

Yard-Scale Socioeconomic and Ecological Factors Shape Urban Forest Structure, Diversity, Soils, and Ecosystem Services

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**Yard-scale Socioeconomic and Ecological Factors Shape Urban Forest Structure, Diversity,
Soils, and Ecosystem Services**

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Abstract

Urban ecology studies have demonstrated that residential vegetation differs across neighborhoods, socioeconomic gradients, housing age, and parcel configuration. But such coarser scale studies often overlook parcel and yard-scale land tenure, individual land and homeowner actions, and within-yard heterogeneity. Thus, we studied how yard location and socio-ecological factors influence urban forest structure, woody plant diversity, and ecosystem service potential in private, residential yards in Los Angeles, California (US). Overall, 2,303 individuals and 325 shrub, 95 tree, and 7 palm taxa were measured across different yard locations (n= 35 yards). Tree crown volume increased with species richness, tree density, and diversity. Older neighborhoods were characterized by higher tree and shrub frequency; newer ones had higher palm frequencies. Tree frequency (12.3%), mean species richness (45.8 ± 21.8) and mean crown widths (2.1 ± 2.4 m) were greatest in front yards. Cultural ecosystem services were most common in back yards; regulating and provisioning ecosystem services were most common in front yards. Tree shade potential was primarily driven by soil quality, tree size, and crown architecture. Urban forest structure, condition, and tree distance to building metrics and results also have implications for assessing potential wildfire hazards. Finally, affluence and education were positively related to tree shade potential while housing age, owner-occupied, and areas with white populations exhibited a negative relationship. Our parcel-level – and yard location- approach and findings show how soils, woody plant diversity, and urban forest structure metrics influence shade potential and woody plant diversity across yard location and socio-economic gradients.

Key words: Yard location, urban soils, Tree shade, urban fire hazard, social-ecological drivers

Introduction

Urban forests and residential landscapes constitute one of the largest and most important components of urban green infrastructure. In many North American cities, residential parcels account for an estimated 35–60% of urban land area and collectively influence biodiversity conservation, urban microclimate regulation, carbon storage, and ecosystem service delivery across metropolitan regions (Nowak and Greenfield, 2012; Pickett et al., 2011). In many cities, residential parcels occupy a greater proportion of urban land than public parks or formally managed green spaces, making yard-level vegetation management a critical driver of urban ecological structure and function (Clarke et al., 2013; Cressotti, 2025; Horn et al., 2015; Locke et al., 2022). Unlike remnant natural ecosystems, residential vegetation and urban forest patterns emerge through the interaction of environmental conditions, parcel configuration, socioeconomic context, and homeowner preferences, producing highly heterogeneous urban landscapes characterized by fine-scale structural and compositional variability (Cavender-Bares et al., 2020; Larson et al., 2016; Wheeler et al., 2022).

Previous urban ecology studies have demonstrated that residential vegetation differs across neighborhoods socioeconomic gradients, housing age, and parcel configuration (Locke et al., 2018a; Ossola et al., 2019). Several studies have shown that affluent neighborhoods often support greater vegetation complexity, larger canopy structure, and higher species richness, whereas older residential areas may maintain more established and compositionally distinct vegetation assemblages (Avolio et al., 2020b; Blanchette et al., 2021). Similarly, parcel-scale characteristics such as yard size and housing density can strongly influence tree planting opportunity, vegetation abundance, and canopy development (Kinzig et al., 2005; Larson et al., 2009). Norlen et al., (2026) recently found that using yard versus neighborhood-level urban tree cover and building characteristic data at different scales can statistically influence the impact of urban tree cover on community well-being and fire hazards. Despite growing recognition of these relationships, many urban forest ecosystem studies continue to consider urban forests and landscapes at coarse spatial scales and often treat groups of parcels and yards as homogeneous units, while overlooking land tenure, individual land and homeowner actions, and within-yard heterogeneity (Avolio et al., 2020a; Clarke et al., 2013; Reyes et al., 2026).

Many studies from the United States (US) have shown that within residential parcels, front, and back yards represent functionally distinct ecological spaces shaped by differing priorities (Avolio et al., 2020b; Blanchette et al., 2021; Locke et al., 2018a; Padullés Cubino et al., 2020). In general, these studies have found that front yards are often associated with ornamental landscaping and neighborhood visibility, whereas back yards may support greater vegetation density, recreational planting, and functional diversity. Locke et al. (2018b) describes this spatial differentiation as the “landscape mullet,” characterized by standardized front-yard vegetation and more heterogeneous backyard plant assemblages. Most of these studies use: 4-6 nested subplots in turf areas in residential front and back yards (Avolio et al., 2020b; Blanchette et al., 2021), nested subplots and whole yard surveys in residential parcels (Locke et al., 2018a; Padullés Cubino et al., 2020), or random fixed area plots across different parcels and land uses (Avolio et al., 2015 and 2020a). However, few studies measure all flora within residential parcels or yards (Reyes et al., 2026; Vila-Ruiz et al., 2014).

These previously mentioned studies primarily focus on measuring plant richness and diversity in front and back yards. Few studies exist that use whole yard field measurements to understand woody plant composition, structure, and ecosystem function-services and how these differ across residential parcels and among yard locations (Larson et al., 2016; Reyes et al., 2026). Accordingly, Larson et al., (2016) used a survey to test the urban homogenization hypothesis. The authors found that well-maintained and irrigated yards, with few exceptions, were important for cultural ecosystem services across residents of several U.S. cities. Reyes et al., (2026) found that native plants provided more cultural ecosystem services than non-native plants in residential yards as they increase charismatic urban insect and bird visitation. Otherwise, most other studies use random, multi-land use tenure, fixed area plots to characterize urban forest structure, composition and benefits (Avolio et al., 2015; Clarke et al., 2013; Escobedo et al., 2016).

Indeed, structural characteristics such as tree canopy dimensions, crown form, woody vegetation structure and woody plant diversity and composition directly influence ecosystem functions and subsequent services such as shade provision, thermal regulation, habitat complexity, and carbon storage (Bowler et al., 2010; Escobedo et al., 2016; Horn et al., 2015) and even wildfire hazard to homes (Norlen et al., 2026). Consequently, integrating structure and composition (i.e., number of different taxa, species richness, growth forms and nativity types) is

necessary to better understand how residential vegetation contributes to urban ecosystem functioning and subsequent ecosystem services (McPherson et al, 2017). Indeed, crown volume provides an important structural proxy for shade potential and ecosystem service provision because larger canopies can enhance cooling capacity, reduce solar radiation exposure, and improve overall quality of life in residential environments (De Guzman et al., 2022; Timilsina et al., 2014).

Similarly, soils are much less scientifically understood and considered in ecosystem service and sustainability studies than vegetation in urban ecosystems despite their strong determination of vegetation structure, ecosystem function, and human well-being in cities (Shankar, et al. 2024). Common issues with urban soils relative to their natural counterparts are greater compaction, lower organic matter, contamination with heavy metals, and overall destruction of profile development (Herrmann, et al., 2018; Pouyat, et al. 2010;). Further, urbanization greatly modifies soils by fragmenting the landscape into smaller, often irregularly shaped patches of impervious soil suitable for plant growth that results in a greater impervious area especially in resource poor communities (Berland, et al. 2025). The result is often a decrease in ecosystem services; however, specific site history, management, and which ecosystem function is creating a desired outcome mediates the impacts of urbanization on ecosystem services (Herrmann, et al., 2017; Ziter and Turner, 2018;). Therefore, the urban ecosystem and its above and belowground environment is highly heterogeneous across residential yards and parcels. As such this structure and composition, and function, need to be understood at relevant scales.

However, structural and compositional attributes of residential urban forests are often analyzed at city or neighborhood-level analyses, which limits the understanding of yard-level ecosystem service provision (Soto et al., 2018). Therefore, to better understand this structure-composition-function nexus in urban ecosystems, there is a need to account for home-level socio-economic dynamics and parcel-scale woody plant effects (Norlen et al., 2026). Additionally, different homeowner actions (Locke et al., 2018b), within-yard heterogeneity (Vila-Ruiz et al., 2014), planting space, and species–area relationships (Rosenzweig, 1995) need to be accounted for. Failure to account for variation in these social and ecological factors areas can confound local-scale interpretations of species richness, vegetation composition, and home-level ecosystem services across residential gradients (Reyes et al, 2026; Vila-Ruiz et al., 2014).

To address this, we studied residential parcel-scale (i.e., yards) urban forest structure, composition, and functional patterns using field measured tree, shrub and palm (i.e., woody plants hereafter) data across yard locations, soil types, and neighborhoods. This study's aim was to understand how yard location and socio-ecological factors influence urban forest structure, diversity, and ecosystem function -service potential in Los Angeles, California (US), a highly populated mediterranean, semi-arid city. Specifically, the study objectives are to first characterize parcel -level urban forest structure, composition, soils and ecosystem functional-service potential across residential homes and yards. Second, we examine how socioeconomic affluence, housing age, and yard size shape parcel-level urban forest composition and structure. And finally, we model the influence of these socio-ecological predictors on yard-scale tree shade potential.

2. Materials and Methods

2.1 Study Area and Field Sampling

Study area

The study area is the Los Angeles metropolitan area, located in the southern, coastal California in the United States (US; Figure A1). The study area has an elevation ranging from sea level to ~1000m but is adjacent to mountain ranges with elevation of up to ~3000m along its northern edge. Its Mediterranean climate is characterized by dry summers and precipitation that occurs in the winters with an average annual precipitation of 362mm and mean maximum and minimum temperatures ranging from 39 to 4 degrees °C and is described by McPherson et al. (2017) as the Southern California Coast climate zone type. Natural vegetation is coastal sage scrub, chaparral shrublands, however there are riparian and hillside woodlands, but most woody vegetation is planted (Avolio et al., 2015 and 2020). The study area has a population of ~18 million making it the second most populous urban area in the country (US Census Bureau 2020). The city is highly diverse with Hispanic, White, Asian and African American comprising 47%, 29%, 12% and 8% of its population, respectively (De Guzman et al., 2022).

Field measured sampling plots were selected using a series of 2 recruitment campaigns in 2024. First, a local Non-Governmental Organization (NGO), sent out a newsletter to the University of California Extension's Master Gardener program participants requesting volunteers to have soil and trees on their properties analyzed. Of the 38 volunteers, 25 residents were selected for soil sampling and 22 of these properties were sampled for both soils as well as trees, shrubs and palms. These 22 residents were then compensated with a pre-paid US\$20 gift card given the soil disturbance aspect of these measurements (See Soil Sampling Section below). A second request for no-compensation volunteers was sent out via the NGO's mailing list, requesting volunteers for an urban forest diversity study and to have their trees, shrubs, and palms measured and this resulted in 30 additional volunteers. Of these, 13 were selected if parcels were located in urban land use-covers, not greater than 1 ha, and safety and access were assured.

Tree, palm, and shrub measurements

Following methods outlined in Speak et al., (2018) and Escobedo et al., (2016) all perennial woody plants (i.e., trees, shrubs and palms) greater than 50 cm in height located on the parcel were identified and measured. In a clockwise manner beginning at the front yard of the house, all shrub, tree, and palm individuals across all yard locations were identified and measured. Refer to Section 2.6 for specific definition of the yard locations used in this study. Shrubs were differentiated from trees and palms if their diameter at breast height (DBH; 1.37 cm from ground surface) was less than 5.0 cm. Individuals were identified to the species or genera level using the PictureThis® application and crown diameters along a north-south and east-west axis were measured as were total heights. All tree and palm DBHs (cm) crown diameters (north and south axes) were measured as were Crown light exposure (amount of light received by the 5 sides of the tree crown: top, front, back, left and right), estimated dieback (%), and percent missing crown (%) using methods outlined in Speak et al., (2016) and Winn and Araman (2012).

Trees and palms with heights that were visually estimated to be less than or equal to the distance of those individuals relative to the residential homes were measured for distance and azimuth direction relative to the house. This included trees that were not on the parcel but in "other yards" as defined in Section 2.6 or trees in the street right of way, adjacent properties or alley ways. Crown width and distances for all trees and palms on the parcels and those that were accessible in "other yards" were measured to the nearest 0.1 m and total heights and crown base

heights were measured using a Nikon Forestry Pro II laser rangefinder/hypsometer (Nikon Vision Co., Ltd., Melville, NY, USA) and recorded in meters.

Soil sampling

Soil sampling was performed within residential parcels to characterize soil properties spatially across different patches, or discrete, pervious areas bounded by impervious surfaces (i.e., concrete, asphalt), significantly distinct non-soil ground cover (e.g., gravel, decomposed granite) or site boundaries (e.g., fences, walls). These patches were located according to yard location in the parcels (i.e., Front, Back, Side, and Other). Sampling depth for both in-situ and collected samples was constrained to the upper mineral soil layer (0-10 cm) where differences in biodiversity, carbon content, and soil fertility would be most pronounced (Delgado-Baquerizo, et al., 2017). See Appendix B (Soil Science Methods) for more details.

Six in-situ measurements were performed per patch including: temperature, electroconductivity, and moisture (as a % of available void space) were measured using a BlueLab Pulse fork-type analyzer calibrated to the specific soil type per manufacturer instructions. pH was measured using a GroStar GS2 Soil pH Pen Tester (Gen II), calibrated with pH 4, 7 and 10 calibration fluids according to manufacturer instructions. Soil compaction was measured using a plunger-type penetrometer, calibrated against a scale. Unsaturated hydraulic conductivity was measured twice per patch using a Meter Group Minidisk Infiltrrometer across a 20-minute interval maximum interval (unless steady-state was achieved sooner) on prepared and sand-leveled ground. Four bagged soil samples per patch were collected using a soil probe. Two identical samples corresponded to soil collected within 50 cm of the patch perimeter, and two identical bagged samples corresponded to soil collected at the center of each patch to reduce potential edge effects (Pouyat, et al., 2010). Each bagged sample consisted of five soil probe repetitions to improve intra-patch representativeness.

2.2 Urban Forest Structural Analysis

Yard level urban forest structure was characterized using DBH, height, and crown attributes. Only woody individuals with recorded DBHs excluding palms were used for tree-related analyses. Differences in mean DBH across parcel-level residential gradients (i.e.,

affluence, yard size, and housing age) were analyzed using two sample t-tests. Individual tree metrics were quantified using DBH, height, crown dimensions, and species richness. For multi-stemmed trees, an equivalent DBH (DBH_{eq}) was calculated following Magarik et al.,’s (2020) equation:

$$DBH_{eq} = \sqrt{\sum(d_i^2)} \dots\dots\dots (1)$$

where d_i represents the diameter of each individual stem.

Mean crown width (CW_{mean}) was calculated by averaging the east-west (CW_{EW}) and north-south (CW_{NS}) axes. In cases where only a single radius value was recorded for an axis, that value was assumed to represent the opposing direction to maintain symmetry following Peper et al., (2001).

$$CW_{mean} = \frac{(CW_{NS} + CW_{EW})}{2} \dots\dots (2)$$

Crown volume (V_c) was estimated by assuming a half-ellipsoid shape, where the vertical semi-axis corresponds to the crown height (H_c) and the horizontal semi-axes correspond to the mean crown radius (McPherson et al., 2016; Owen and Lines, 2024; Winn and Araman, 2012). The volume was calculated as:

$$V_c = \frac{2}{3} \times \pi \times \left(\frac{CW_{mean}}{2}\right)^2 \times H_c \dots\dots\dots (3)$$

Crown radius was estimated using formula:

$$(CW_{radius} = CW_{mean}/2) \dots\dots\dots (4)$$

Crown height (H_c) was determined by subtracting the total height to the crown base from the total tree height.

$$(CW_{height} = Total\ height - height\ to\ the\ crown\ base) \dots\dots (5)$$

Finally, tree condition was assessed by measuring the percentage of branch dieback per woody individual and the percentage of missing crown volume (Escobedo et al., 2016).

2.3 Socioeconomic and parcel classification

Residential parcels were classified into binary categories using median-split thresholds to facilitate comparative analyses of neighborhood vegetation patterns. Data for property value (\$), parcel lot size (sqft), building size (sqft), and year built were obtained from the county assessor's website using addresses and Assessor's Identification Numbers (AIN; Table A1). Yard area was calculated by subtracting building footprint area from total parcel lot size. Parcels exceeding the median value of US\$616,312 were subjectively classified as affluent. Median yard size was used to categorize large parcels as those greater than 442.404 m² and the median housing age (built in 1947) was used to classify homes as old. These binary variables served as explanatory variables for regression models for all composition, structure, soils, and ecosystem service analyses. Descriptive statistics for all parcel-level variables used in the classification procedure are presented in (Table A2).

2.4 Woody plant taxonomic and soil data

All species taxa were standardized and reconciled using information from the California Native Plant Society Calscape database (2026). Observations lacking species-level identification were retained at the genus level (e.g., *Quercus* spp.). A standardized taxonomic field was created for all statistical analyses, including species richness, composition modeling, and Beta diversity ("diversity" hereafter) as measured using the Jaccard similarity index (Chung et al., 2019) and pairwise compositional similarity among neighborhoods. Taxa were classified as native and non-native (California Native Plant Society, 2026). Sampled individuals with a measured DBHs were categorized as trees or palms; as opposed to shrubs which had no DBHs. Patch-level soil data (n=22) were aggregated to the residential parcel level and location prior to statistical analysis. Mean values were calculated for each soil variable and linked to vegetation, parcel, and socioeconomic datasets using residential address identifiers. We define composition in subsequent analysis as the number of different taxa, or species richness, as well as different growth forms and nativity types found across the different parcels.

2.5 Ecosystem function-service potential and yard characteristics

All tree, shrub, and palm taxa were classified into four ecosystem service groups: provisioning, regulating, supporting, and cultural (Soto et al., 2018; USDA, 2026; Native West Nursery Plant database, 2026). For species with multiple documented functions, we used the highest-ranked ecosystem service from the Global Useful Native Trees database (Kindt et al.,

2023) and most frequently documented or most ecologically and economically significant service. Given the study area's warm, semi-arid climate and the importance of tree shade as a highly valued ecosystem service in Los Angeles (De Guzman et al., 2022; McPherson et al., 2017), we used potential tree shade as our representative and site-specific, yard-level ecosystem service for subsequent analysis. Specifically, we used tree crown volume as our proxy for potential tree shade using Timilsina et al.,'s (2014) approach. Palms were excluded from subsequent shade potential analyses given their crown characteristics.

Yard location was categorized into four primary zones: front, back, sides, and other. Observations recorded as "left" or "right" were grouped into the side yard category. The "other" included alleys, streets, trees on neighboring properties, corner lots, and any site-specific yard designations not explicitly defined as front, back, or side. Since larger residential yard areas will likely have a greater number of species, yard area was accounted for to address potential species–area effects and differences in planting intensity across parcels. Accordingly, a species accumulation curve was developed using cumulative species richness across sampling observations (Figure A2). Since species accumulation curves are influenced by sampling effort and sampled area, yard area was incorporated into subsequent analysis to account for variation in parcel size and planting space among residential properties. Yard-area classes were then used for subsequent statistical analyses. However, given differing areas of the sampled parcels, species richness density was calculated as the number of unique species per unit yard area (species m⁻²) to account for differences in yard area among residential properties.

$$\text{Species Richness Density} = \frac{\text{Species richness}}{\text{Yard Area (m}^2\text{)}}$$

2.7 Statistical Analysis

Tree crown volume (m³), was used as a proxy for potential shade service provision. Tree crown volume was log-transformed prior to analysis to reduce right-skewness and improve normality of residuals. Mean crown width and diameter at breast height (DBH) variables were square root transformed to stabilize variance and improve linear model assumptions. Socioeconomic variables were derived from 2024 American Community Survey (ACS) 5-year estimates at the census block group level and spatially linked to sampled parcels using Census GEOIDs (U.S. Census Bureau, 2024a, 2024b). Ordinary Least Squares (OLS) regression was

used to evaluate the relationships between crown volume and parcel-level, structural, and neighborhood socioeconomic predictors. Predictor variables included yard characteristics, housing attributes, educational attainment, household composition, occupancy patterns, and demographic variables derived from ACS 5-year census block group estimates. See Appendix B (Statistical Analysis Methods) for more details.

3. Results

3.1 Residential urban forest structure, composition, and soils

A total of 2,303 individuals were measured including 1,676 shrubs, 594 trees and 33 palms (n=35 yards). Of these, 620 individuals that included both trees and palms had valid DBH measurements and were included in structural analyses (Table 1). Overall, 427 unique taxa were identified including 325 shrub taxa, 95 tree taxa and 7 palm taxa across all sampled yards.

Number of trees per parcel did not differ significantly between affluent and less affluent neighborhoods ($p = 0.459$). Conversely, the number of tree-shrub-palm individuals was related to yard-size and neighborhood age (both $p < 0.001$), with some categories supporting more than three times as many individuals as others (Table 1 and Appendix Table C1).

Table 1. Summary of tree and palm structural and condition metrics across residential gradients in Los Angeles, USA. Note: "NS" denotes non-significant differences ($p > 0.05$). Arrows ($\uparrow$) and greater-than symbols ($>$) denote significantly higher values in the first group listed.

Variable	Affluence	Yard size	Median age
Diameter at Breast Height	$\uparrow$ Affluent	NS	NS
Height	$\uparrow$ Affluent	Small > Large	New > Old
Crown size	$\uparrow$ Affluent	Large > Small	Old > New
Dieback	NS	Large > Small	Old > New
Crown Missing	$\uparrow$ Affluent	NS	NS
Crown Light Exposure	NS	NS	New > Old
Crown Base Height	$\uparrow$ Affluent	NS	New > Old
Distance from Building	NS	NS	New > Old

Descriptive statistics for soil characteristics (n=22) are shown in Table 2. In total, 315 unique observations were taken for each soil property measured except for pH which had 278 unique observations (Table 2). Overall, across all soil properties, substantial variation was observed but characteristics should be related to ecosystem services provision. This is especially true for soil moisture which, while more dynamic than the other soil properties (Table 2), can vary substantially with management in drier climate cities like Los Angeles where irrigation is common.

Table 2. Descriptive Summary of Soil Characteristics in Residential Yards in Los Angeles, USA (n=22).

Variable	Obs	Mean	Std. dev.	Min	Max
Soil Temperature (C)	315	17.96	3.28	14.34	30.63
Electroconductivity (μS)	315	1.36	0.28	0.23	1.71
Moisture content (% void space)	315	55.46	21.94	0.58	87.82
Soil pH	278	6.95	0.30	5.28	7.29
Dry bulk density (g cm^{-3})	315	1.29	0.16	0.96	1.51
Soil Organic Matter (%)	315	5.59	2.24	2.24	11.85
Hydraulic conductivity (cm hr^{-1})	315	1.46	0.87	0.19	5.23

Tree-Palm Proximity to Homes and Tree Condition

Mean distance between trees and residential homes did not differ significantly according to affluence (5.43 vs. 5.72 meters; $t = -0.46$, $p = 0.645$) or yard-size ($p = 0.506$). However, woody individuals in newer, as opposed to older, neighborhoods were significantly farther from residential buildings (6.44 vs. 4.71 meters; $t = -2.84$, $p = 0.005$). Yard types differed significantly according to affluence ($\chi^2 = 38.0$, $p < 0.001$) and neighborhood age ($\chi^2 = 55.8$, $p < 0.001$), while the association with yard size was marginally significant ($\chi^2 = 7.77$, $p = 0.051$). In particular, the “Other” yard-position category was concentrated in affluent (84.9%) and newer (79.3%) residential parcels (Appendix Table C2). See Appendix C for more results on residential urban forest structure, composition, and soils as well as tree-palm proximity to homes and tree condition findings.

Urban Forest Composition and Beta Diversity

Native species were more frequent in affluent ($\chi^2 = 90.1$, $p < 0.001$), larger ($\chi^2 = 34.1$, $p < 0.001$), and older parcels ($\chi^2 = 128.3$, $p < 0.001$). Tree, shrub, and palm frequency also

significantly differed according to affluence ($\chi^2 = 11.85$, $p = 0.003$), yard size ($\chi^2 = 10.52$, $p = 0.005$), and neighborhood age ($\chi^2 = 15.25$, $p < 0.001$). Species composition, however, varied significantly between socioeconomic groups. Species richness differed between affluence classes (Figure 1). Affluent parcels exhibited greater species richness counts (raw richness), with higher median richness values and a broader range of species counts than non-affluent parcels (Figure 1; left). However, when standardized by yard area and expressed as species richness density (species per 100 m²), non-affluent parcels exhibited higher richness density than affluent parcels (Figure 1; right).

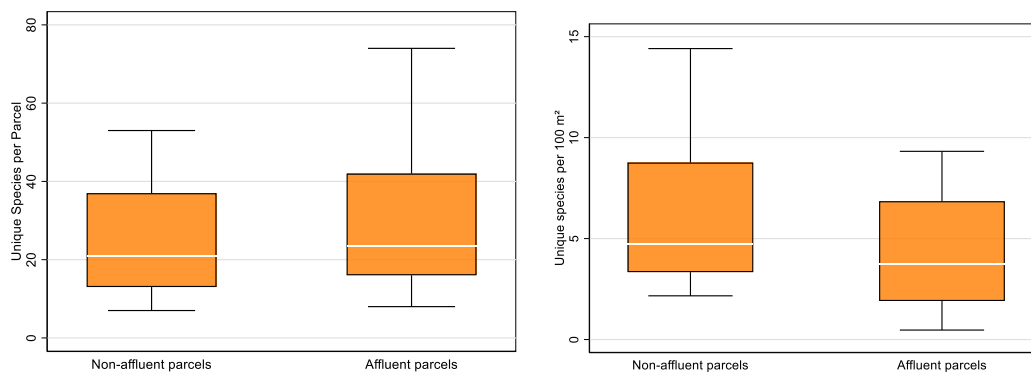


Figure 1. Species richness patterns across affluent and non-affluent residential parcels. Parcel-level species richness (left) and species richness density (right) by affluence class in Los Angeles USA.

Species richness according to property value and tree crown volume

The fitted relationship between property value and species richness was positive in affluent neighborhoods and weaker in non-affluent neighborhoods (Figure 2). But species richness varied widely within neighborhood types, indicating within-group heterogeneity. Species richness counts show a weak positive association with log-transformed property value in affluent parcels but a weak relationship in non-affluent parcels (Figure 2; left). Considerable variability in species richness was observed across the range of property values in both groups. In contrast, species richness density (i.e., standardized richness) exhibited a weak negative association with log-transformed property value in affluent parcels versus no clear trend in non-affluent parcels (Figure 2; right).

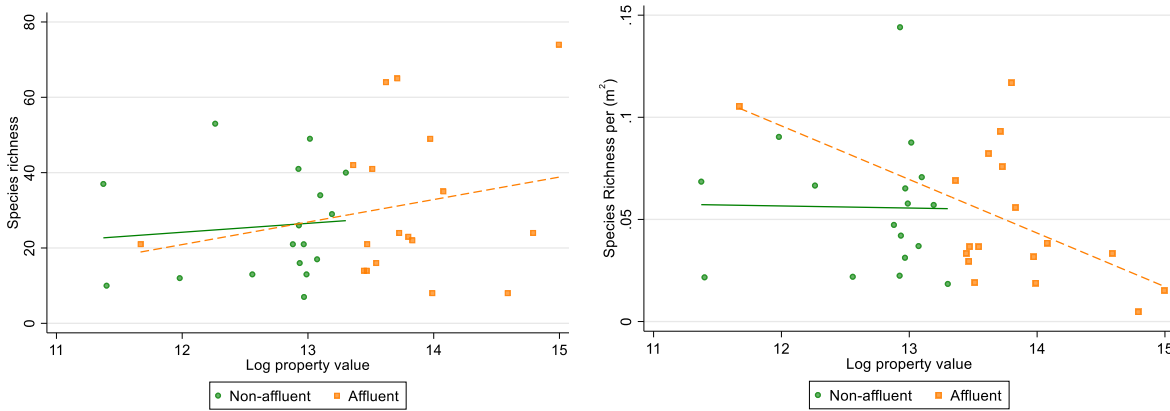


Figure 2. Relationships between log-transformed property value and species richness counts (raw richness) (left) and species richness density (standardized richness) (right) across affluent and non-affluent residential parcels in Los Angeles USA.

3.2 Urban Forest Structure, Composition, and Beta Diversity According to Yard Location

Urban forest structure and composition varied across residential yard locations (Table 3). Overall, trees were most common in front yards (12.3%) but shrubs were the most common woody plants in all locations. (Figure A4). Palms constituted only a minor component of the vegetation community across all yard positions, with the highest proportional occurrence in back (0.7%) and front yards (0.6%). Collectively, front and back yards accounted for most recorded individuals within residential landscapes, whereas side yards contributed comparatively little to overall vegetation composition. The “other” yard category included vegetation associated with areas adjacent to residential parcels, which likely contributed to greater number of individuals relative to side yards alone. Affluent neighborhoods exhibited higher median tree crown volumes in back and side yards compared to non-affluent neighborhoods. Side yards in affluent neighborhoods showed the highest size and crown characteristics compared with other yard locations. (Figure A5).

Table 3. Mean ($\pm$ SD) tree and palm structural and compositional attributes by yard location

Yard Location	Stats	Richness	DBH (cm)	Total height (m)	Mean Crown width (m)	Crown volume (m ³)
Back	mean	38.62	4.52	2.76	2.37	93.71

	Sd	17.97	10.19	3.34	2.45	206.56
	n	965.00	965.00	945.00	943.00	255.00
Front	mean	45.75	3.88	2.47	2.11	197.92
	Sd	21.79	11.39	3.42	2.38	732.44
	n	889.00	889.00	887.00	873.00	157.00
Side	mean	36.19	3.99	2.33	2.00	66.04
	Sd	19.17	10.18	2.55	1.91	206.95
	n	393.00	393.00	389.00	377.00	96.00
Other	mean	32.66	29.43	11.25	8.67	775.72
	Sd	13.95	29.82	9.56	4.55	1293.77
	n	53.00	53.00	53.00	51.00	36.00

Species richness patterns varied among yard positions and affluence classes (Figure 3). Affluent parcels generally supported higher species richness counts, particularly in back yards. However, after standardizing richness by yard area, these differences were reduced, suggesting that higher richness in affluent parcels was partly attributable to larger yard sizes rather than greater species density alone (Figure 3, right).

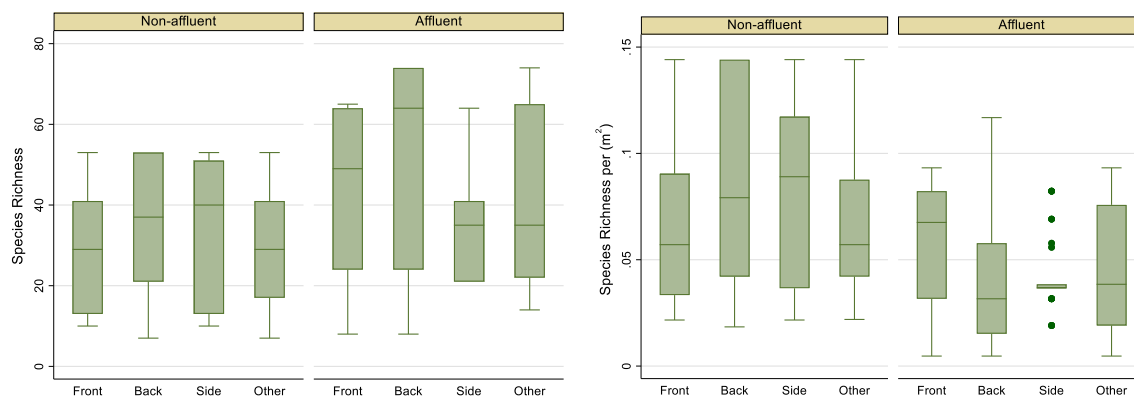


Figure 3. Species richness by residential yard position across affluent and non-affluent neighborhoods. Species richness counts (left) and species richness density (species richness standardized to area; right) are shown for front, back, side, and other yard positions.

3.3. Affluence, Housing Age, and Yard-level Influence on Composition, Diversity and Ecosystem Service Potential

Beta Diversity

Beta diversity varied according to residential gradients, with Jaccard similarity indices indicating relatively limited overlap in species assemblages between comparison groups. Affluence-based comparisons yielded a Jaccard similarity index of 0.317, with 170 taxa unique to affluent parcels and 121 unique to non-affluent parcels. Yard-size comparisons produced an index of 0.310, where large yards supported 190 exclusive taxa compared to 104 in small yards. Housing age comparisons exhibited the lowest compositional similarity (0.286), with 202 taxa unique to older homes and 102 unique to newer homes.

Ecosystem Function-Service Potential

Tree-related cultural ecosystem service potential types were most common across all yard locations (Figure 4), with back yards providing the most (21.2%), followed by front yards (17.3%). Regulating services followed, with most in front yards (12.4%), while provisioning and supporting services potential was less frequent. Ecosystem service potential differed significantly across affluence classes ($\chi^2 = 10.62$, $p = 0.014$) and yard-size categories ($\chi^2 = 15.93$, $p = 0.001$).

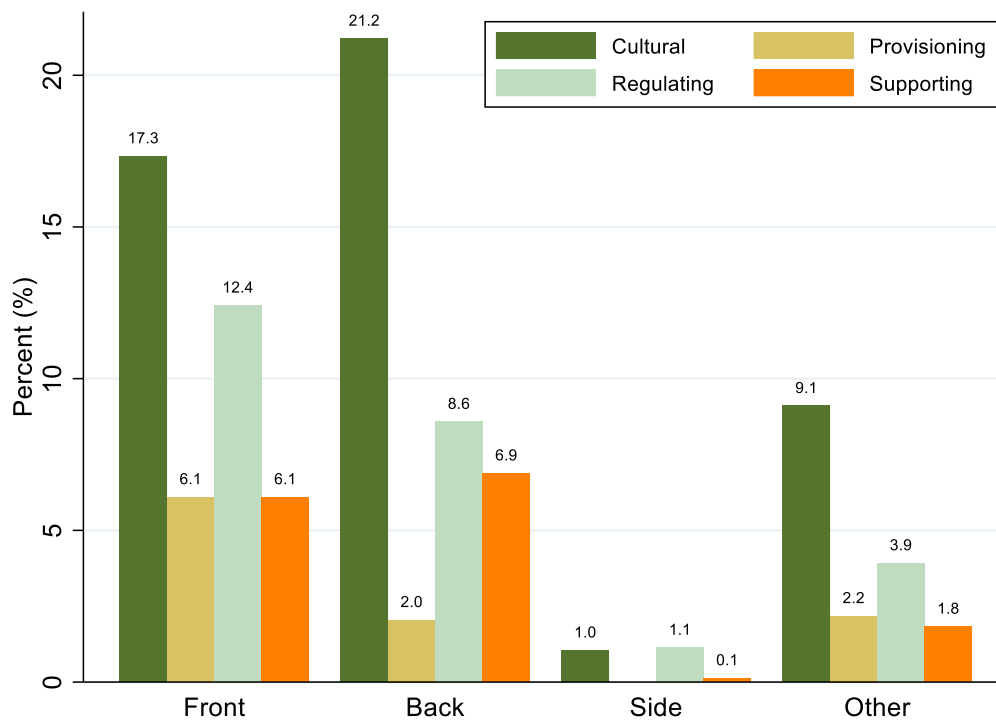


Figure 4. Distribution of ecosystem service utility categories (cultural, regulating, provisioning, supporting) by residential yard position. Values represent the percentage of total observations within each service category and location.

3.4 Socio-Ecological Predictors of Shade Potential

Soil and Tree Predictors of Residential Shade Potential

According to Table 4, Soil organic matter ($p < 0.001$), dry bulk density ($p < 0.001$) and nutrient status (i.e., electroconductivity $p < 0.001$) were the properties with the most significant and positive relationship with tree shade potential. As expected, DBH exhibited a significant positive relationship with tree shade potential ($p = 0.001$) and multi-stemmed trees also showed significantly greater shade potential than single-stemmed trees ($p = 0.018$; Table 5). Total tree height ($p < 0.001$) and % dieback ($p = 0.001$) also showed a positive relationship with shade potential; but, as expected, % missing crown significantly reduced tree shade potential ($p = 0.009$).

Table 4. Multiple Linear Regression Model of Soil Quality Predictors of Residential Shade Potential (n=22 parcels).

Description of Variables	Coefficient	Std. Err.	t	P>t	[95% conf. interval]
Soil pH	1.179789	0.367763	3.21	0.002	0.455124 1.904455
Soil Organic Matter (%)	0.5380407	0.085088	6.32	0.000	0.370378 0.705703
Moisture content (% void space)	0.0232179	0.010746	2.16	0.032	0.002043 0.044393
Dry Bulk Density (gcm ³)	4.791036	1.304554	3.67	0.000	2.220452 7.36162
Electroconductivity (μS)	-4.092025	1.21982	-3.35	0.001	-6.495643 -1.688408
Hydraulic Conductivity (hr)	-0.2375698	0.132055	-1.8	0.073	-0.497781 0.022641
Constant	-9.107361	2.627942	-3.47	0.001	-14.28564 -3.92908

R² 23%, Mean VIF 4.73, AIC 806.6207, BIC 830.8079

Table 5. Multiple Linear Regression Analysis of tree Structural Predictors of Log Transformed Crown Volume for trees only (Shade Potential – Palms excluded)

Description of Variables	Coefficient	Std. Err.	t	P>t	[95% conf. interval]
DBH (cm)	0.0132567	0.003805	3.48	0.001	0.005781 0.020732
Multi-stem trees	0.2125233	0.089538	2.37	0.018	0.036594 0.388453
Mean crown diameter (m)	0.0116779	0.001164	10.03	0.000	0.009391 0.013965
%Die Back	0.0130558	0.004008	3.26	0.001	0.005181 0.02093

%Crown Miss	-0.0066435	0.002545	-2.61	0.009	-0.011644	-0.001643
Crown Light Exposure	-0.011863	0.020573	-0.58	0.564	-0.052286	0.02856
Total Height (m)	0.141337	0.011614	12.17	0.000	0.118517	0.164157
Crown Base Height (m)	-0.1697239	0.031382	-5.41	0.000	-0.231384	-0.108064
Constant	2.255555	0.11811	19.1	0.000	2.023487	2.487624

R² 67.52%, Mean VIF 1.86, AIC 1347.7, BIC 1385.54

Socioeconomic and Parcel-Level Predictors of Residential Shade Potential

Building distance to trees was the strongest positive predictor of tree shade potential ($p < 0.001$), but affluence ($p = 0.005$) and yard size ($p = 0.005$) were also positively related. Housing age ($p = 0.001$) and % owner-occupied ($p = 0.002$) exhibited a significant negative relationship. In contrast, residential stability, measured as the percentage of residents living in the same house one year prior, was not significantly associated with crown volume ($p = 0.923$). Also, residents with undergraduate ($p = 0.001$) and graduate degrees ($p = 0.006$) were associated with increased tree shade potential. Areas with greater white populations exhibited a weak negative association with shade potential ($p = 0.031$).

Table 6. Multiple Linear Regression Model of Socioeconomic and Parcel-Level Predictors of Residential Shade Potential-palm excluded

Description of Variables	Coefficient	Std. Err.	t	P>t	[95% conf. interval]
Affluence	0.669104	0.236439	2.83	0.005	0.203324 1.134884
Housing age	-0.735691	0.22312	-3.3	0.001	-1.175233 -0.29615
Yard size	0.627207	0.222517	2.82	0.005	0.188853 1.065561
Building to tree distance (m)	0.173677	0.015469	11.23	0.000	0.143204 0.204151
Owner occupied (%)	-0.026108	0.008354	-3.13	0.002	-0.042564 -0.009651
Stability (%)	-0.00239	0.024623	-0.1	0.923	-0.050895 0.046116
High school (%)	0.042362	0.022732	1.86	0.064	-0.002418 0.087143
Undergrad (%)	0.058969	0.016984	3.47	0.001	0.02551 0.092428
Graduate (%)	0.057244	0.020538	2.79	0.006	0.016786 0.097703
Family households (%)	0.023242	0.007998	2.91	0.004	0.007486 0.038998
White (%)	-0.018166	0.008397	-2.16	0.031	-0.034707 -0.001625
AIAN (%)	0.318097	0.052113	6.1	0.000	0.215436 0.420758
Constant	0.118625	2.168161	0.05	0.956	-4.152612 4.389861

R² 48.71%, Mean VIF 3.38, AIC 865.74, BIC911.57

Discussion

We explored how yard location, socioeconomic and ecological factors across different properties influenced urban forest structure, diversity, and potential ecosystem service provision. Our whole-yard woody plant inventories, soil sampling, ecosystem services accounting protocols present an interdisciplinary approach for measuring residential parcel-scale urban forests. Findings show how woody plant structure and composition vary across front, back and side yards and how these and other site and socioeconomic factors and yard-level soils influence the level of tree shade and other ecosystem services and disservices provided to homes in Los Angeles, California (US). Below, we show how our findings have implications for urban forest planning and management, Nature-Based Solutions, and understanding the role of woody plants in community well-being and even wildfire hazard implications (i.e., ecosystem disservices; De Guzman et al., 2022; Berland et al., 2025; Norlen et al., 2026).

Studies from throughout the US and in Mediterranean climate cities, including from our study area, show that affluent neighborhoods and homes generally have greater urban forest cover and tree density (Clarke et al., 2013; Escobedo et al., 2016) as well as overall plant diversity (Avolio et al., 2015 and 2020b; Blanchette et al., 2021). We found that number of trees per parcel did not differ significantly between affluent and less affluent neighborhoods ($p = 0.459$; Appendix Table C1). In contrast, woody plant types differed significantly by yard size ($\chi^2 = 10.52$, $p = 0.005$) and neighborhood age ($\chi^2 = 15.25$, $p < 0.001$; Appendix Table C2). Tree crown volume increased slightly and weakly ($R^2 = 0.026$) with species richness, indicating that species-rich parcels did not necessarily support substantially larger tree crowns (Figure 4). Considerable variability in crown volume was observed across the full range of species richness values.

Tree, shrub, and palm frequencies, as well as native species occurrence, differed significantly according to affluence, yard size, and neighborhood age. In Los Angeles, Clarke et al. (2013) found that older and affluent neighborhoods had the highest tree species richness, while new, non-affluent neighborhoods had the lowest. Also in Los Angeles, Avolio et al., 2020a found that cultivated areas had more than two times the number of plant species than adjacent, remnant natural areas. In San Juan, Puerto Rico, Vila-Ruiz et al., (2014) found 383 woody species across 424 yards and shrubs were the most common growth form and nearly 70% of all woody species were non-native ornamentals. We found that native species were more frequent in affluent, larger, and older parcels (Appendix Table C2). Older neighborhoods were characterized by

higher trees and shrub frequency, whereas newer ones have higher palm frequency (Appendix Table C2).

Our woody plant composition and beta diversity findings corroborate these previous studies by showing that affluent and non-affluent neighborhoods support distinct plant assemblages (Appendix Table C3). Affluent parcels were characterized by higher species richness counts and a greater number of unique taxa (Figure 1; Appendix Table C3). However, when standardized for growing area (i.e., standardized richness per m²) we found that non-affluent parcels exhibited higher species richness densities. Thus, larger yards, that are more common in affluent areas, support a substantially higher number of unique species, contributing to distinct assemblages compared to those found in smaller residential parcels (Avolio et al., 2020b; Appendix Table 3). But lower species richness densities found in our sampled yards suggest that affluent yards have fewer species per unit area (Figure 1) and that older residential parcels support a larger and more distinct pool of unique taxa compared to newer developments (Appendix Table C3).

Similarly, non-affluent parcels frequently exhibited comparable or greater species richness density across different yard locations, suggesting a higher concentration of species per unit area despite supporting fewer species (Figure 3). These results indicate that affluent parcels tend to support greater total species richness, whereas non-affluent parcels often maintain higher species richness density within available planting space. At first glance these findings corroborate the “luxury effect” or “ecology of prestige” theories where affluent residential parcels tend to support greater overall plant diversity (Avolio et al., 2020b; Clarke et al., 2013). However, richness density analysis suggested otherwise; that smaller or more intensively planted parcels, common in non-affluent area, may contain higher concentrations of species per unit area (Figure 2).

The range of conditions and heterogeneity in soil characteristics reveal differences in woody plant structure across the parcels and socioeconomic gradients (Table 4). Berland et al. (2025) found that Los Angeles neighborhoods with greater social vulnerability had less available growing space and that individual patches of soil were smaller, creating conditions for greater damaging edge effects on soil. Further, it appeared that soil quality was more degraded in smaller patches relative to larger patches creating a mechanism in which less soil area reinforces social inequity through greater potential for soil compaction and other negative built environment interactions.

Previous research has identified neighborhood-scale variation in urban vegetation associated with income, housing age, and spatial context (Avolio et al., 2015; Avolio et al., 2020b; Blanchette et al., 2021; Clarke et al., 2013;). These studies consistently show that socioeconomic factors, particularly income and related measures of affluence, shape urban plant diversity, vegetation composition, and distribution, although the strength of these relationships varies across cities and spatial scales. Despite this neighborhood-level evidence, less is known about how such patterns emerge at finer residential parcel and yard-position scales. Our study provides additional information on how parcel-scale woody plant structure and diversity vary according to yard type and location. We found that yard types differed significantly according to affluence ($\chi^2 = 38.0$, $p < 0.001$) and neighborhood age ($\chi^2 = 55.8$, $p < 0.001$), whereas yard-size differences were marginally significant ($p = 0.051$). The “Other” yard-position category, representing locations outside the conventional front, side, and back yard classifications, occurred disproportionately in affluent and newer residential parcels (Appendix Table C2).

Locke et al., (2018a) studied yards across 7 US cities and found that front yards had significantly fewer plant species than back yards. Vila Ruiz et al., (2014) also found that in a more tropical context, front yards had more non-native ornamental species per unit area. Indeed, Locke et al., (2018b) found that social factors and maintenance practices are not evenly expressed across front and back yards. Padullés Cubino et al., (2020) found that homeowners priorities for “natural landscapes” across 7 US cities including Los Angeles, did not actually relate to the actual measured percentages of native plants in people’s yards. We found that tree frequency in front, back, other, and side yards was 12.3%, 7.1%, 4.3%, and 2.0%, respectively (Figure A4). Similarly, Compositional analyses showed that 170 species were exclusive to affluent parcels and 121 were exclusive to non-affluent parcels. Beta diversity findings show that housing age showed the lowest similarity at 0.286, with 202 taxa exclusive to older homes and 102 to newer homes, suggesting that older landscapes maintain more distinct species.

As opposed to vegetation in natural areas, homeowners plant and maintain for a yard-scale woody plant structure and composition that favors cultural ecosystem services more so than regulating or provisioning ecosystem services (Soto et al., 2018; Figure 8). Other studies in Los Angeles (Avolio et al., 2020a) and in 6 US cities including Los Angeles (Larson et al., 2016), have also observed this same trend. That said, Larson et al., (2016) found that regulating ES related to

thermal regulation was more important in warm southern US cities. De Guzman et al., 2022 also found tree shade was a highly valued tree-related ecosystem service in Los Angeles. Overall, we found that woody plant related cultural ecosystem services were also most common in back yards, whereas regulation and provisioning ecosystem services were most common in front yards (Figure 8). But when modeling for how social-ecological factors influence tree shade potential at the yard-level, we found that as expected, residential shade potential is primarily driven by soil nutrient status, tree size, crown architecture, and structural characteristics (Table 4 and 5). Also, larger residential parcels supported greater shade potential and increased spacing between vegetation and built infrastructure facilitates canopy expansion (Table 5 and Appendix Table C1).

Soil properties alone predicted tree shade potential despite being indirect factors related to vegetation structure factors. However, “better” soil quality values were not necessarily associated with greater tree shade potential. Rather, tree shade potential and soil properties were co-developed. For example, higher soil organic matter and moisture content corresponded with greater tree shade potential indicating the development of soil through leaf litter and a potentially moderating effect of shade on evaporation which in turn can benefit tree growth and health (Table 4). Perhaps surprisingly, though, more compacted soil, lower infiltration rates, and less nutrient availability corresponded with greater shade potential. Using a plant-soil interaction lens, shading from trees may be competing with fine-rooted understory plants that would provide protection of the surface as well as maintain porosity and drive nutrient cycling in surface soils. Shading in urban environments has been shown to decrease productivity of lawns by more than half (Herrmann and Cadenasso, 2017). As such, here we demonstrate a soil development mechanism whereby ecosystem services of trees can create tradeoffs with services that can be provided by understory vegetation; which was not sampled.

Soto et al., (2018) point out that yard-level homeowner decisions and values are complex and there will be tradeoffs associated with the multiple functions associated with woody plants and context-specific factors such as water scarcity and increased fire hazard from dense, dry vegetation near homes (Norlen et al., 2026). Although wildfire mitigation-related ecosystem functions are little studied (Escobedo et al., 2025) found that woody vegetation type, condition and proximity to homes in southern CA was related to home survival during fire events. Thus, our urban forest structure, composition, condition and tree distance to home findings (Appendix Table C1; Table C2; Table 5) also have implication for such fire-related ecosystem disservices.

Escobedo et al., (2025) found that woody vegetation type and moisture condition was related to home loss and survival during fire events in southern CA US. Additionally recent urban fire hazard policies recommend that all “vegetation” within 2 meters of homes be removed in high fire hazard areas (i.e., Zone 0 policy; Norlen et al., 2026).

Furthermore, we found that socioeconomically, affluence ($p = 0.005$) was positively related to tree shade potential but housing age ($p = 0.001$) and interestingly, % owner-occupied ($p = 0.002$) exhibited a significant negative relationship (Table 6). Residential stability, measured as the percentage of residents living in the same house one year prior, was however not significantly associated with tree shade potential ($p = 0.923$). Finally, residents with undergraduate and graduate degrees were associated with increased shade potential; but areas with greater white populations exhibited a weak negative relationship ($p = 0.031$). Thus, our findings corroborate those of other studies such as those of Avolio et al., (2020a) and Larson et al., (2016).

That said, we do note some study limitations. First, our study is based on a sample size of 35 yards, however all woody plant individuals and palms were measured across yard locations. Further, our sample size is in-line with other studies from Los Angeles such as Reyes et al., (2026) who measured 31 yards, and Avolio et al., 2015 who measured 10, 0.04 ha plots. Second, we estimated yard area indirectly from parcel boundaries and building footprint data and therefore this does not represent pervious, plant available growing space within residential properties. Impervious and non-vegetated surfaces such as driveways, sidewalks, patios, paved areas, pools, and other built landscape features were not quantified or excluded from the yard area estimates. And third, we did not measure forbs or other ground cover types that can compound residential plant richness (Herman et al., 2017) and modulate the provision of some ecosystem services.

Conclusion

This study integrates a yard-scale multivariate diversity structural morphology analysis—including nativity and condition—within a single analytical framework, following approaches used to link forest structure and composition to ecosystem services. By using a socio-ecological lens to analyze how compositional turnover and vegetation structure influence structural proxies

of ecosystem services (i.e., tree shade potential), the study improves our understanding of how residential yard patterns correspond to societally relevant urban ecosystem services and disservices (e.g., fire hazard).

Overall, tree species richness patterns largely reflect those found in other studies that focused on portions of residential yards and landscapes. Notably, shrubs species, an often-neglected component of urban forest studies, notably contributed to the compositional makeup of residential woody flora. Despite being often small, yards in less affluent areas had a relatively high species density, thus enhancing human exposure to urban nature and its health and wellbeing benefits. Interestingly, the different composition across yards at different affluence levels can present new opportunities for strategic planting and the prioritization of taxa to increase exposure to specific woody plant species and assemblages.

Tree shade for climate regulation is a highly valued ecosystem service in semi-arid Mediterranean cities including in our study area. Although city-level tree planting initiatives and tree cover ordinances are important for achieving this benefit, here we show that private, yard-level social and ecological factors need to be accounted for when considering the role of tree shade and its role in improving home-level and individual human thermal comfort. Accordingly our approach and parcel-level – and yard location- finding on how soils and woody plant diversity and structure influence shade potential are key factors that need to be accounted for. Future studies could use such yard-level and location approaches to measure climate regulation using field instruments or simulation modeling. An additional contribution of this study is that findings and methods can be used to better understand how yard-scale urban forest composition and structure can influence home survival or loss in high fire hazard environments. For example, trees in newer, as opposed to older, neighborhoods were significantly farther from residential buildings. This implies that shrub location and tree crowns over homes are probably of more concern than tree stems alone. And finally, % tree dieback (i.e. potential fuels) was greater in larger, older yards versus smaller and newer ones. Thus, parcels with dense woody plants in older, larger yards appear to be more relevant for identifying potential fire hazards.

In conclusion, our findings show a high diversity of woody plant growth forms, densities, and taxa, and these significantly differ according to affluence, yard size/location, neighborhood age and even socio-demographics. Accordingly, care is warranted when using “vegetation” as

criteria for management, since woody plants in our study area were far too heterogeneous and diverse to group into one category. These findings highlight the importance of considering both woody plant diversity and yard location when planning and managing residential vegetation. Differences across front, back, side, and other yard positions indicate that vegetation structure and composition are not distributed uniformly within residential parcels. Urban greening strategies should therefore move beyond parcel-level vegetation totals and consider where woody plants are located, as yard position may influence opportunities for canopy development, species diversity, and associated ecosystem services. Maintaining a diverse mixture of trees, palms, and shrubs across available yard spaces may help strengthen the ecological function and resilience of residential landscapes.

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Appendices

Table A1. Summary of Datasets, Variables, Sources, and Analytical Applications Used in the Study

Data Type	Variables / Metrics	Source	Description / Usage
Residential parcel data	Parcel lot size, building footprint area, year built, Assessor's Identification Number (AIN), address verification	Los Angeles County Assessor's Office/ Portal	Used to derive parcel-level structural variables and residential classifications
Derived parcel metric	Yard area	Calculated from parcel data	Calculated as total parcel lot size minus building footprint area
Field vegetation inventory	Species identity, DBH, crown width, crown base height, total height, crown condition, dieback, crown missingness, multi-stem status	Field survey measurements from residential yards	Used for vegetation structure, shade potential, richness, abundance, and crown volume analyses
Soil quality data	Soil quality indicators and field soil measurements collected from sampled residential yards	Field soil sampling from residential yards	Used to evaluate relationships between residential shade potential and soil conditions
Vegetation structural classification	Trees, palms, shrubs	Field DBH records and taxonomic identification	Species with DBH measurements classified as trees/palms; remaining woody vegetation classified as shrubs
Species taxonomy and native status	Native vs non-native status	USDA NRCS PLANTS Database; California Native Plant Society	Used to verify taxonomy, California occurrence, and native distribution
Ecosystem service classification	Provisioning, regulating, supporting, and cultural functional groups	Millennium Ecosystem Assessment (2005)	Used to classify taxa into ecosystem service categories
Useful species classification	Human-use categories for useful trees	Global Useful Native Trees (GlobUNT) database	Used to cross-check useful tree classifications and documented uses
Neighborhood socioeconomic variables	Median household income, median home value, owner occupancy, renter occupancy, educational attainment, family households, residential stability, population metrics	2024 ACS 5-year estimates	Block group socioeconomic characteristics spatially linked to residential parcels using GEOIDs
Census geographic identifiers	Census tract, block group, census block, GEOID	U.S. Census Geocoder	Used to spatially assign socioeconomic variables to residential parcels

Table A2. Descriptive Statistics for Residential Parcel Variables Across Sampled Yards

Parcel Variables	Obs	Mean	Std. dev.	Min	Max
Property Value (\$)	35	772145.5	684828.9	86957	3251736
Parcel lot (ft ²)	35	10265.4	12254.32	4375	57120
Building footprint (ft ²)	35	1604.77	711.12	600	3330
Yard Area (ft ²)	35	8660.62	11903.44	2272	54975
Year Built (Years)	35	1945.2	17.00	1907	1980

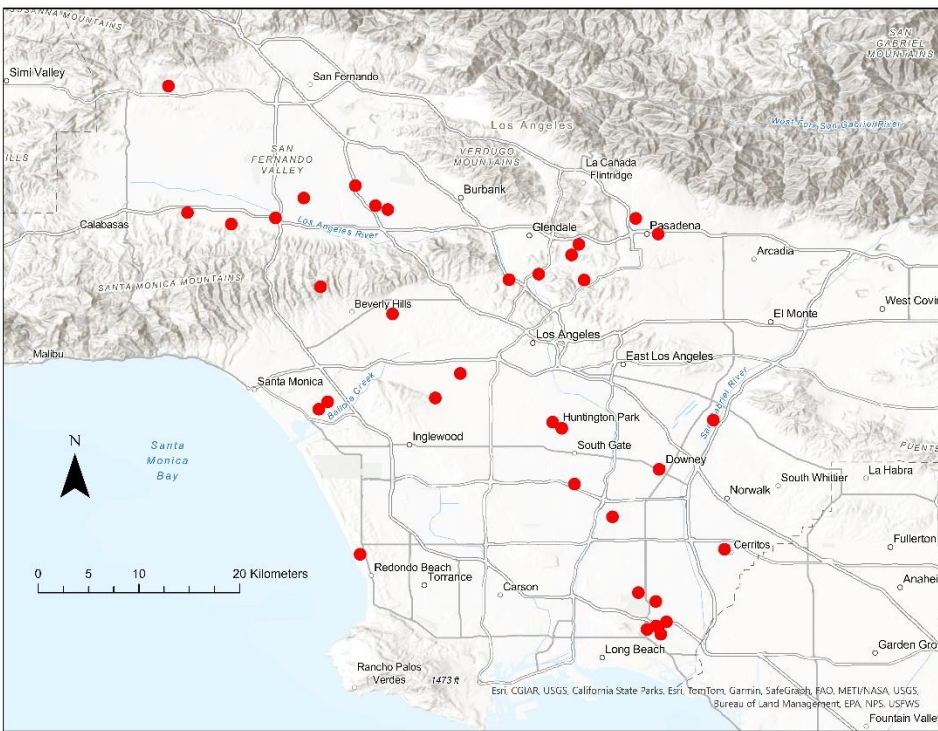


Figure A1. Study area in the City of Los Angeles, US and sampled parcels (red dots).

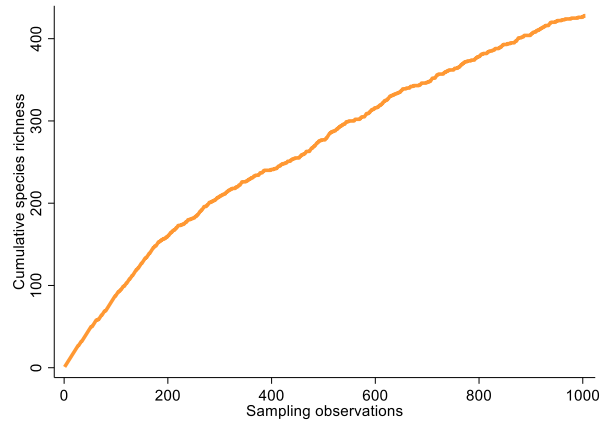


Figure A2. Species accumulation curve illustrating cumulative species richness across sampling observations with in surveyed residential landscapes. The curve increased rapidly during the initial sampling phase and gradually approached and asymptote, indicating the majority of the most common species within sampled parcels were likely successfully captured, although additional sampling may still detect several rare taxa.

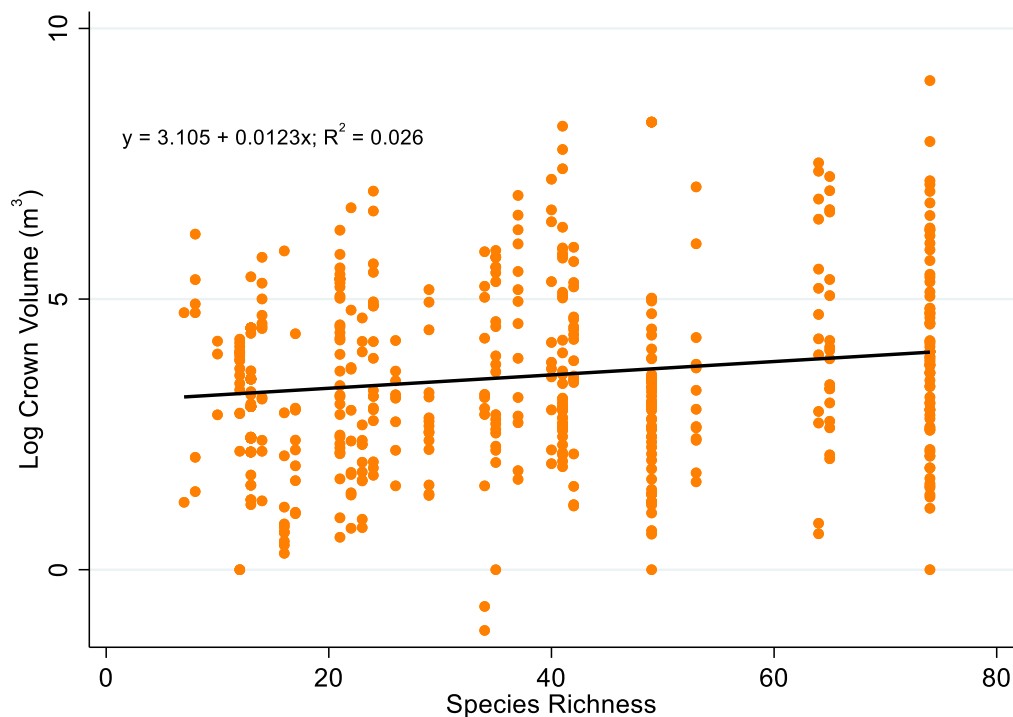


Figure A3. Relationship between species richness and log tree crown volume across all sampled trees in 35 Los Angeles USA yards.

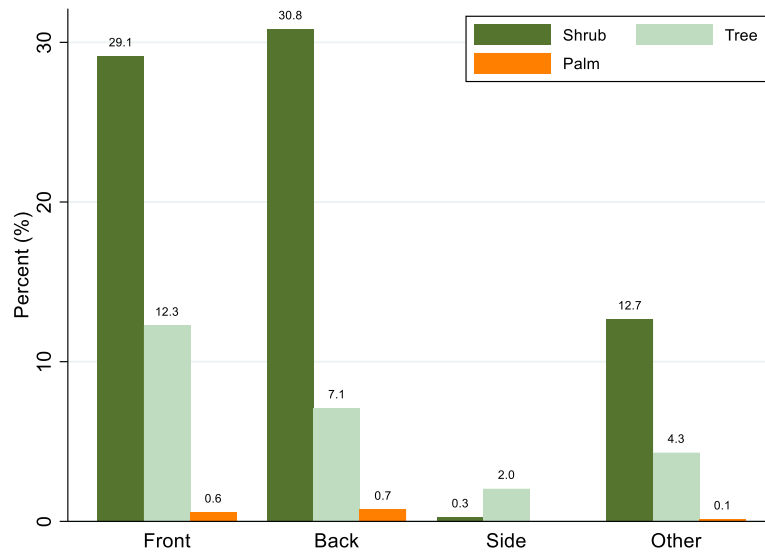


Figure A4. Distribution of vegetation types (shrub, tree, palm) by residential yard location. Values represent the percentage of total vegetation observed within each category and location.

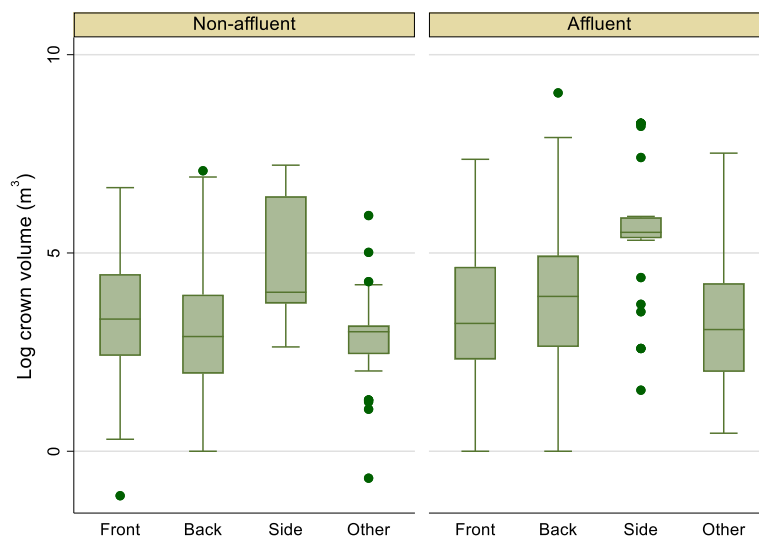


Figure A5. Distribution of log tree crown volume (m^3) across residential yard positions, stratified by neighborhood affluence.

Appendix B. Methods

Soil Sampling

Due to time constraints to minimize disturbance to home occupants, a maximum of six patches were sampled for each parcel. Parcels with more than six distinct patches, patches notably similar in composition, location, ground cover, and sun exposure were excluded; for example, a front yard bisected by a concrete path creating two distinct patches may result in one patch being excluded from sampling in favor of more structurally distinct patches.

Each bagged sample was weighed using a scale calibrated with a 1000 gram weight and were analyzed in the laboratory for dry bulk density, pH (1:1), electroconductivity (2:1), soil texture (percentage of sand, silt, clay), moisture content, and soil organic matter (loss on ignition) using standard methods. A second, identical bag sample was placed under cold storage and subsequently analyzed for pH (replicate, 1:1), electroconductivity (replicate), soil respiration, microbial functional diversity (Shannon Diversity), substrate richness, and average well color development using BioLog EcoPlates.

Statistical Analysis

Prior to model development, pairwise correlation analyses and Variance Inflation Factors (VIF) were used to assess multicollinearity. Candidate models were compared using Akaike Information Criterion (AIC) and Bayesian Information Criterion (BIC), with lower values indicating improved model fit and model parsimony. Model assumptions were assessed using residual-versus-fitted plots to assess linearity, variance structure, and influential observations. Model performance was also evaluated using coefficient of determination (R^2) and adjusted R^2 values. Final model selection was based on statistical performance, diagnostic evaluation, and ecological interpretability of predictors. All statistical analyses were performed using Stata 17 (StataCorp, College Station, TX).

For objective 3, multiple linear regression was used to evaluate the relationships between soil variables and residential shade potential. The final model explained approximately 23% of the variation in residential crown volume ($R^2 = 0.23$), indicating moderate explanatory power for soil-related predictors. Multicollinearity among predictors was within acceptable limits (Mean VIF = 4.73). Model fit statistics included an AIC of 806.62 and BIC of 830.81. Multiple linear

regression analysis was also used to identify significant socioeconomic and parcel-level predictors of tree crown volume. The final model explained 48.71% of the variation in crown volume ($R^2 = 0.487$). Multicollinearity among predictors was low to moderate (Mean VIF = 3.38), indicating acceptable independence among explanatory variables.

Finally, Ordinary Least Squares (OLS) regression was used to evaluate the relationships between residential shade potential and tree structural characteristics (Table 5). Crown volume was log-transformed prior to analysis to reduce right-skewness and improve normality of residuals. Structural predictor variables included DBH, multi-stem growth form, crown dimensions, crown condition metrics, total tree height, and crown base height. Model validity was evaluated using correlation analyses, Variance Inflation Factors (VIF), residual-versus-fitted plots, AIC, and BIC. All retained predictors exhibited low multicollinearity (Mean VIF = 1.86), indicating acceptable independence among structural variables. The final model explained approximately 67.5% of the variation in log-transformed crown volume ($R^2 = 0.675$; AIC = 1347.7; BIC = 1385.54), indicating strong explanatory performance for structural canopy predictors.

Appendix C. Results

Residential Urban Forest Structure, Composition, and Soils

Open-growing conditions for trees and palms were measured using Crown Light Exposure (CLE05,) which differed significantly according to yard size and neighborhood age, with trees in small yards exhibiting higher scores than those in large yards (3.55 vs. 2.80; $p < 0.001$). Similarly, trees in newer neighborhoods recorded higher scores than those in older neighborhoods (3.30 vs. 2.83; $p = 0.007$). The effect of affluence on CLE05 scores was not statistically significant ($p = 0.100$).

Tree dieback did not differ significantly between affluent (6.76%) and non-affluent parcels (7.35%; $p = 0.53$) but was greater in larger (7.90%) versus small yards (4.66%; $p = 0.002$) and significantly greater in older (7.96%) than newer parcels (5.43%; $p = 0.009$). Mean crown missing was significantly greater in affluent (28.82%) versus non-affluent parcels (25.71%; $p = 0.044$) but differ according to yard size ($p = 0.157$) or neighborhood age ($p = 0.786$).

Appendix Table C1. Mean values and two-sample t-test results for tree structural characteristics across residential gradients

Variable	Affluence (Non-affluent vs. Affluent)	p-value	Yard Size (Small vs. Large)	p-value	Neighborhood Age (Old vs. New)	p-value
DBH (cm)	14.33 vs. 20.85	<0.001	16.81 vs. 18.17	0.405	17.46 vs. 18.43	0.514
Height (m)	5.85 vs. 7.39	0.001	7.40 vs. 6.41	0.049	5.93 vs. 7.91	<0.001
Crown Width (m)	4.56 vs. 5.25	0.015	3.91 vs. 5.33	<0.001	5.09 vs. 4.70	0.182
Dieback (%)	7.35 vs. 6.76	0.528	4.66 vs. 7.90	0.002	7.96 vs. 5.43	0.009
Crown Missing (%)	25.71 vs. 28.82	0.044	25.57 vs. 28.04	0.157	27.23 vs. 27.66	0.786
Crown Light Exposure	3.15 vs. 2.87	0.100	3.55 vs. 2.80	<0.001	2.83 vs. 3.30	0.007
Distance from Building (m)	5.43 vs. 5.72	0.645	5.85 vs. 5.43	0.506	4.71 vs. 6.44	0.005
Crown Base Height (m)	1.04 vs. 1.79	<0.001	1.29 vs. 1.49	0.260	1.16 vs. 1.99	<0.001

Appendix Table C2. Chi-square tests examining associations between residential gradients and woody plant characteristics

Response Variable	Affluence χ^2 (p-value)	Yard Size χ^2 (p-value)	Neighborhood Age χ^2 (p-value)
Native vs. Non-native Composition	90.12 (<0.001)	34.05 (<0.001)	128.30 (<0.001)
Tree–Shrub–Palm Composition	11.85 (0.003)	10.52 (0.005)	15.25 (<0.001)
Ecosystem Service Category	10.62 (0.014)	15.93 (0.001)	23.26 (<0.001)
Yard Position Category	38.04 (<0.001)	7.77 (0.051)	55.76 (<0.001)

Appendix Table C3. Beta diversity comparisons across residential gradients using the Jaccard similarity index

Residential Gradient	Shared Species	Unique to Group 1	Unique to Group 2	Jaccard Similarity Index
Affluent vs. non-affluent	135	170 (Affluent)	121 (Non-affluent)	0.317
Large vs. Small Yards	132	190 (Large)	104 (Small)	0.310
Older vs. Newer Neighborhoods	122	202 (Older)	102 (Newer)	0.286