Geolytics Census 2000 Long Form database (Geolytics 2000).

Parcel Boundaries

Property parcel boundaries were obtained for Baltimore City and County. These parcel boundaries, converted to digital format from cadastral maps, were current as of July 2001. The parcel data is structured so that polygons exist for all land not in PROW. This allows a distinction to be made among lands with different types of property owners. For each study area, parcel data were overlain on the aerial imagery (discussed later) and edited to produce a topologically correct uniform parcel-PROW dataset for each of the four study areas.

Vegetation Data

Fine-scale Landcover Classification. The HERCULES landcover classification discussed earlier (Cadenasso et al. in press) was applied to the four study regions. Color infrared 0.60-m resolution, 1:10,000-scale digital aerial imagery were acquired in October 1999 prior to leaf drop for McDonogh, Glyndon, and Rognel Heights, and September 2004 for W263. The imagery served as the base layer for delineating landcover polygons in a GIS through “heads-up” digitizing. A patch was required to be at least 20 m in two orthogonal directions to be discriminated. This avoided treating each street as a separate patch. If two patches were separated from each other by a road, the patch boundary was drawn down the middle of the road. Once all of the polygons were drawn as a layer on top of the images, the patches were categorized.

At its finest categorical resolution, there are 317 theoretical classes. However, some of these classes are unlikely in practice: for instance, vegetation with a closed canopy and connected structures at high density.

Table 2. Summary social characteristics of PRIZM categories

Variable	PRIZM category						
	3	12	15	18	30	45	47
Households	5656	862	901	1267	9985	3327	20137
Household building units	5958	951	867	1349	11306	4398	24663
Average persons per household	2.5	2.9	2.8	1.9	2.8	2.9	2.6
Single-family detached units (%)	33.0%	76.6%	91.7%	1.8%	13.5%	7.7%	6.4%
Multi-family attached units (%)	37.0%	1.8%	1.6%	48.3%	17.9%	9.0%	37.1%
Townhomes (%)	40.0%	19.0%	4.4%	61.3%	72.9%	75.2%	45.8%
Mean housing age (years)	12	31	37	15	67	99	70
Newest house age (years)	<1	1	<1	3	<1	8	3.5
Oldest house age (years)	252	177	183	69	203	153	158
Homeowner (%)	67.3%	89.9%	91.3%	63.5%	64.5%	46.1%	39.2%
Renter (%)	32.7%	10.1%	8.7%	36.5%	31.9%	53.9%	60.8%
Median residence time (years)	2.75	7	10.0	3.0	13.75	6.0	8.7

Table 3. Summary of social and vegetation structure by PRIZM category

Social structure			Vegetation structure		
PRIZM	Housing type(s)	Housing age (mean, years)	Residence time (median, years)	Home/ renter	Dominant landcover type
3	Even mix of single-family detached, multifamily attached, and townhomes	12	2.75	2.10	Closed canopy, mix of large and small crowns (17.2%)
12	Single-family detached (76.6%)	31	7.00	8.90	Detached, clustered housing with medium percentage of area in coarse vegetation (41.5%)
15	Single-family detached (91.7%)	37	10.00	10.50	Detached housing in rows or clusters with high percentage of area in coarse vegetation (25.0%)
					Forested patches with large and small crowns (34.9%), and clustered housing with low to medium percentage of area in coarse vegetation (12.7%)
					Clustered housing with low to medium percentage of area in coarse vegetation (47.4%), and closed and open canopy forest (19.7%)
					Detached housing in rows or clusters with medium to high percentage of area in coarse vegetation (38.3%), and open and closed canopy forest (18.4%)

18	Townhomes (61.3%) and multifamily attached (48.3%)	15	3.00	1.70	Attached clustered housing with low percentage of area in coarse vegetation (37.1%)	Includes mix of forest, coarse vegetation, and housing types
30	Townhomes (72.9%)	67	13.75	2.00	Closed canopy forest with large crowns (26.87%)	Cemetery (13.6%), detached clustered housing and townhomes with low to medium percentage of area in coarse vegetation (22.9%)
45	Townhomes (75.2%)	99	6.00	0.86	Attached, clustered buildings with a low percentage of area in coarse vegetation, and paved areas (49.9%)	Townhouses and low percentage of area in coarse vegetation (7.38%) and recreation fields (22.9%)
47	Multifamily attached (37.1%) and townhomes (45.8%)	70	8.7	0.65	Townhomes with medium percentage of area in coarse vegetation, and paved areas (17.5%)	Attached housing in rows or clusters with low to medium percentage of area in coarse vegetation with some bare soil and pavement (75.6%)

Data Analyses

Analysis of Covariation Among PRIZM Categories and HERCULES Classes

Statistical analyses using chi-squared tests, analyses of variance (ANOVAs), or logistic regressions were not performed on the data for a combination of reasons. The availability of HERCULES data for only the four study areas created a situation where there were not enough U.S. Census Block Groups included as observations, not enough variation in terms of HERCULES classes within those U.S. Block Groups, or not enough observations in each PRIZM category.

Ideally, the data could be analyzed with U.S. Census Block Groups as individual observations, attributed with a PRIZM category and a percentage for each land cover type. Because there are so many HERCULES classes, however, such an analysis would be more tractable if they were aggregated into fewer HERCULES classes. The predictor variable in this analysis is a PRIZM class, which is categorical. Hence, analysis of variance (ANOVA) could be used. However, ANOVA performs best with a balanced design (equal number of observations by category), which is not the case in this analysis, and when the dependent variable is unbounded, which percentages are not. A preferred alternative would be to use a logistic regression, in which the dependent variable takes the form of a proportion ranging from 0 to 1. Logistic regression also does not assume multivariate normality. Using logistic regression, the effect of PRIZM categories on percent cover in a given landcover class by U.S. Census Block Group could be assessed. However, the small sample size and unbalanced design produced unreliable results using logistic regression.

Although the availability of HERCULES data was the limiting factor in this analysis, this is associated with the resource intensive approach for deriving the HERCULES database. Currently, HERCULES is produced through on-screen digitizing and classification methods. Semiautomated methods using multispectral and object-oriented image classification methods are being developed for deriving HERCULES databases.

To accommodate the current sample distribution and size, a summary table was generated based upon all landcover patches constituting at least 5% or more of the private lands for each PRIZM category in the four study regions (Table 3). This table was used for interpretative analysis of the data in order to compare differences among PRIZM lifestyle categories in terms of the dominant landcover type and the distribution of landcover types.

Results

Preliminary results suggested that differences in landcover structure on private lands existed among PRIZM lifestyle categories for both the dominant landcover type and distribution of landcover types (Table 3). The dominant landcover patch for PRIZM-3 was a closed canopy forest with a mix of large and small crowns (17.2%). In addition, the distribution of landcover patches included mostly forested areas (34.9%) and clustered housing with low to medium percent of the area in coarse vegetation (12.7%). In contrast, PRIZM-12 areas were characterized by detached housing in clusters with a medium percent of the area in coarse vegetation (41.4%). The distribution of landcover included mostly clustered housing with low to medium percent of the area in coarse vegetation (47.4%) and a mix of closed and open canopy forest (19.7%). In PRIZM-15 areas, detached housing in rows

or clusters with a high percent of the area in coarse vegetation dominated (25.0%). Two groups of landcover were prevalent, detached housing in rows or clusters with medium to high percent of the area in coarse vegetation (38.28%) and open and closed canopy forest (18.4%). PRIZM-18 areas were dominated by attached, clustered buildings with a low percent of the area in coarse vegetation (37.1%). Landcover types were distributed across the range of housing types, area in coarse vegetation, and forests. Closed canopy forest with large crowns dominated PRIZM-30 (26.9%), with three remaining landcover types: cemetery (13.6%), and detached clustered housing and townhouses with low to medium percent area in coarse vegetation (22.9%). PRIZM-45 sites had no forested areas and were dominated by attached, clustered buildings with a low percent area in coarse vegetation (49.9%). The balance of landcover types included townhouses with a low percent area in coarse vegetation (7.4%) and recreation fields (22.9%). PRIZM-47 sites also had no forested areas, but were dominated by townhouses at medium density with a medium percent area in coarse vegetation (17.5%). The remaining landcover types included mostly attached housing in either rows or clusters with low to medium percent area in coarse vegetation (75.6%).

The average age of housing may have played a partial role in the landcover structure for each study area. Grove et al. (in press) and Troy et al. (in press) found that vegetation cover increased with median housing age until about 40–50 years, after which point the inverse was true. The three PRIZM categories with mean housing age closest to this inflexion point, PRIZM-12, PRIZM-15, and PRIZM-30, were also the three areas that included a medium to high percent area in coarse vegetation. In contrast, younger areas such as PRIZM-18 and older areas such as PRIZM-45 and PRIZM-47 tended to have a lower percent area in coarse vegetation.

Discussion and Conclusion

Although our findings were not analyzed for statistical significance, our preliminary results (Table 3) indicate that new kinds of data and methods—remote sensing, digital parcel and building data, social area analysis, and landcover classification—are adequate to address whether “vegetation structure varies among urban neighborhoods.” However, while these types of data are adequate for comparing differences among lifestyle groups, an underlying issue remains: the adequacy of the number and distribution of biophysical observations associated with the HERCULES landcover database.

This issue is related to the high-resolution categorical nature of the predictor variable: the PRIZM lifestyle classification and its 62 categories. Because of this large number of categories, an extensive vegetation database that is well-distributed among each PRIZM category is necessary. While it would be tempting to statistically solve the problem by changing the categorical resolution and aggregating from 62 to 15 classes, this would change the theoretical intent of the analysis from a test of lifestyle behavior to a test of socioeconomic status.

The need for a vegetation database based on a stratified sample of 62 lifestyle categories has important implications for future efforts focused on this type of interdisciplinary research. This sampling issue has been less problematic in the past because researchers have used indices of urbanization, socioeconomic status, or ethnicity and coarse-resolution categorizations of vegetation cover in terms of

impervious surfaces, grass areas, and tree canopy. Most often, these landcover databases were generated using semiautomated, multispectral image-processing techniques. An advantage to this approach was that the vegetation database for a reasonably large area could be generated in a cost-efficient manner. In contrast, databases of vegetation structure and biodiversity based on high resolution remotely sensed imagery or field observation data do not lend themselves well to automation and thus tend to be labor intensive. The costs associated with these types of data are increased significantly by differences in the sampling requirements associated with changing from a continuous, independent variable such as an index of socioeconomic status to a high-resolution categorization of social groups such as PRIZM's lifestyle categorization.

This sampling issue is likely to emerge as a significant and widespread issue for other types of interdisciplinary, urban ecology research when high-resolution categorical variables are used. In these cases, significant attention will need to focus on the sampling plan. Also, significant resources will be needed when intensive image processing methods are used or field-based measurements are taken. For example, in addition to measurements of vegetation structure and biodiversity, research on microclimates, water and soil quality, and wildlife requires extensive field-based measurements. This sampling issue is unavoidable, as urban ecology research increasingly asks questions about the fine-grain heterogeneity of human behavior and ecological patterns and processes in densely settled areas.

For our second question, "whether motivations, pathways, and capacities for vegetation management vary among households and communities," the tabular results from our analysis provided no direct indication about differences among households' and communities' motivations, pathways, and capacities for vegetation management. However, the geographic display and interpretation of the data suggest some insights about property regimes, ownership, and settlement patterns that may be significant to vegetation management in urban areas (Grove and Hohmann 1992; Grove et al. 2005). For instance, residential areas with comparable amounts of coarse vegetation structure may be characterized by both private (Figure 3.3A) and community property regimes (Figure 3.3B). Similar forested areas are characterized by differences in ownership fragmentation, with some forested areas characterized by one owner (Figure 3.3C) and others by many owners (Figure 3.3D). Finally, areas with similar amounts of coarse vegetation are characterized by different settlement patterns (Figures 3.3E and 3.3F).

Although these data and cartographic methods suggest potential influences of property regimes, ownership, and settlement patterns on vegetation structure, these types of data and methods are not adequate for moving from associations between social and vegetation structure at a high resolution to processes related to neighborhood-level management of vegetation structure. Indeed, the adaptation of traditional field methods from anthropology, sociology, and political science may be more appropriate to answer this second question, particularly approaches that have been developed and applied to natural resource issues in rural areas (Grove et al. 2005). These methods are necessary to address both the complexity of the question and its focus on processes rather than associations among social and vegetation structure (Table 4).

For example, some lifestyle groups may locate in areas with particular combinations and amounts of existing vegetation cover, while other lifestyle groups may manage for and cultivate specific combinations and amounts of vegetation for the

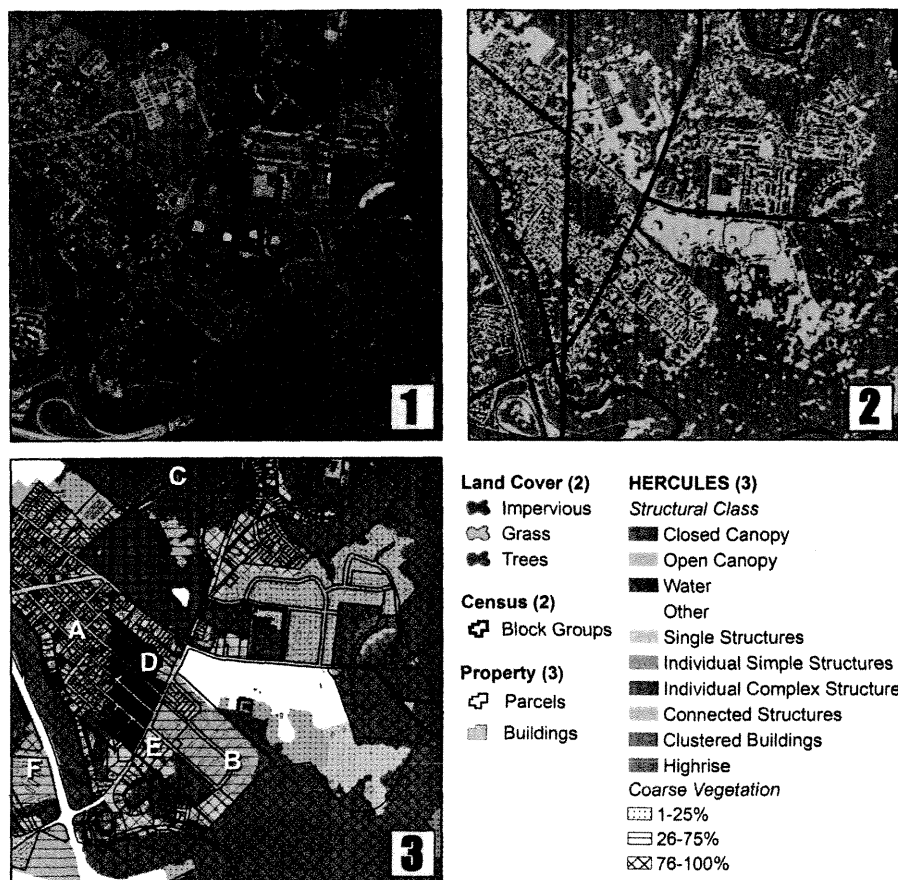


Figure 3. Comparison of vegetation cover, vegetation structure, and social structure.

future. The answer is complex because some lifestyle groups may be more likely to prefer a residential landscape of mature trees, established lawns, and perennial gardens: “buy as is.” Other lifestyle groups may be more likely to cultivate for a preferred residential landscape by planting new trees, replacing paved areas with grass, and putting up flower boxes: “fixer-uppers.” In other words, the direction of causality may vary by lifestyle groups. Finally, whether residents are owners or renters and how long they have lived in a neighborhood may affect their willingness to invest in the neighborhood through planting and maintenance of vegetation. Additional time-series data and combinations of household, key-informant, and focus-group surveys would elucidate these dynamics.

The pathways for urban and community forestry management may be affected by private, community, state, and open access property regimes (Grove 1995; Parker et al. 1999). For instance, the dominance of attached housing and absence of forested areas in PRIZM-45 and PRIZM-47 suggest that most of the landcover is in individual ownership. In contrast, the mix of clustered housing and forested areas in PRIZM-3 and PRIZM-18 indicates that both lands may be under

Table 4. Examples of process-based questions, methods, and data

Questions	Methods	Data
Motivations		
• How do group identity and social status affect preferences and motivations for land management? • Are some lifestyle groups more likely to “buy as is” and others to be “fixer-uppers”? • Do homeownership and/or length of residence time affect willingness to invest in the neighborhood through planting and maintenance?	• Conjoint analyses of land management attitudes and preferences • Time-series analyses	• Average housing age • Median residence time • Ratio of homeowners to renters • Attitudes and preferences • Demographic and socioeconomic change
Pathways		
• Do private, community, state, and open access property regimes affect how lands are managed? • Does parcel size affect how lands are individually and collectively conserved or rehabilitated?	• Property regime analyses	• Housing type(s) • Parcel size • Neighborhood association covenants • Parcel boundaries (parcels/vegetation patch) • Property regimes within and among parcels

Capacity

- Does human and/or social capital in a neighborhood affect the ability to plant or maintain vegetation on private, community, state, and open access lands?
 - Do past sociodemographic neighborhood characteristics affect current vegetation structure (social legacies)?
 - Do the configuration and density of building types influence collaboration among individual, private landowners and among co-owners in clustered housing with covenants?
 - What is the "goodness of fit" between management capacities and needs?
 - Where and how does this "goodness of fit" change over time?
-
- Network and institutional analyses
 - Neighborhood forecasting models
 - Vegetation forecasting models
 - Neighborhood-vegetation interaction models
 - Human capital
 - Access to private financial resources
 - Access to information resources
 - Social capital
 - Ability to work collectively
 - Ability to access community and state resources
 - Parcel boundaries and building footprints
 - Land available for stewardship (potential)
 - Household expenditures on land management goods and services
 - Time-series sociodemographic data
 - Time-series vegetation structure data

community ownership, such as a condo or neighborhood association, with landscaping around residences and community open space conserved as forest. Finally, the prevalence of detached, low-density housing and forested areas in PRIZM-12 and PRIZM-15 suggests that most of these lands may be in single-family home ownership.

Additional factors may influence how vegetation structure is managed. Parcel size and fragmentation may be an important factor. For instance, if the forested areas in PRIZM-3 are held by a few owners, the approach to how those areas are managed is very different than if they are owned by numerous households. Likewise, the parcel size and fragmentation of paved and bare areas in PRIZM-45 and PRIZM-47 may affect whether those areas are converted to planted areas. In all of these cases, additional examination of administrative records, key-informant interviews, and parcel-level analyses would increase our understanding of management pathways for different lifestyle groups and types of vegetation structure.

The realization of different motivations and pathways may be constrained by the capacity of residents to manage the vegetation structure in their neighborhoods. Varying levels of human and social capital in a neighborhood (Dietz et al. 2003; Pretty 2003) may have significant effects on the ability to plant or maintain vegetation (Grove et al. 2005). Human capital may be associated with access to private financial resources to support planting and maintenance activities. Social capital may be associated with the ability to work collectively or access government resources. And the configuration and density of building types may influence collaboration among individual, private landowners and among co-owners in clustered housing with covenants and community open space.

The idea of management capacity is complicated by the fact that both social and vegetation components systems are dynamic. The needs for vegetation management may change over time in terms of planting and replanting, pruning and maintenance, and removals. For instance, the human and social capital needed to prune a 10 foot tree is very different than pruning a 100-foot tree. Likewise, the management capacity needed to thin a 10-year-old forest is very different from maintaining the successional dynamics of a 100-year-old forest. At the same time, the human and social capital of a neighborhood is likely to change over time. In some cases the social structure and vegetation structure may be well matched to each other; in other cases the capacity for management may not be appropriate for the vegetation management that is needed.

These different combinations of motivations, pathways, and capacities associated with vegetation structure underscore the realization that the social and biophysical interactions associated with urban vegetation are far richer than previously conceived of and studied when focusing exclusively on vegetation cover (cf. Figure 3.2 and 3.3). Group identity and social status, human and social capital, property regimes, and social legacies are examples of concepts and data to include and to consider how they affect and respond to an organic system of vegetation change over the long term (Table 4). Ultimately, our ability to pose hypotheses about and understand the dynamic relationships between social structure and vegetation structure of urban neighborhoods over time will require employing long-term social and biophysical data, adapting existing methods to novel settings, and increasing our sensitivity to the complex, fine-grain heterogeneity of social and ecological interactions in urban areas.

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