

Linking yard plant diversity to homeowners' landscaping priorities across the U.S

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ABSTRACT

Residential yards contribute to human well-being and urban biodiversity. The structure, diversity, and composition of yard floras are largely determined by personal choices and landscaping priorities at local scales, but it is unclear whether these relationships hold across broader geographical areas. We investigated the relationship between homeowners' criteria for vegetation and yard management choices, ecosystem-service based traits, and yard plant diversity (i.e., taxonomic, phylogenetic and functional) in 145 yards distributed across 6 major cities in the U.S. Individual priorities for a set of ecosystem services were collected with closed-ended questions and reduced into four main principal components using factor analyses: *natural*, *neat*, *showy* and *low cost*. Across cities, priorities for *neat* yards were negatively related to overall and spontaneous species richness. Priorities for *showy* yards were positively related to yard aesthetics (based on showiness of flowers, fruits and leaves for component plants) and spontaneous species richness. Homeowners that preferred *low-cost* yards had a significantly higher proportion of exotics, and yards with significantly lower functional diversity (i.e., a composite measure for plant height, seed mass, and specific leaf area). The proportion of natives was not related to homeowners' priorities for *natural* yards and phylogenetic diversity was only weakly and negatively related to priorities for *showy* yards. Our study corroborates previous research showing that homeowners' landscaping priorities are only partially related to their yard vegetation at the continental scale. The disconnection might be attributed to broader institutional, structural, and ecological constraints that prevent people's personal ideals and priorities from being realized.

1. Introduction

As urban areas expand globally (UN DESA, 2018), residential yards will become increasingly important contributors to people's health and wellbeing (Dunnett & Qasim, 2000), urban ecological biodiversity (Goddard, Dougill, & Benton, 2010) and ecosystem functions (Sperling & Lortie, 2010). Within cities, homeowner preferences and management practices shape yard biodiversity patterns (Avolio et al., 2015; Kendal, Williams, & Williams, 2012; Marco, Barthelemy, Dutoit, &

Bertaudière-Montes, 2010; Politi Bertoncini, Machon, Pavoine, & Muratet, 2012). However, whether these linkages between landscaping priorities and floral communities at the individual household scale occur across broad climatic gradients has not yet been investigated.

Yard vegetation composition and structure are products of multiple biophysical and socioeconomic factors, as well as the cumulative product of individual decisions about plant choices—and whether or not to manage yards—over time. Those choices may be in turn climatically driven or culturally determined from individual values, beliefs, and

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attitudes (Aronson et al., 2016; van Heezik, Freeman, Porter, & Dickinson, 2013). For example, homeowners' aesthetic priorities might strongly relate to the visual attributes of vegetation, such as flower size and foliage color (Goodness, Andersson, Anderson, & Elmqvist, 2016; Kendal et al., 2012). Aesthetic priorities may then affect the way residents plan and manage their yards, with implications for the resulting vegetation diversity and characteristics. Following the example above, native species may have smaller flowers than many exotic species, and so may not be selected in planting decisions despite playing an important role in feeding or providing habitat to the species they have coevolved with. Consequently, homeowners' landscaping priorities select for individual characteristics (traits) of plants that ultimately determine different components of plant diversity (i.e., taxonomic, phylogenetic, and functional) and ecosystem processes.

Plant traits are frequently used in ecology to allow comparisons of vegetation communities that are taxonomically distinct and to investigate the functional response of plants to their environment (Cornelissen et al., 2003). However, plant traits that are desired in yards by homeowners may not match those typically used in ecological research (Gerstenberg & Hofmann, 2016; Goodness, 2018). Thus, urban biodiversity research has begun to use ecosystem service-based traits (Avolio et al., 2015; Pataki, McCarthy, Gillespie, Jenerette, & Pincetl, 2013) that are more directly relevant to the values and priorities of homeowners who are purchasing and managing plants, or traits that result from lack of active yard management. Each plant trait can be a component of functional diversity (Díaz & Cabido, 2001) and can help explain processes of plant establishment and persistence. For example, traits associated with aesthetics, such as flower and fruit showiness, leaf fall color, or resistance to herbivory tend to be important for human choices about the configuration of cultivated ornamental landscapes (Acar, Acar, & Eroğlu, 2007; Avolio, Pataki, Trammell, & Endter-Wada, 2018). Plant lifespan, seed mass, or plant height might help explain successful establishment and persistence of spontaneously occurring vegetation (Díaz et al., 2016; Knapp et al., 2012). Shorter plants, particularly lawns, have also been considered important for social interaction and recreation in private landscapes (Larson, Casagrande, Harlan, & Yabiku, 2009; Monteiro, 2017). Interestingly, varied landscapes that display vegetation of different sizes and with a moderate level of complexity and depth are often preferred by people regardless of their cultural backgrounds (reviewed in Goodness et al., 2016).

Because data on plant traits is sometimes incomplete or missing, phylogenetic diversity has been proposed as a surrogate for functional diversity (Cadotte & Davies, 2016; Cavender-Bares, Kozak, Fine, & Kembel, 2009). Yet, functional traits are not necessarily phylogenetically conserved such that variation in plant traits does not necessarily correspond to phylogenetic relationships (Cavender-Bares, Keen, & Miles, 2006). In fact, in urban environments phylogenetic diversity has been found to be a weak surrogate for functional diversity (Lososová, Chytrý, Danihelka, Tichý, & Ricotta, 2016), highlighting the need to incorporate multiple diversity components when examining human-plant interactions. Nevertheless, both phylogenetic and functional diversity predict ecosystem functions and properties better than taxonomic diversity or species richness (Cadotte, Cardinale, & Oakley, 2008; Díaz & Cabido, 2001). Although phylogenetic diversity of spontaneous species in private yards (Knapp et al., 2012) and in the total yard flora (Pearse et al., 2018), is lower than in adjacent natural areas, associations between homeowners' yard management priorities and phylogenetic and functional diversity remain poorly understood.

Most studies exploring the relative importance of homeowners' priorities in structuring yard plant diversity have been carried out at local scales (e.g., Avolio et al., 2018; Goodness, 2018; Kendal et al., 2012; Marco et al., 2010; van Heezik et al., 2013). Results from these studies generally stress the role of aesthetics, plant utility, ease of maintenance, and environmental suitability in planting priorities, but disparities in sampling designs and examined taxa make it difficult to extrapolate among different biogeographic regions and social groups

with contrasting cultural backgrounds. Additionally, planting priorities are not always aligned with realized yard choices because of broader climatic, structural and institutional constraints that prevent priorities from being realized (Larsen & Harlan, 2006). Yard management practices such as irrigation or fertilization have been shown to partially relax environmental filters and climatic constraints (Groffman et al., 2016; Larson et al., 2009; Padullés Cubino, Cavender-Bares, Hobbie, Pataki et al., 2019), which may facilitate similar vegetation outcomes to emerge across broad geographic areas. For example, priorities for colorful ornamental and showy landscapes might translate into yards having greater proportions of exotic plant species, no matter where they are located. Likewise, priorities for visually pleasing landscapes might be associated with higher proportions of flowering plants irrespective of taxonomically distinct floras or geographical areas (Acar et al., 2007; Fernandez-Cañero, Emilsson, Fernandez-Barba, & Herrera Machuca, 2013; Marco et al., 2010). To date, such associations have not been tested at the continental scale, despite having important implications for national and regional programs that wish to promote certain landscape designs by influencing gardening behaviors.

In this study, we evaluated the relationship between homeowners' landscaping priorities and yard plant diversity and composition across the continental U.S. as part of an ongoing exploration of urban homogenization and future possibilities for residential yards (Groffman et al., 2014). To do so, we recorded plant species composition in 145 yards across six major U.S. metropolitan areas in different climatic regions and collected data on vegetation and yard priorities from residential homeowners using a written survey with closed-ended questions. In a previous study using data from the same questionnaire, Larson et al. (2016) concluded that homeowners' landscaping priorities—as measured by the importance people assigned to particular benefits or ecosystem services—were similar across the six metropolitan areas. For example, U.S. residents similarly prioritized the aesthetic qualities of traditional lawns such as their green, weed-free, and neat appearances. Also, previous work on vegetation data from this project has shown increased similarity of overall yard flora (Pearse et al., 2018) and lawn flora specifically (Wheeler et al., 2017) in cities when compared to adjacent natural areas, and has related yard plant diversity to macroclimatic conditions (Padullés Cubino, Cavender-Bares, Hobbie, Pataki et al., 2019). Here, we further this research to test the extent to which homeowners' priorities are associated with yard plant diversity in terms of taxonomic, phylogenetic, and functional diversity, individual traits, and composition of yard floras at different spatial scales.

We hypothesized that values placed on aesthetic plant traits, such as flower or foliage color, would translate into greater plant 'showiness' in yards. We expected such association, in turn, to result in an overall increase in taxonomic, phylogenetic, and functional diversity because of an increase in the number of visually attractive and diverse exotic species in place of potentially less showy native vegetation. In contrast, landscaping choices made by people who value more natural yards would result in higher proportions of native and spontaneously-occurring plants, which may decrease taxonomic and phylogenetic diversity, but not necessarily functional diversity. We predicted a negative association between yard plant diversity and priorities for low-cost yards, where a lower investment in yard upkeep may decrease all components of diversity. Finally, we predicted priorities for neat yards to result in lower overall and spontaneous species richness because of weed removal. If functional diversity, measured through a particular set of ecologically significant traits, does not respond to homeowners' value-based priorities at the continental scale, then we will have further evidence that there is a disconnection between ecological processes and homeowners' landscaping ideals.

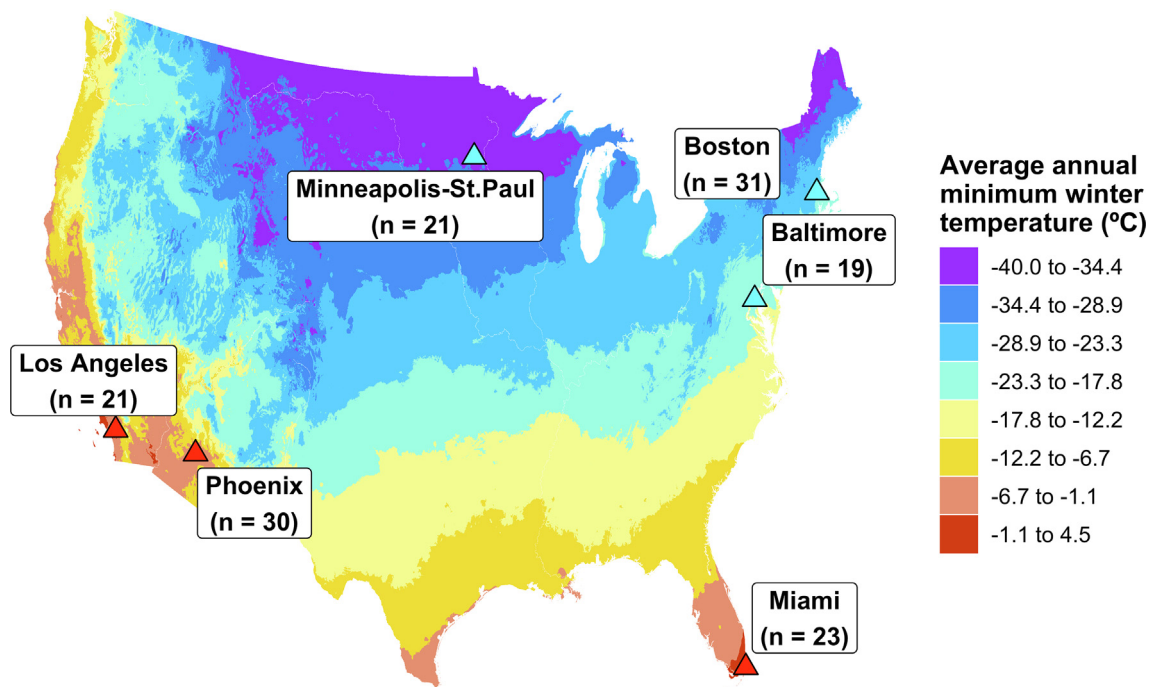


Fig. 1. Map of plant hardiness zones in the continental U.S. with the six cities included in our study. Plant hardiness zones were based on average annual minimum winter temperatures and obtained from the United States Department of Agriculture (planthardiness.ars.usda.gov). Blue and red triangles represent northern and southern cities, respectively. “n” is the number of sampled yards in each city.

2. Methods

2.1. Site selection

We selected six major Metropolitan Statistical Areas in the U.S. (hereafter “cities”) to represent six different ecological biomes and major climatic regions across the U.S. (Groffman et al., 2014; Fig. 1): Baltimore (BAL), Boston (BOS), Los Angeles (LA), Miami (MIA), Minneapolis-St. Paul (MSP), and Phoenix (PHX). To select yards for the study, we first identified social groups common to the six cities using the PRIZM marketing classification scheme (CLARITAS, 2013; Polsky et al., 2014). From this classification, we selected single family residences across classes of urban density (urban, suburban, and exurban) and socioeconomic status (high, medium, and low; based on income and house values) for inclusion in a telephone survey. Of the > 100,000 households initially contacted for the telephone survey, > 13,500 qualified for our study (respondent was over 18 years of age and their home had either or both a front and/or back yard) (Polsky et al., 2014). From the 9,480 homeowners who completed the telephone survey, we randomly selected 19–31 residential properties equally distributed among the six cities (n = 145) for field sampling (Fig. 1). Fig. 2 shows example yards from residential properties in each of our cities.

2.2. Vegetation survey

We identified plants in 145 yards across the six cities (Padullés Cubino & Narango, 2019). We inspected the entire area of each yard, including front and backyard. Yards were sampled during the season of peak plant productivity (summer for BAL, BOS, MIA, and MSP; spring for LA and PHX). We sampled all yards in 2012, except for those in LA that were sampled in 2013. We identified plants at the species level and recorded the genus for those we could not identify at the species level (~15%). In total, we identified 2,408 species, of which 49% were herbs, 19% shrubs, 15% trees, 9% grasses, 4% vines, 4% succulents or cacti, and 1% epiphytes.

We classified species as cultivated or spontaneous based on the

information provided by homeowners, observations of placement, and current and past land use. Cultivated plants were those intentionally planted by homeowners, while spontaneous plants were assumed to be naturally regenerated. A same species could be classified as both cultivated and spontaneous in the same yard if different individuals of that species showed evidence of different histories. Approximately 13% of the species could not be classified as either cultivated or spontaneous during the field survey. In these cases, classification was done based on records for the same species in other sampled yards. The taxonomy and nomenclature of vascular plants follow The Plant List (theplantlist.org) version 1.1.

2.3. Plant traits and missing data imputation

We assigned traits to recorded plant species to assess whether their characteristics could be predicted from homeowners’ priorities. We selected ecosystem-service based traits that have previously been shown to be related to homeowners’ priorities and needs: cultivation status, native status, edibility, and plant aesthetics (e.g., Kendal et al., 2012; Pataki et al., 2013; Goodness et al., 2016; Avolio et al., 2018) (Table 1). We also collected data on plant traits related to different ecological processes, including plant dispersal, establishment, and persistence (Díaz et al., 2016; Westoby, 1998), when data were available for at least 50% of our species. This group of ecological traits included maximum plant height, seed mass, and specific leaf area (SLA) (Table 1). SLA is associated with species relative growth rates, photosynthetic rates, resource acquisition, and response to nutrient and moisture gradients (Wright et al., 2004); plant height relates to resource allocation and competitive ability (particularly for light) (Tilman, 1988; Westoby, 1998), and seed mass relates to dispersal ability, stress tolerance and predation risk (Westoby, Leishman, & Lord, 1996; Westoby, 1998). Plant traits were determined from the following sources: TRY database (try-db.org, see Appendix S2 for specific references); USDA PLANTS database (plants.usda.gov); Missouri Botanical Garden database (missouriherbarium.org); the Encyclopedia of Life (EOL; eol.org); and other specialized literature (Table 1).



Fig. 2. Examples of yards in the three northern cities (Baltimore (a), Boston (b), and Minneapolis-Saint Paul (c)), and the three southern cities (Miami (d), Los Angeles (e), and Phoenix (f)).

We classified species as either “native” or “exotic” individually for each U.S. state where the study cities were situated following the USDA PLANTS (plants.usda.gov) and EOL (eol.org) databases (further details on species’ native status classification can be found in [Padullés Cubino, Cavender-Bares, Hobbie, Pataki et al., 2019](#)). Plant aesthetic beauty was based on visual attributes that are identifiable to most homeowners. It was calculated, for all recorded species, as the sum of three categorical plant traits: flower, fruit, and foliage showiness ([Avolio et al., 2015](#)). Flower showiness included three categories: 0 for species that did not flower or species with inconspicuous flowers; 1 for species whose flowers are visible and conspicuous; and 2 for species with large showy flowers ([Avolio et al., 2015](#)). Fruit showiness consisted of two categories: visible (1) or not visible (0) fruits or berries. Likewise, foliage showiness also had two categories that depended on whether leaves turn a color (e.g., red or orange) in the fall or have whitish, bluish, or other neutral tones in their leaves (e.g., *Jacobaea maritima*, *Caladium bicolor*) (1), in contrast to leaves that are only green and turn brown in the fall (0). We also digitized and measured the proportion of the entire yard covered by tree canopy using aerial photography and the information obtained during vegetation survey in ArcGIS v.10 ([ESRI, 2017](#)).

Data for continuous plant traits (plant height, seed mass, and SLA)

were not available for a number of species ([Table 1](#)). Removing species with missing trait data from the analysis would probably bias the results because of the selective exclusion of less well known species ([Swenson, 2014](#)). We accommodated these cases by estimating the missing values using phylogenetic information from species with available data ([Swenson, 2014](#)). Specifically, we used R package *Rphylopars* ([Goolsby, Bruggeman, & Ané, 2017](#)) to compare available trait data across four alternative evolutionary models (i.e., Early-Burst, Brownian motion, Ornstein-Uhlenbeck and multivariate Ornstein-Uhlenbeck) and selected the best-fitting model on the basis of the lowest AIC value (i.e., Ornstein-Uhlenbeck) to impute trait data (see [Padullés Cubino, Cavender-Bares, Hobbie, Pataki et al., 2019](#) for more details on the methods used to impute missing trait data). When we obtained multiple values for any species we used mean trait values.

Online trait databases are important tools for examining plant assembly processes in urban environments (e.g., [Duncan et al., 2011](#)), but they might not capture population-level variations that have been shown to be important in many urban studies ([Alberti et al., 2017](#)). For this reason, the majority of the traits included in this study are categorical and unlikely to shift considerably across populations.

Table 1

Functional traits collected from the literature for this study. For continuous traits, the unit of measurement is provided in parentheses following trait name. Specific references for the TRY database can be found in the [Appendix S2](#).

Trait	Values	% Missing data	Data source ²
Cultivation	Categorical (1 = cultivated; 0 = non-cultivated)	0	Vegetation survey
Native	Categorical (1 = native; 0 = non-native)	0	USDA PLANTS and EOL
Edibility	Categorical (1 = edible; 0 = non-edible)	0	Missouri Botanical Garden
Showy flowers ¹	Categorical (0 = no flowers or inconspicuous; 1 = small flowers/inflorescences; 2 = big flowers/inflorescences)	0	USDA PLANTS, Missouri Botanical Garden
Showy fruits ¹	Categorical (0 = non-showy; 1 = showy)	0	Specialized floras
Showy leaves ¹	Categorical (0 = green leaves; 1 = non-green leaves)	0	Specialized floras
Plant height (m)	Continuous	38	TRY
Seed mass (mg)	Continuous	32	TRY
Specific leaf area (SLA) (mm ² /mg)	Continuous	50	TRY

¹ See Methods for a full explanation of showy traits.

² USDA PLANTS (plants.usda.gov); TRY (try-db.org); EOL (eol.org), Missouri Botanical Garden (missouribotanicalgarden.org).

2.4. Homeowners' priorities

We collected ordinal data on vegetation and yard priorities from residential homeowners using a written survey. The survey incorporated nine closed-ended questions (Larson, 2019), two of which were used here: 1) "What criteria guide your household's vegetation (grass, trees, and other plants) choices?" and 2) "What criteria guide your yard management choices overall?" Responses were ranked on a 4-point ordinal scale in order to gauge the importance that homeowners place on particular benefits obtained from their yards: 0 = not important, 1 = low, 2 = medium, and 3 = high importance. Homeowners rated multiple criteria for each question (see Appendix S3 for verbatim wording of the different criteria).

In LA, 11 out of 21 respondents did not use the full response scale including the 0. Instead, they only used the 1, 2, and 3 response options indicating low to high importance. These 11 responses were standardized to maintain the full sample size and the appropriate statistical power as follows: 1 = 0; 2 = 1.5; 3 = 3. We conducted *t*-tests on the two groups of responses (full scale vs. abbreviated scale) in LA before and after standardization and found no statistical difference between the two groups after standardization, supporting our approach. For further details on data collection and a complete list of vegetation and yard criteria evaluated see Appendix S3 and Larson et al. (2016).

2.5. Diversity metrics and vegetation characteristics

For each yard, we calculated overall species (or taxonomic) richness (SR) as the total number of different taxa in the yard, the density of species per yard area ($SR_D = SR/\text{yard area}$), spontaneous species richness as the total number of spontaneously occurring species in the yard, the proportion of species that are both cultivated and exotic, and the proportion of native species. We also calculated the aggregated aesthetic properties of yard vegetation as the mean aesthetic traits across all species in the parcel.

We calculated phylogenetic and functional diversity of each yard using a set of different metrics. For phylogenetic diversity, we calculated Faith's PD (Faith, 1992), mean pairwise distance (PD_{MPD}) (Pavoine & Bonsall, 2011), and mean nearest taxon distance (PD_{MNTD}) (Webb, Ackerly, McPeck, & Donoghue, 2002). Faith's PD is the phylogenetic analogue of species richness and is expressed as the sum of total phylogenetic branch length for a sample, thus capturing the amount of shared evolutionary history and also increases with species richness. PD_{MPD} is the mean pairwise phylogenetic distance of all possible species pairs in a sample and it measures the overall relatedness of species. PD_{MNTD} is the mean phylogenetic distance between each species and its phylogenetically nearest neighbor in the sample and reflects the relatedness closer to the tips of the phylogeny. Additionally, we calculated evolutionary distinctiveness (ED) (Redding, 2003), as a measure of the phylogenetic uniqueness of each species in a sample. We calculated all phylogenetic diversity metrics and ED using a phylogeny produced by Qian and Jin (2016), which expands that from Zanne et al. (2013), and R package *picante* (Kembel et al., 2010). We used the 'congeneric.merge' function in the R package *pez* (Pearse et al., 2015) to add species missing from this phylogeny at the genus level. We excluded from the analysis species for which we had no phylogenetic information (~1.5%).

For functional diversity of continuous plant traits (plant height, seed mass and SLA), we calculated Functional Richness (FRic) (Villéger, Mason, & Moullot, 2008), Functional Dispersion (FDis) (Laliberté & Legendre, 2010), and again MPD (FD_{MPD}) and MNTD (FD_{MNTD}). FRic is defined as the amount of niche space occupied by the species within a community. FDis is the mean distance of individual species to the centroid of all species in the multidimensional trait space, and it is little influenced by species richness. We calculated these two metrics in R package *FD* (Laliberté & Legendre, 2010). For FD_{MPD} and FD_{MNTD} , we computed the functional distance matrix using Euclidian distances and

repeated the same procedure as for phylogenetic diversity.

We initially included these metrics in our analysis because they can respond differently to various topological aspects of phylogenetic and functional dissimilarities (Tucker et al., 2017). We performed Spearman's rho tests between all diversity metrics (Appendix S1: Table S1) and retained only for the Results and Discussion those phylogenetic and functional diversity indices that showed the lowest correlations with SR and other metrics: PD_{MPD} for phylogenetic diversity and FDis for functional diversity. Results for all other phylogenetic and functional diversity metrics and for the density of species per yard area can be found in Appendix S1 (Tables S2 to S4).

2.6. Data analysis

We used Principal Component Analysis (PCA) to reduce vegetation and yard priorities into a smaller subset of composite variables for the subsequent analysis. From the complete list of vegetation and yard priority variables analyzed for the purpose of this study, we first included in our PCA those related to aesthetics, plant diversity, and yard management cost (see Appendix S3). With this initial subset of variables, we performed principal components extraction with a promax rotation. We then performed another PCA after removing variables with loadings < 0.5 in all components, and kept these PCA factors for subsequent analysis. Factors with eigenvalues > 1 formed the basis for interpreting the results (Kim & Mueller, 1978). PCA was implemented using R package *psych* (Revelle, 2018).

To examine the effect of homeowners' individual landscaping priorities on yard plant composition, we performed an ordination of yard species data with non-metric multidimensional scaling (NMDS) with the Sørensen dissimilarity index in R package *vegan* (Oksanen et al., 2017). We then fitted individual priority variables (Appendix S3) as vectors using the 'envfit' function in the same R package. Additionally, we fitted in the ordination two climatic variables ('mean annual temperature' and 'annual precipitation') to explore associations between yard plant composition and major climatic factors and to help interpret the results. We extracted climatic data from the 30 arc-second WorldClim database (worldclim.org).

We used linear mixed-effects models with 'lme' function in R package *nlme* (Pinheiro, Bates, DebRoy, Sarkar, & R Core Team, 2018) to investigate relationships between response variables (diversity metrics and vegetation characteristics) and predictor variables (homeowners' priorities [PCA factors]). FDis was log-transformed to meet the assumptions of normality and homoscedasticity. We standardized all response variables before introducing them to the model to allow coefficients comparison (Zuur, Ieno, & Smith, 2007). In all models, we included the random effect of 'city' to cluster yards and control for spatial autocorrelation. Given that results from NMDS clearly defined two clusters of yards on the first axis based on taxonomic similarities (i.e., northern cities [BAL, BOS and MSP] and southern cities [MIA, LA and PHX]) (Fig. 3), we produced models for three different subsets of households considering (1) all yards across the 6 cities, (2) yards in the relatively cool northern cities, and (3) yards in the relatively warm southern cities.

Additionally, we also used linear mixed-effect models with 'city' as random effect and for three different subsets of households (all, northern, and southern cities) to look for associations between 2 individual vegetation choices ("provides food" and "provides shade or helps cool the area") and two response variables that we hypothesize represent associated ecosystem services (i.e., the proportion of edible species in yards and the proportion of the yard covered by tree canopy, respectively).

We established significance at $\alpha < 0.05$ and performed all analysis in R version 3.4.1 (R Core Team, 2018).

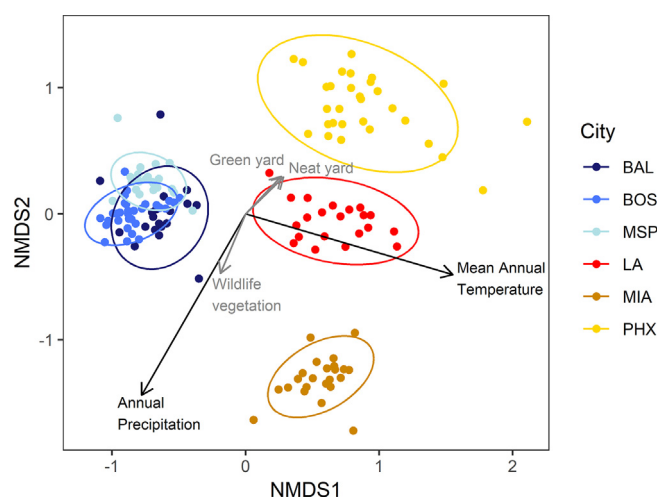


Fig. 3. Result of the non-metric multidimensional scaling (NMDS) based on Sørensen dissimilarity index (stress = 0.165) of the flora of 145 private yards in 6 major metropolitan areas in the U.S. Significant ($P < 0.05$) climatic gradients (black arrows) and homeowners' priorities (grey arrows) are plotted on the ordination as vectors. Length of the vector is positively related to the strength of the gradient. Northern cities (Baltimore (BAL), Boston (BOS), and Minneapolis-St. Paul (MSP)) are colored in blue cool tones, while southern cities (Los Angeles (LA), Miami (MIA), and Phoenix (PHX)) are colored in red warm tones. Ellipses represent 95% confidence intervals.

3. Results

3.1. Homeowners' priority dimensions

In the PCA of homeowners' priorities, the individual variables clustered along four significant factors/dimensions that explained 69% of the variation in the data (Table 2). PCA factors (in *italics* throughout this section) were labelled according to their overarching meaning, as interpreted by our interdisciplinary research team. The first *natural* factor reflected priorities for natural landscapes, native plants and wildlife habitat. The second factor represented a *neat* and orderly landscape with few weeds. The third factor represented *showy* aesthetics, with values placed on greenness and the provision of flowers and a variety of plants. The fourth *low-cost* factor reflected priorities for inexpensive plants and yard upkeep.

Table 2

Loadings of yard and vegetation priorities on Principal Component Analysis (PCA).

Vegetation and yard priorities	PC1 (Natural)	PC2 (Neat)	PC3 (Showy)	PC4 (Low cost)
Is native to the area	0.76			
Looks natural	0.74			
Supports wildlife	0.77			
Is neat and orderly (vegetation)		0.87		
Is neat and orderly (yards)		0.88		
Reduces weeds		0.61		
Provides flowers			0.84	
Makes things green			0.66	
Offers a variety of plants			0.78	
Is inexpensive (vegetation)				0.96
Is inexpensive (yards)				0.89
Eigenvalues	2.09	1.87	1.82	1.76
% Cumulative variance	19	36	53	69

3.2. Yards floristic composition related to personal priorities and climatic gradients

Yard floras in the three northern cities (i.e., BAL, BOS, and MSP) were taxonomically distinct from those in the three southern cities (i.e., LA, MIA, and PHX) (Fig. 3). Moreover, yard floras in the northern cities were more similar to each other than yard floras in the three southern cities. The two groups of cities (northern vs. southern) clustered along the first NMDS axis, which strongly correlates with mean annual temperature: northern cities had lower mean annual temperature, and southern cities had higher mean annual temperature. Overall variation in the floristic composition of yards was significantly and strongly related to annual precipitation ($R^2 = 0.83$; $P < 0.001$) and mean annual temperature ($R^2 = 0.81$; $P < 0.001$), and less strongly to priorities for wildlife ($R^2 = 0.01$; $P < 0.01$), neatness ($R^2 = 0.05$; $P = 0.04$), and greenness ($R^2 = 0.05$; $P = 0.04$) of yards.

3.3. Diversity metrics and vegetation characteristics predicted from homeowners' landscaping priorities

Peoples' priorities for *natural* yards had no significant relationship (confidence interval overlapped zero) with any of the diversity metrics and vegetation characteristics (Fig. 4a). In contrast, priorities for *neat* yards had a significant negative relationship with overall and spontaneous species richness across all cities. This relationship was also significant when considering only yards in the north (BAL, BOS and MSP) or in the south (LA, MIA and PHX) (Fig. 4b). Priorities for *showy* yards showed a positive significant relationship with yard aesthetics at the two regional (northern and southern cities) and continental scale, and with spontaneous species richness across all cities and considering only those in the north (Fig. 4c). Furthermore, priorities for *showy* yards had a negative relationship with phylogenetic diversity (PD_{MPD}) in the northern cities only (Fig. 4c). Priorities for *low-cost* yards had a significant positive relationship with the proportion of cultivated exotics (across all and northern cities), and a significant negative relationship with functional dispersion ($FDis$) (across all cities) and yard aesthetics (northern cities) (Fig. 4d).

Homeowners that prioritized food production in their yards had significantly higher proportions of edible species in their yards in both the northern cities (β -coefficient = 0.05, CI: 0.02, 0.07), and the southern cities (β -coefficient = 0.08, CI: 0.05, 0.12) as well as at the continental level (β -coefficient = 0.07, CI: 0.04, 0.09). Priorities for shady and cooling yards were not significantly associated with the proportion of the yard covered by tree canopy in the northern cities (β -coefficient = 0.02, CI: -0.03, 0.07), the southern cities (β -coefficient = 0.02, CI: -0.02, 0.05), or at the continental level (β -coefficient = 0.02, CI: -0.01, 0.05).

4. Discussion

As we predicted, our findings indicate that personal priorities for neatness correspond to lower species richness in yards, which was largely driven by a decrease in the number of spontaneous (weedy) species. Nassauer (1988) referred to neatness as one the most important attributes of private landscape to be considered attractive in the U.S., and a survey of residents in Phoenix, Arizona found that a third of residents preferred neat and orderly landscaping over a natural and informal aesthetic (Martin, Peterson, & Stabler, 2003). Neat yards are usually associated with obvious cues of human stewardship, such as well-kept, orderly landscapes with carefully-planned and trimmed lawn areas and flower beds. However, the pursuit of neatness can be costly in terms of time and maintenance fees. Here, we provide evidence that such investment decreases taxonomic diversity across regions with different climatic conditions. Given homeowners' priorities for neatness, landscape designers might explore a way of maintaining species richness in neat and orderly designs, for example by planning diverse

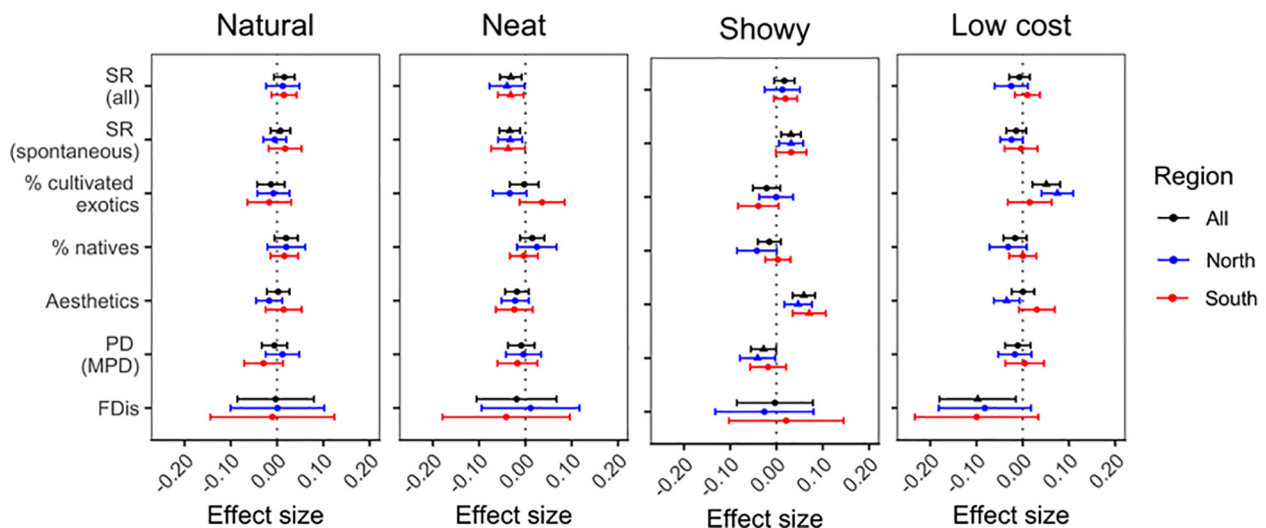


Fig. 4. Estimated effect sizes derived from linear mixed-effect models for homeowners' priorities for natural (a), neat (b), showy (c) and low cost (d) yards predicting different components of plant traits and diversity in 145 yards distributed among 6 cities in the U.S. Points represent the mean coefficient estimate, and lines represent the 95% confidence interval. Triangles indicate significant effects, and circles indicate non-significant effects. SR (all) = Overall species richness; SR (spontaneous) = Species richness of the spontaneous pool; Aesthetics = Aggregated aesthetic properties of yard vegetation; PD = Phylogenetic diversity, MPD = Mean Pairwise Distance; FDis = Functional dispersion; All = all yards ($n = 145$); North = yards in the northern cities ($n = 71$); South = yards in the southern cities ($n = 74$).

but clearly designed and manicured yards.

Using the same survey data used here, [Larson et al. \(2016\)](#) concluded that priorities for neat, green and weed-free landscapes were similarly important across homeowners of the 6 cities (see also [Appendix S4: Fig. S1](#)). However, our study showed that, despite such similarities in landscaping priorities across the country, homeowners' priorities for neat and green landscapes more strongly predicted plant composition in semi-arid regions (i.e., Phoenix) than in wetter regions. This relationship between composition and priorities for neatness may be due to a relatively higher proportion of graminoid species found commonly in lawns in the overall flora of yards in drier cities ([Appendix S4: Fig. S2](#)). A number of studies conducted in the Phoenix metropolitan area showed that longer-term residents preferred lawns more than newcomers did (for a review, see [Larson, Hoffman, & Ripplinger, 2017](#)). This finding suggests there is potential for promoting xeric yards as drought-tolerant alternatives to traditional lawns, especially among longer-term residents. However, the preference for exotic grasses may be engrained in long-term residents and reinforced by regional campaigns that market the region as an "oasis" ([Larson et al., 2009](#)). Further research should explore the potential to shift landscape designs and floral composition in ways that maintaining the priorities that are most important to particular social and cultural groups.

As expected, homeowners that rated showiness as an important reason for their yards cultivated more vegetation with showy flowers, leaves, and fruits. Other studies have reported that visual aesthetics strongly influence vegetation choices in private yards (e.g., [Acar et al., 2007](#); [Avolio et al., 2018](#); [Kendal et al., 2012](#); [Marco et al., 2010](#)). This study expands that idea by correlating such aesthetic desires with visual traits of all species found in yards across a wide range of environmental conditions and social backgrounds. Colorful and bright vegetation might be correlated with particular functions, such as habitat diversity through a greater variety of plants, and pollination through a greater abundance of flowers ([Garbuzov & Ratnieks, 2014](#)). Accordingly, we found that priorities for showy vegetation were correlated positively with spontaneous species richness but not functional diversity. Spontaneous species can be a useful, although sometimes undervalued, pollinator resource ([Larson, Kesheimer, & Potter, 2014](#)). Nevertheless, the increase in aesthetic traits and spontaneous species richness in yards managed by homeowners prioritizing showy landscapes came at the expense of phylogenetic diversity and the proportion of native species

in the three northern cities.

Contrary to our hypotheses, residents' priorities for natural yards had no significant influence on either the proportion of native species or other diversity metrics and vegetation characteristics. This finding was inconsistent with other studies from Australia that have shown that the presence of native plants in yards relate to preferences for natives ([Kendal et al., 2012](#)) and conservation attitudes ([Zagorski, Kirkpatrick, & Stratford, 2004](#)). The causes leading to differences in our findings compared to previous work in Australia may include differences in how the word "natural" was socially or culturally constructed interpreted in our survey, as well as differences in how nature and native species are conceptualized. In this regard, [van Heezik et al. \(2013\)](#) showed that the ability of New Zealand householders to discriminate between native and exotic species positively predicted native species richness in yards, but this association could not be tested in our study. Structural barriers such as legacies of what was planted before, or limited availability or high prices for native species at nurseries may also prevent residents from including native species in their landscapes ([Larson et al., 2017](#)). Government or non-profit initiatives that subsidize and provide native plantings, potentially through plant giveaway programs and information about native plant requirements, may translate into higher native diversity in private yards if cost and access are primary barriers.

Vegetation choices are strongly influenced by local topographic, edaphic, and climatic conditions, and gardeners usually select species that are well adapted to local environmental conditions to reduce maintenance costs ([Marco et al., 2010](#)). In our study, homeowners' priorities for low-cost yards translated into higher proportions of cultivated exotic species in their yards, especially in the three northern cities. Exotic species may possess traits that make them more adapted to microclimatic conditions in yards, but also more appealing to homeowners because of reduced maintenance when compared to natives. For example, evergreen exotic trees might replace native trees that shed leaves or messy seeds and fruits that require higher maintenance and cleanup. As a result, exotic species can be seen as easier to maintain as well as more suitable in certain locations, despite having the potential to spread and naturalize in adjacent natural areas ([Padullés Cubino, Vila Subirós, & Barriocanal Lozano, 2015](#)). Moreover, exotic species may be cheaper and more readily available in nurseries ([Avolio et al., 2018](#)). In this regard, further research is required to compare plant traits of exotic and native species in relation to homeowners' ideals and

expectations.

Following our predictions, homeowners who prioritized plants that supplied food consistently also cultivated higher proportions of edible plants across the two regional levels (northern and southern cities) and the continental scale. Priorities for useful plants, particularly for food provisioning, have been proposed to be an important criterion for plant selection among urban residents in several studies. However, such priorities tend to receive greater attention from residents in low-income urban areas where edible plants might be cultivated for food security or as an additional income source (Goodness, 2018).

Priorities for plants that cast shade or help to cool yards were not significantly related to the proportion of the yard covered by tree canopy in any of the three regions considered, although effect sizes were positive in all cases. This lack of significant association between priorities for shady vegetation and tree canopy cover might be especially relevant in yards located in the southern semi-arid cities, where Larson et al. (2016) found that preferences for vegetation cooling effects were more important. Other artificial structures, such as umbrellas or pergolas, or other vegetation land cover, such as lawn areas, might be fulfilling the desire for cooling more than the relative amount of tree canopy. Nevertheless, another study in southern California found that neighborhoods in hotter regions hosted more shade trees than neighborhoods in cooler regions, in part as a response to residents' priorities for landscapes to mitigate heat (Avolio et al., 2015).

Apart from a negative correlation between priorities for low-cost yards and functional diversity, no other homeowners' priorities were associated with phylogenetic or functional diversity at the continental scale. The three traits included in our composite functional diversity index (plant height, seed mass and specific leaf area) generally reflect plant size variation and relate to different ecological processes, including plant dispersal, establishment, and persistence (Díaz et al., 2016; Westoby, 1998). Therefore, the disconnection between functional diversity and homeowners' priorities suggests that there was a mismatch between some aspects of ecological processes at this scale and homeowners' landscaping expectations. Consequently, biogeographic, environmental, and structural (i.e., yard area) factors collectively may impose stronger constraints on ecological processes associated with dispersal and establishment than the social environment. The larger-scale influences of climatic and structural factors on taxonomic and phylogenetic diversity have been demonstrated at the continental scale (Padullés Cubino, Cavender-Bares, Hobbie, Pataki et al., 2019; Pearse et al., 2018). The negative association between functional dispersion and priorities for low-cost yards indicates that homeowners who emphasize low-cost landscapes cultivate plants that are more functionally similar and clustered together and presumably have less structural complexity and similar ecological strategies.

Our study corroborates that homeowners' landscaping priorities are not always in agreement with existing yard vegetation (Larsen & Harlan, 2006). Other important factors that might also explain yard plant diversity and community composition include broader biophysical, structural and institutional constraints that prevent preferences from being realized. For example, landscaping styles may reflect conformity to social or neighborhood norms relative to personal lifestyles and values (Larsen & Harlan, 2006; but see Daniels & Kirkpatrick, 2006) or simply apathetic behavior towards yard management (Larson et al., 2009). Moreover, vegetation patterns in yards may lag behind preferences because landscape designs change over time. The availability and price of cultivated plants in nurseries might also influence homeowners' landscaping priorities regionally. These considerations, along with the disconnection between preferred versus actual landscapes, are areas for future research that would benefit from a more integrated socio-psychological perspective. Further research should also examine the associations between homeowners' priorities and yard design features across diverse social and international contexts, as our work is limited to the U.S. context.

5. Conclusions

We have shown that the diversity and composition of vegetation in yards do not always correspond to homeowner landscaping priorities. Consistently across different spatial scales, residents that rated showiness as an important priority in managing their yards cultivated more vegetation with showy flowers, leaves, and fruits, and those that preferred neat landscapes had fewer species in their yards. Homeowners who prioritized low-cost yard management harbored lower functional diversity in their yards. Contrary to our hypotheses, priorities for more natural landscapes did not translate into yards having a higher proportion of natives, and the proportion of cultivated exotics increased with priorities for low-cost landscapes in the northern cities. The contrasting results between regions and spatial scales highlight the need to account for geographical and social differences when assessing how landscaping ideals and priorities translate into actual plantings. Therefore, changing residents' landscaping priorities and behavior with similar strategies across broad geographic areas to promote specific landscape designs may have limited success. Managers and policy-makers interested in informing landscaping decisions should consider residents' priorities for particular plant attributes, while also considering plant availability and cost in the nursery industry. Finally, future research should assess what factors prevent personal landscaping priorities from being realized, and why homeowners choose to make changes to their yards.

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Appendix A. Supplementary data

Supplementary data to this article can be found online at <https://doi.org/10.1016/j.landurbplan.2019.103730>.

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