Homeowner preferences drive lawn care practices and species diversity patterns in new lawn floras

Tracy L. Fuentes

Urban Design and Planning, University of Washington, Box 355740, 410 Gould Hall, Seattle, WA, 98195-5740, USA

*Corresponding author. E-mail: tracyfuentes@gmail.com

Submitted: 28 October 2020; Received (in revised form): 11 April 2021. Accepted: 27 April 2021

Abstract

Households intensively manage lawns to create uniformly green, low diversity plant communities. Because lawns occupy a large proportion of urban green space, they are a crucial case for understanding how people manipulate urban vegetation. In this study, I focused on 58 homeowners who purchased a newly constructed home and yard in the Seattle Metropolitan Statistical Area, USA, to see how preferences, lawn care regimes and new lawn floras develop within a multi-scalar urban environment. A typical homeowner watered 3 times in spring, watered 24 times in summer, applied fertilizer twice, mowed 21 times and edged 15 times. Most new lawn turfgrasses were Lolium perenne, Poa pratensis and/or Festuca spp. Mean species richness was 6.5 ± 5.3 species. The most frequent species were non-native and cosmopolitan (turfgrasses, Hypochaeris radicata, Taraxacum officinale and Trifolium repens). Five variables increased the probability of homeowners managing their lawns as turfgrass monocultures: living in a neighborhood with larger yards, summer watering frequency, fertilizer frequency, valuing space for children and valuing wildlife habitat. Valuing an easy to manage yard decreased the turfgrass monoculture probability. In polyculture yards, having a larger lawn was positively correlated with non-turfgrass species richness, but elevation was negatively correlated. Homeowners who valued space for children appeared to have more intensive lawn care regimes than those who valued wildlife habitat or easy to manage yards. Although lawn floras result from complex interactions of the environment and households, urban characteristics appeared to be weaker drivers of diversity than homeowner preferences and lawn care.

Key words: residential lawns, homeowner preferences, lawn care practices, lawn floras, species diversity

Introduction

Lawns are dominant features of urban ecosystems, covering about 11–23% of the area of cities that have them (Akbari, Rose, and Taha 2003; Robbins and Birkenholtz 2003; Hedblom et al. 2017; Ignatieva et al. 2020). Created and intensely maintained to provide a uniform, green surface, lawns provide attractive spaces for outdoor social interactions, exercise and play for adults, children and pets (Beard and Green 1994; Rasidi, Jamirsah, and Said 2012; Cao and Kang 2019; Evenson et al. 2019). Robbins and Birkenholtz (2003) called the expansion of the urban lawn a critical, but overlooked, component of regional ecosystem change. Given the tremendous subsidies of plant materials, water, chemicals, labor, time, capital and energy to establish and maintain them (Robbins and Sharp 2003; Robbins 2007; Naylor 2012; Gu et al. 2015; Locke et al. 2019), lawns are a crucial case (Gerring 2004) to explore how and why people manipulate urban vegetation.

The modern lawn aesthetic has roots in traditional European landscape designs and paintings of the 18th and 19th centuries (Robbins and Sharp 2003; Jenkins 2015). Closely trimmed, grassy fields surrounding the homes of aristocrats required large amounts of space and labor for their production and management (Ignatieva et al. 2020). A neat, highly...
manicured lawn transmits a message of wealth, power and beauty. Green lawns came to represent an ideal, pastoral landscape to be displayed, enjoyed and consumed (Robbins and Sharp, 2003; Harris et al. 2013). In Germany, Sweden and China, lawns tend to be in publicly accessible green spaces (Yang et al. 2019; Ignatieva et al. 2020). In Anglo-American cities with a tradition of detached, single-family residences, a large proportion of the lawns are privately owned (Thompson et al. 2004; Stewart et al. 2009).

A typical home lawn in the USA averages 540 m² and requires 4–9 h of maintenance per 100 m² lawn/year (Brede 2000). Residents typically prefer green lawns with turfsgrasses only, allowing few or no broadleaf species. To maintain a green, weed-free surface, most residents implement an intensive regime of frequent watering, mowing, managing weeds and pests and applying fertilizer (Varlamoff et al. 2001; Robbins 2007; Blaine et al. 2012; Martini and Nelson 2015). Robbins (2007) argued that having a lawn converts homeowners into ‘lawn people’ who adopt intensive lawn care regimes to comply with neighborhood norms for aesthetics and concern for property values. In particular, neighborhood income and wealth related variables appear to lead to different outcomes in urban vegetation. The ‘luxury effect’ describes the urban phenomenon whereby wealthier residents and neighborhoods have greater plant species diversity, more green space and greener land covers (Hope et al. 2003; Leong, Dunn, and Trautwein 2018). For perennial plant species, the luxury effect may lead to greater plant species diversity (Clarke, Jenerette, and Davila 2013; Wang et al. 2015; Chamberlain et al. 2020) and greater tree cover (Lowry, Baker, and Ramsey 2012; Schwarz et al. 2015). For lawns, the luxury effect may result in the opposite trend: reduced lawn species richness (Wheeler et al. 2017), more greenness (Zhou et al. 2009), more frequent fertilizer application (Carrico, Fraser, and Bazuin 2013; Martini and Nelson 2015) and more frequent irrigation (Bremer, Keeley, and Jager 2015).

The apparently continental-scale homogeneity of lawn floras and lawn care in the USA (Wheeler et al. 2017) suggests a need to understand how lawn floras and lawn care develop in situ, from multi-scalar urban environments of homeowner preferences and neighborhood norms interacting with broader scale drivers and species pools (Chowdhury et al. 2011; Cook, Hall, and Larson 2012; Pearse et al. 2018). In addition to wealth metrics, researchers have found density (Polsky et al. 2014; Locke et al. 2019) and house age (Zhou et al. 2009; Bremer, Keeley, and Jager 2015) to be associated with different lawn care regimes. Others identified links between yard care and residents’ gender, age and life stage (Blaine et al. 2012; Martini and Nelson 2015; Locke et al. 2019). Padullés Cubino et al. (2020) linked resident preferences to species richness. Residents who preferred neat landscapes had fewer spontaneous plant species. Those who preferred showy landscapes had more.

The main goals of this study were to characterize new lawn floras and to evaluate the human systems that influence them, as part of an effort to document initial conditions of new residential landscapes (hereafter ‘yards’) in the Seattle Metropolitan Statistical Area, USA. Do new homeowner preferences or lawn care practices already lead to diversity differences in new lawns? After recruiting a stratified random sample of 60 homeowners who bought a newly constructed single-family home and yard, I collected four datasets: lawn species composition, homeowner goals for the appearance and use of their new yards, lawn care practices and parcel and neighborhood characteristics. I had four main objectives: (i) to describe new homeowners’ preferences and lawn care, (ii) to describe and compare species composition and diversity of new residential lawns to other lawns of mixed ages, (iii) to test whether parcel, neighborhood and homeowner drivers could already be influencing species diversity and (iv) to examine whether homeowner preferences might represent the expression of different lawn care regimes across the urban landscape.

I hypothesized that yard goals based on normative ideas of lawn appearance should be ranked highly, while ideas about ease of maintenance should be more variable to reflect homeowner ambivalence about lawn care labor (Robbins 2007; Harris et al. 2013). Because the full regime of actual lawn care (seasonal irrigation, fertilization, mowing, edging and herbicide application) is not well documented in the literature [but see Gu et al. (2015) for resident lawn care and Yang et al. (2019) for public park lawn care], I made no predictions about lawn care frequencies. Rather, my goal was to describe new homeowner lawn care, because new homeowners have strong incentives to protect the appearance and value of their new spaces to meet neighborhood norms (Nassauer, Wang, and Dayrell 2009; Carrico, Fraser, and Bazuin 2013; Sisser et al. 2016).

Given lawn age and the green, weed-free lawns aesthetic, I predicted lawn species diversity would be low and that species composition and urban drivers of species diversity should be similar to other lawn studies. Because richness tends to increase as lawn area increases (Thompson et al. 2004), yards with more lawn area should have more species. However, the species–area relationship may not hold for new lawns, because not enough time has passed for species establishment. Homeowners who have large lawns and who intensively manage their lawns may also have fewer species than homeowners with smaller lawns and less intensive management. Because the luxury effect suggests that wealthier homeowners tend to have fewer species (Wheeler et al. 2017) and more intensive lawn care regimes (Robbins and Sharp 2008; Bremer, Keeley, and Jager 2015; Locke et al. 2019), higher home and neighborhood values should be associated with decreased species richness and more intensive lawn care practices. Homeowners who prioritized easier to care for lawns should have more species than those who prioritized neatness. Higher frequencies of watering and fertilizer application should lead to lower diversity lawns (Nielson and Smith 2005; Wheeler et al. 2017).

**Methods**

**Study area**

The Green-Duwamish River flows northwest from the Cascade Mountains in Washington State, USA, through forests, agricultural areas, residential lands, commercial zones and heavily industrialized lands (King County 2005; Sheppard, Ryan, and Blahna 2017). Draining about 1730 km² (Sheppard, Ryan, and Blahna 2017), the watershed intersects the Cascade and the Puget Lowland ecoregions (Omernik 1987; Collins, Montgomery, and Sheikh 2003). Because the upper watershed (~569 km²) has no permanent residents, I eliminated it from further study.

Within the study area (Fig. 1), elevation ranges from 0 to 365 m above mean sea level. Lower elevations are in the north-west part of the study area; higher elevations are in the east. Climate is temperate and summer dry (Climate-Data.Org 2020; National Oceanic and Atmospheric Administration 2020) with warmer, drier conditions at lower elevations. For the Seattle-Tacoma airport (N 47°26′, W122°18′, 132 m elevation), mean annual temperature is 12°C (52°F) and mean annual precipitation is 982.7 mm (38.7 in). For the City of Enumclaw, (47.220278°,
121.963889°W, 232 m elevation), mean annual temperature is 9.8°C (49.7°F) and mean annual precipitation is 1432 mm (56.4 in). Lowland vegetation in the western Cascades is temperate coniferous forest (Henderson et al. 1992; Kruckeberg 1995) dominated by *Pseudotsuga menziesii* (Douglas-fir), *Picea sitchensis* (Sitka spruce), *Tsuga heterophylla* (western hemlock) and *Thuja plicata* (western red-cedar). Occasional deciduous species are *Alnus rubra* (red alder), *Acer macrophyllum* (bigleaf maple), *Salix* spp. (willows) and *Populus trichocarpa* (black cottonwood).

Part of the rapidly urbanizing Seattle Metropolitan Statistical Area, the study area supports about 630,000 residents (Hutyra et al. 2011; Sorenson 2012; Sheppard, Ryan, and Blahna 2017). Industrial land uses are concentrated to the northwest, around the estuary and the cities of Tukwila and Kent (Puget Sound Regional Council 2015). Residential land uses cover about 39% of the lower study area and 50% of the upper study area (King County 2005). Remaining land uses are forestry, agriculture and commercial.

**Data and data management**

I downloaded real estate transactions and relevant shapefiles (parcels, watersheds, ecoregions and Census Block Groups) from public sources (Environmental Protection Agency 2016; King County 2016) to build a sampling frame of new homebuyers in the study area (Supplementary File S1). I used QGIS (QGIS Development Team 2019) to plot study sites and land cover. For other data manipulation, I used R version 3.5.1 (R Core Team 2019) and ‘tidyverse’ (Wickham 2019). I plotted figures using ‘tidyverse’, ‘patchwork’ (Petersen 2020), ‘viridis’ (Garnier 2018), ‘likert’ (Breyer and Speerschneider 2016), ‘psych’ (Revelle 2018) and ‘corrplot’ (Wei and Simko 2017).

Below, I describe data collection, calculations and analyses for the following datasets: lawn species composition and diversity, lawn area, homeowner goals for the appearance and use of their yards, lawn care practices and parcel and neighborhood characteristics. The University of Washington Human Subjects Division determined that this human subjects’ research qualified for exempt status, based on procedures, lack of participant risk and subject matter.

**Lawn species composition and diversity**

I recruited a stratified random sample of 60 new homeowners, from a sampling frame of 1258 homeowners in the study area who bought a single-family residence built in 2014 or 2015. Each stratum had 15 homeowners. Strata represented the number of homes each unique developer had within the sampling frame: Stratum 1 (one home/unique developer), Stratum 2 (two homes), Stratum 3 (three to eight homes) and Stratum 4 (nine or more homes).

In 2016, I visited each new home. The new yards contained non-vegetated (mulch, gravel and rock) and vegetated patch types (planting beds, tree clumps and lawns). I defined lawns as turfgrass dominated patches, whether they occurred as curb strips, front yards or backyards (Fig. 2). Most lawn patches were newly installed sod and consisted of combinations of *Lolium perenne* (perennial ryegrass), *Poa pratensis* (Kentucky bluegrass) and
**Festuca** spp. (fescues). Two yards did not have lawns. Final sample size is 58 yards.

Within each yard, my field crew and I counted vascular plant species within each patch (woody and herbaceous perennial patterns will be published later). Assuming that most homeowners would focus on removing non-turfgrass species as weeds, I identified all non-turfgrass taxa to species and lumped all turfgrasses as ‘turf’ (Supplementary File S2). Nomenclature follows Hitchcock and Cronquist (2018). I compared the final species list to species lists from other lawn studies and evaluated how many non-turfgrass species they had in common.

For each yard, I calculated diversity indices using ‘vegan’ (Oksanen 2018). All indices were in effective species form (Hill 1973; Jost 2006): species richness ($x$), Shannon entropy ($\exp(x)$) and Simpson concentration ($1/x$). For indices requiring a species abundance metric, I used counts of individuals. For turfgrass, count was the number of lawn patches in the yard. For all other species, count was the number of individuals in all lawn patches. After calculating yard species richness, I scored each yard as a lawn monoculture or polyculture. Monoculture yards had no species other than turfgrass in any patch of lawn (yard species richness = 1). Polyculture yards had species richness >1. I used ‘survey’ (Lumley 2019) to estimate total lawn area in the sampling frame by management (turfgrass monoculture or lawn polyculture).

**Lawn area**

To account for species–area differences, I measured dimensions of all patches with a 50-m tape. I converted dimensions to area, using standard geometry equations or the offset method for irregular patches (Christians and Agnew 2008). From these area measurements, I divided total lawn area by total yard area. To correct measurement error, I multiplied the above lawn proportion by yard area estimates from aerial photo interpretation. Estimated yard area was the difference between the developed area of the parcel and all impervious surfaces within it. I used the King County parcel viewer (King County 2018) to measure impervious surfaces (building footprint, other pavement) and the total developed area on 2017 aerial photos. Developed parcel area did not include areas that the developer did not convert to pavement or landscaping (steep slopes and wetlands) or difficult to access areas (outside of fences).

**Homeowner questionnaire**

After I completed the site visit in 2016, I sent homeowners a questionnaire (Supplementary File S1), which they returned in 2016 or early 2017. The new homeowners answered 18 questions about their yard, how they manage their yard, how they select plants, and information about their household. Only 35/60 participating households responded. Two of these responses were from homeowners without lawns. Sample size for analyses based on the questionnaire is 33 yards.

Because aesthetics, ease of maintenance and planned uses influence yard care and landscaping recommendations (Brenzel 2007; Larson et al. 2009; Nassauer, Wang, and Dayrell 2009; Stoecklein 2011; Kruckeberg and Chalker-Scott 2019), I asked homeowners to circle the importance of eight yard goals: looks beautiful; looks neat/tidy; easy to maintain; provides wildlife habitat; place to grow food; place to entertain; place for...
Homeowner preferences drive lawn care practices

I asked several questions about yard care. For activities except irrigation, I asked each household to circle the active seasons (fall, winter, spring and summer) and to estimate frequency by activity (1× per week or more; 2–4× per month; 1× per month; 1× per season; 1–3× per year; never). For lawn irrigation, I asked them to circle frequency (daily; 2–3×/week; 1×/week; 2–3×/month; 1×/season; and never) by season (spring, summer, fall and winter). I asked them to name specific fertilizers and herbicides they applied. Although several homeowners reported using no herbicides, they reported using lawn fertilizers that did contain herbicides. I therefore excluded herbicides from further evaluation. From these responses, I created annual estimates of lawn care activity frequency for each household: mowing (using a lawn mower to cut grass), edging (cutting the lawn edge vertically to maintain a distinct border between lawn and pavement, mulch, gravel or planting beds), and watering (cutting the lawn edge vertically to maintain a distinct border between lawn and pavement, mulch, gravel or planting beds).

**Variables and analysis**

I calculated four sets of independent variables (Table 1). Parcel scale variables represented site-specific conditions (elevation, 2016 improvement value and lawn area). Neighborhood scale variables (residential density, median age, median assessed value and median yard area) represented broader scale development decisions and neighborhood wealth. Because these were all newly built and sold homes, neighborhood changes may not be reflected in Census data. Therefore, I calculated all neighborhood variables from 2016 assessor parcel data, using Census Block Groups as neighborhood surrogates. Appraised improvement value and median assessed value were surrogates for household and neighborhood wealth to test for the luxury effect (Moudon et al. 2011; Bremer, Keeley, and Jager 2015). Because of the small sample size for household variables (n = 33), I analyzed six of eight yard goals (Beautiful, Neat, Easy, Habitat, Food Space and Kid Space). I chose to exclude Pet Space and Entertain'. Pet Space repeatedly caused model overfitting error messages. Entertain was negatively correlated with Easy (Spearman’s rho = −0.36) and positively correlated with Beautiful, Neat, Habitat and Food Space (Spearman’s rho ≥ 0.2). I analyzed five lawn care practices (spring watering, summer watering, fall watering, annual mowing and annual fertilization).

To fit four sets of regressions to model lawn diversity (Table 2), I used ‘MASS’ (Ripley et al. 2018). To model the probability that yards supported turfgrass monocultures, I fit logistic regressions. To model polyculture species richness, I fit negative binomial regressions with a spatial filtering lag using ‘spdep’ (Bivand et al. 2019). For each analysis, I fit the full model with all variables for that group (parcel, neighborhood, yard goals or lawn care). Then, I used the ‘stepAIC’ function (both directions) in ‘MASS’ to suggest the best fitting model. Given small sample sizes, I selected the final models to interpret based on corrected Akaike Information Criterion (AICc) values, Bayesian Information Criterion (BIC) values and likelihood tests (Long 1997). I calculated AIC, values with ‘MuMIn’ (Barton 2018).

Because some variables were correlated, I calculated the variance inflation factor (VIF) post hoc for predictor variables using ‘car’ (Fox and Weisberg 2019). VIFs estimate variance inflation in the final regression models as a result of correlations between the predictor variables. VIFs range from unity to infinity.

**Table 1: Summary of independent variables evaluated in diversity analysis**

| Model                           | Variable                                      | Variable description                                      |
|---------------------------------|-----------------------------------------------|----------------------------------------------------------|
| Parcel                          | Elevation (m)<sup>a</sup>                    | Elevation above mean sea level                            |
|                                 | Improvement Value ($)<sup>b</sup>            | 2016 value of buildings and other improvements            |
|                                 | Lawn Area (log 10 m²)<sup>c</sup>            | Area of yard dominated by turf grasses                    |
| Neighborhood (Census Block Group)| Residential Density (no. of residences/km²)<sup>b</sup> | Calculated: no. of residential units/area of Census Block Group |
|                                 | Median Age (years)<sup>b</sup>               | Calculated: 2016—median year built all residential properties |
|                                 | Median Assessed Value ($)<sup>b</sup>        | Calculated: median parcel value (improvements and land value 2016) |
|                                 | Median Yard Area (log 10 m²)<sup>b</sup>     | Calculated: median (lot area—estimated building footprints) |
| Yard Goals                      | Beautiful<sup>d</sup>                        | Yard is beautiful (Likert scale) from 1 (very unimportant) to 5 (very important) |
|                                 | Neat<sup>d</sup>                             | Yard is neat (Likert scale) from 1 (very unimportant) to 5 (very important) |
|                                 | Easy<sup>d</sup>                             | Yard is easy to manage (Likert scale) from 1 (very unimportant) to 5 (very important) |
|                                 | Habitat<sup>d</sup>                          | Yard provides wildlife habitat (Likert scale) from 1 (very unimportant) to 5 (very important) |
|                                 | Food Space<sup>d</sup>                       | Yard provides food (Likert scale) from 1 (very unimportant) to 5 (very important) |
|                                 | Kid Space<sup>d</sup>                        | Yard provides space for kids (Likert scale) from 1 (very unimportant) to 5 (very important) |
| Lawn Care                       | Spring Water<sup>d</sup>                     | Count estimate—no. of times watered in spring             |
|                                 | Summer Water<sup>d</sup>                     | Count estimate—no. of times watered in summer             |
|                                 | Fall Water<sup>d</sup>                       | Count estimate—no. of times watered in fall               |
|                                 | Annual Mow<sup>d</sup>                       | Count estimate—no. of times mowed per year                |
|                                 | Annual Fertilizer<sup>d</sup>                | Count estimate—no. of times fertilized per year           |

<sup>a</sup>Google Maps.

<sup>b</sup>Assessor data for 2016 (King County 2016).

<sup>c</sup>Field measurements corrected by aerial photo interpretation measurements.

<sup>d</sup>Yard Questionnaire.
Values above 3.3-10 indicate possible collinearity problems (Kock and Lynn 2012; Fox and Weisberg 2019). The square root of VIF shows how much larger the standard error would be compared with an uncorrelated predictor. All predictor variables in final models had VIFs <3.

To see if yard goals that influenced lawn diversity were correlated with lawn care, parcel variables, or neighborhood variables, I ran Spearman rank correlations in ‘Hmisc’ (Harrell 2019). Correlations between influential preferences, lawn care and urban metrics would have been more robust if more homeowners had returned the survey.

**Results**

**Yard goals and lawn care**

At least 73% of responding households ranked Neat, Easy, Beautiful, Pet Space and Entertain as important or very important (Fig. 3A). They ranked Kid Space, Habitat and Food Space more variably. Neat and Beautiful were positively correlated (Spearman rho = 0.66, P < 0.001), as were Habitat and Entertain (Spearman rho = 0.42, P = 0.009). Easy and Entertain were negatively correlated (Spearman rho = −0.36, P = 0.028).

Based on medians, a typical homeowner watered 27 times: thrice in the spring, 24 times in the summer, and not at all in the fall (Fig 3B). The typical homeowner fertilized twice, mowed 21 times, and edged 15 times (Fig 3C). Extreme watering counts (>45/season) were from daily watering. Extreme fertilizer counts (6+/year) were from monthly watering.

**Lawn species diversity and composition**

Eleven sites had monoculture lawns. About 2 + 0% of sampling frame lawn area was strict turfgrass monoculture: (33 418 ± 16 489 m² monoculture versus 128 967 ± 24 317 m² polyculture). Effective species richness declined steeply as sensitivity to common species (diversity order, q) increased (Fig. 4): species richness (q = 0) was 6.5 ± 5.3 species, exp (Shannon) (q = 1) was 4.1 ± 2.7 species and inverse Simpson (q = 2) was (3.2 ± 2.1) species.

Only 28/55 lawn taxa occurred at more than three sites (Fig. 5). Turfgrasses, *Hypochaeris radicata* (spotted cat’s ear), *Taraxacum officinale* (dandelion) and *Trifolium repens* (white clover) were the only species to occur at 50% or more of the study sites. *Epilobium ciliatum* (common willowherb) was the only frequent Pacific Northwest native taxon. All other native taxa occurred at two or fewer sites.

The new lawn flora had substantial overlap with 13 other lawn floras (Table 3 and Supplementary S2), particularly for florals from temperate cities. In addition to turfgrass, the following study species occurred in at least 8/13 other lawn floras: *Malva neglecta* (cheeseweed), *Medicago lupulina* (black medic), *Poa annua* (annual bluegrass), *Plantago lanceolata* (English plantain), *Plantago major* (common plantain), *Polygonum aviculare* (common knotgrass), *Stellaria media* (chickweed), *T.officinale* and *T.repens*. Eighty-two percent of study species were detected in at least one other lawn flora.

**Diversity drivers**

Five variables increased the probability that a homeowner maintained a turfgrass monoculture (Table 4): median neighborhood yard area, wanting to provide wildlife habitat (Habitat), wanting space for children (Kid Space), summer watering frequency and annual fertilizer frequency. However, having easy to manage (Easy) as a yard goal decreased the probability. Despite their smaller sample size, yard goal (Pseudo $R^2 = 0.57$) and lawn care (Pseudo $R^2 = 0.33$) models explained more deviation than the census block group model (Pseudo $R^2 = 0.13$). The final parcel model was intercept only (Pseudo $R^2 = 0$).

For homeowners who managed their yards as polycultures, only the parcel model predicted species richness (Pseudo $R^2 = 0.40$). Higher elevation was negatively correlated with species richness and lawn area was positively correlated. All other models were spatial lag only.

The correlation matrix (Fig. 6) showed the complex interactions of households choosing homes and yards to purchase and manage. Habitat was negatively correlated with improvement value (Spearman’s rho = −0.33, P = 0.0583). Kid Space was positively correlated with lawn area (Spearman’s rho = 0.57, P = 0.0005) and median yard area (Spearman’s rho = 0.48, P = 0.0047) and negatively with neighborhood residential density (Spearman’s rho = −0.40, P = 0.02) and age (Spearman’s rho = −0.39, P = 0.025). Homeowners who prioritize Kid Space appear to have a much more intensive...
lawn care regime. When compared with Habitat and Easy, Kid Space was more positively correlated with greater frequencies of irrigation, mowing and fertilizing.

Luxury effect

Neither appraised improvement value nor median assessed value increased the probability that the yard was a turfgrass monoculture (Table 4). Neither variable was associated with decreased species richness in polyculture yards. However, the next most likely parcel and neighborhood models for polyculture species richness included appraised improvement value and median assessed value (Supplementary File S2). I found a positive correlation for median assessed value and fertilizer frequency (Spearman’s rho = 0.41, P = 0.02). No other variables were correlated with appraised improvement value or median assessed value.

Discussion

Homeowner preferences

As in other studies, homeowners ranked Beautiful, Neat and Easy as important. They also ranked Pet Space and Entertain highly, but they had more divergent views about other uses of their yards. Similarly, residents in six US cities also cited
Beautiful (plants create a beautiful yard) and Easy (yard is easy to maintain) as two of the most important preferences (Larson et al. 2016). In Phoenix, AZ, residents rated yard appearance and maintenance as important factors in their preference for different yard types, especially for front yards (Larson et al. 2009). Of the residents who preferred mesic and oasis yard types (which contain lawns), they cited appearance and recreation as the main reasons for their preference. Recreation included playing, socializing and gardening, which, like Entertain, encompasses several leisure preferences that appear similar to Kid Space, Habitat and Food Space. Recreation and Entertain may represent household willingness to engage in outdoor leisure activities.

Lawn care

The lawn care regimes of new homeowners are similar to each other and to Tennessee residents (Gu et al. 2015). Mean frequencies of fertilization (2.6 vs. 2.5/year) and mowing (21 vs. 18 times/year) were similar as were irrigation seasons (nearly everyone in summer, about 75% of households in spring, and <10% in fall). However, total irrigation frequency was greater for this study (48.0 vs. 38.7 times/year), which could be from promoting new lawn establishment and/or the summer dry Pacific Northwest climate. Other researchers have found substantial differences in lawn irrigation and fertilization within and across cities (Polak et al. 2014; Bremer, Keeley, and Jager 2015; Gu et al. 2015).

It is unclear whether new homeowners’ lawn care was more intensive than longer-term residents or public space managers. In addition to Gu et al. (2015), few studies described lawn care other than irrigation and fertilization. In Minnesota, USA, Carpenter and Meyer (1999) investigated the effectiveness of an environmental education campaign, documenting residents’ lawn care before and after the campaign. They reported the proportion of residents who conducted specific activities and reported weekly frequencies for irrigation and mowing, but did not come up with seasonal or annual estimates. Locke et al. (2019) examined irrigation, fertilization and pesticide application in six US cities and found that 53% of residents applied pesticides. In China, Yang et al. (2019) reported annual lawn care frequencies in 28 public parks in Xi’an. Park workers mowed more than 11 times annually. They mainly controlled weeds by manually removing them. Only two to three parks reported using herbicides.

Lawn herbaceous composition

I found substantial compositional overlap in lawn floras. The most frequent species in sampled lawns (Fig. 5) were often highly frequent in lawns in 13 cities (Supplementary File S2). These globally frequent species appear to quickly establish and tolerate typical lawn care. Oddly, H. radicata, the most frequent and abundant forb in my sample, is neither frequent nor abundant in other lawn floras, although it is present in 5/13 cities. Homeowners who manage their lawns less intensively may choose to keep T. officinale, which looks superficially similar. Plot-based sampling may not capture true frequencies of this disturbance tolerant, highly plastic weed (Ortiz et al. 2008; Mitchell and Bakker 2014), given its patchy distribution in sampled lawns.

Lawn diversity and drivers

Lawn species richness in study yards (6.5 ± 5.3) was on the lower range of mean species richness elsewhere: 15 in the UK (Thompson et al. 2004), 9.2 in Paris (Bertoncini et al. 2012) and 5–15 in seven US metropolitan areas (Wheeler et al. 2017). The low richness in this study was probably from lumping turfgrass species and from researching new lawns. When compared with older lawns, not enough time may have passed for species establishment.
Table 3: Comparison of study with 13 other lawn floras (Supplementary File S2)

| Study location          | % of study species in Flora | No. of lawns sampled | Comments                                                                 |
|-------------------------|----------------------------|----------------------|--------------------------------------------------------------------------|
| Seattle, WA, USA (this study) | 100                        | 58                   | Newly established private residential lawns installed                     |
| Sheffield, UKa           | 55                         | 52                   | Private gardens                                                           |
| Paris, Franceba          | 42                         | 100                  | 22 public lawns; 4 private lawns                                         |
| Wooster, OH, USAc         | 36                         | 38                   | Mix of lawns across city; ownership not described                        |
| Baltimore, MD, USAd       | 35                         | 23                   | Private residential lawns                                                |
| Santiago de Chile, Chilee | 35                         | 30                   | Lawns and grasslands in five city parks                                  |
| Boston, MA, USAd          | 31                         | 31                   | Private residential lawns                                                |
| Szczecin, Polandf        | 27                         | 30                   | Lawns of 3 housing estates established 10, 20 and 30 before study        |
| Minneapolis-St. Paul, MN, USAd | 26                     | 21                   | Private residential lawns                                                |
| Christchurch, New Zealandf | 20                        | 327                  | Public and private lawns; complete species list not found                |
| Phoenix, AZ, USAd         | 16                         | 28                   | Private residential lawns                                                |
| Salt Lake City, UT, USAd  | 18                         | 30                   | Private residential lawns                                                |
| Los Angeles, CA, USAd     | 15                         | 20                   | Private residential lawns                                                |
| Miami, FL, USAd           | 6                          | 21                   | Private residential lawns                                                |

aThompson et al. (2004).
bBertoncini et al. (2012).
Whitney (1985).
cWhitney (1985).
dWheeler et al. (2017).
fFischer et al. (2016).
gGamrat and Saran (2018).
hStewart et al. (2009).

Table 4: Summary of variables predicting turfgrass monocultures and polyculture lawn species richness (Supplementary File S2)*

| Variable                                | Monoculture Lawn Logistic Regression (y = 0 not turfgrass monoculture or y = 1 turfgrass monoculture) | Polyculture Lawn Species Richness Negative Binomial Regression (y > 0) |
|-----------------------------------------|---------------------------------------------------------------------------------------------------|---------------------------------------------------------------------|
| Final parcel model                      | Pseudo R² = 0, P = 1; n = 58                                                                      | Pseudo R² = 0.40, P = 0.005; n = 47                                 |
| Elevation                               |                                                                                                   | Pseudo R² = 0.30; **P < 0.001; n = 47                                |
| Improvement value                       |                                                                                                   | **P < 0.001; n = 47                                                 |
| Log10 lawn area                         |                                                                                                   | 0.37; **P < 0.001; n = 47                                           |
| Spatial lag                             |                                                                                                   | 1.68; **P < 0.001; n = 47                                           |
| Final neighborhood model                | Pseudo R² = 0.13, P = 0.008, n = 58                                                                | Pseudo R² = 0.27; **P < 0.001, n = 47                               |
| Residential density                     |                                                                                                   |                                                                     |
| Median age                              |                                                                                                   |                                                                     |
| Median assessed value                   |                                                                                                   |                                                                     |
| Median log 10 yard area                 | 0.947; *P < 0.05, n = 58                                                                           |                                                                     |
| Spatial lag                             |                                                                                                   |                                                                     |
| Final yard goal model                   | Pseudo R² = 0.57, P = 0.02; n = 33                                                                | Pseudo R² = 0; n = 1, n = 25                                        |
| Neat                                    | −2.63; **P < 0.001                                                                               |                                                                     |
| Easy                                    | 2.77; *P < 0.05                                                                                 |                                                                     |
| Habitat                                 |                                                                                                   |                                                                     |
| Food Space                              | 2.02; **P < 0.001                                                                               |                                                                     |
| Kid Space                               |                                                                                                   |                                                                     |
| Spatial lag                             |                                                                                                   |                                                                     |
| Final lawn care model                   | Pseudo R² = 0.33, P = 0.013, n = 33                                                               | Pseudo R² = 0; n = 1, n = 25                                        |
| Spring water                            |                                                                                                   |                                                                     |
| Summer water                            | 1.25; *P < 0.05                                                                                 |                                                                     |
| Fall water                              |                                                                                                   |                                                                     |
| Mow                                     |                                                                                                   |                                                                     |
| Fertilizer                              | 1.29; *P < 0.05                                                                                 |                                                                     |
| Edge                                    |                                                                                                   |                                                                     |
| Spatial lag                             |                                                                                                   |                                                                     |

*If the cell is blank, the final model did not contain that term.
Significance levels: P < 0.1;
*P < 0.05;
**P < 0.01;
***P < 0.001.
Using the effective species form of diversity indices puts them on the same scale, allowing for direct comparison between indices (Hill 1973; Jost 2006). The diversity order of an index \( q \) represents its sensitivity to rare or common species. Species richness \( (q = 0) \) disproportionately favors rare species; inverse Simpson \( (q = 2) \) disproportionately favors common species. Shannon entropy favors neither. The 51% decrease in effective species, from species richness to inverse Simpson (Fig. 4), demonstrated that study lawns were very uneven communities, consisting of turfgrass and two other very abundant species.

Self-reported yard goals were stronger predictors of lawn monoculture status than urban system variables. Kid Space, Habitat and Easy appear to link homeowner preferences to management systems and floral diversity. Kid Space and neighborhood yard size may be proxies for suburbanization and preferring the traditional lawn aesthetic, just as median assessed yard care practices and urban variables (Fig. 6). Study lawns were very uneven communities through reduced species richness and more frequent lawn care regimes (Fig. 6). Carrico, Fraser, and Bazuin (2013) found that wanting space for children or pets was predictive of fertilizer application. In contrast, Habitat and Easy appear to have less intensive lawn care (negative lawn care correlations). Because Kid Space and Habitat seem to have different lawn care but have higher probabilities of turfgrass monocultures, I speculate that their weed removal methods are different. Habitat may represent active gardeners who view weed control as an act of land stewardship (Robbins and Sharp 2008; Larson et al. 2009; Mustafa et al. 2010). Participants who favor Easy may not have time, energy, or interest in intensive lawn care. In a study of six US cities, Padullés Cubino et al. (2020) also found links between residents’ landscaping priorities and plant species diversity in yards. For spontaneous species in these yards, Neat was negatively correlated, while Showy was positively correlated. Neither Low Cost nor Natural (which is similar to Habitat) showed a relationship with spontaneous species diversity, but both influenced cultivated species diversity.

Higher frequencies of fertilizer use and summer irrigation were also positively associated with monoculture lawns. Nielson and Smith (2005) found Oregon lawn homogeneity and greenness were associated with more frequent watering and fertilization. They also found more frequent fertilization to be positively associated with higher household income. Wheeler et al. (2017) found lawn species richness to be lower in higher income neighborhoods and in fertilized lawns. In studies examining lawn fertilizer use only (not lawn communities or greenness), higher household or neighborhood income was associated with greater fertilizer frequency and application amounts (Robbins and Sharp 2008; Zhou et al. 2009; Blaine et al. 2012; Carrico, Fraser, and Bazuin 2013; Bremer et al. 2015; Carrico et al. 2018).

In defining the luxury effect, Hope et al. (2003) noted that socioeconomics drive plant diversity, finding positively correlations between woody species diversity and median family income. For lawns, I argue that the luxury effect should be expanded to include how socioeconomics structure lawn communities through reduced species richness and more frequent fertilizer application, as noted by Schell et al. (2020).

Implications

Green, weed-free lawns are highly desirable (Carpenter and Meyer 1999; Varlamoff et al. 2001; Nielson and Smith 2005) and provide evidence of care (Nassauer, Wang, and Dayrell 2009; Sisser et al. 2016). Adhering to this traditional lawn aesthetic requires a tremendous investment of time, energy, water, energy and chemicals (Robbins 2007). Alternative lawns and lawn care may reduce negative effects of maintaining lawns, by reducing chemicals inputs, reducing water use, decreasing carbon emissions, providing more nectar sources, promoting species diversity and growing food (Naylor 2012; Larson, Redmond, and Potter 2013; Gu et al. 2015; Wastian, Unterweger, and Betz 2016; Ignatieva and Hedblom 2018; Lerman et al. 2018). As Mustafa et al. (2010) and Naylor (2012) noted, transforming yards from the traditional lawn aesthetic is personal and political, transgressing neighborhood norms. Individuals and organizations promoting alternative lawn aesthetics will have to address social norms and personal decisions about private space.

Less frequent mowing and allowing more diverse lawns benefit pollinators by providing more nectar sources (Wastian et al. 2016; Lerman et al. 2018). Few researchers have investigated mowing and lawn weed control (but see Carpenter and Meyer 1999; Zirkle, Lai, and Augustin 2011; Gu et al. 2015; Yang et al. 2019; Locke et al. 2019). Study households mowed more than the twice-monthly regime that maximized nectar sources (Lerman et al. 2018) and provided unreliable herbicide usage information. Creating reliable herbicide estimates from household self-reported data depends on consumer knowledge of ingredients and willingness to admit using herbicides. More herbicide education and clearer product labels may be needed. Specific household lawn weed removal practices require further investigation. Despite the fact that Kid Space households appear to water, mow and fertilize more frequently than ‘Habitat’ households (Fig. 6), both Kid Space and Habitat increased the probability of lawn monocultures. Kid Space households probably use different weed control methods than ‘Habitat’ households, given that their lawn care appears different.

Because Kid Space, Habitat and Easy link household preferences, lawn care and floral outcomes, they represent potential targets for urban planners and conservations to craft strategies for reducing lawn inputs and promoting lawn alternatives.
Kid Space seems to represent households who chose neighborhoods with large yards and who prefer large, high input lawns. Working with homeowners in these suburban neighborhoods to reduce water use and fertilizer frequency could provide substantial benefits. Because Habitat or Easy households appear to have less intensive lawn care than Kid Space households, the messages should be different. Both homeowner types could be interested in polyculture lawns that require less care and provide more wildlife habitat (Ignatieva and Hedblom 2018). Habitat valuing homeowners may be active gardeners and could become intrigued by evaluating and selecting appropriate alternative trample-resistant plants. Easy valuing homeowners may be more interested in lawns that require less maintenance. Promoting low maintenance perennials instead of lawns may also be appropriate.

Conclusions
New residential lawns support a very low diversity, cosmopolitan plant community dominated by turfgrasses. Through a detailed case study of new lawns, I used multiple lines of evidence to link lawn diversity to parcel, neighborhood and household drivers. Homeowner preferences and lawn care were strong drivers of lawn diversity. Although the admittedly small sample size limited generalizability, other researchers should attempt to validate the Kid Space, Habitat and Easy lawn care regimes. More work is needed to document actual lawn care practices, especially mowing and weed control. Future researchers should consider analyzing drivers of turfgrass and non-turfgrass species diversity separately when using univariate analyses. Assessing the probability that lawns are turfgrass monocultures or are uniformly green with logistic regressions may be more appropriate when investigating why people adopt intensive lawn care practices. Non-turfgrass species richness may represent household willingness or ability to control weeds. The unusual frequency and abundance of \textit{H. radicata} need further investigation.

Supplementary data
Supplementary data are available at JUECOL online.

Data availability
All project data except personally identifiable information are available (DOI: 10.6084/m9.figshare.13218017). Personally identifiable information includes landowner name, address, unique parcel identification number and geographic coordinates.

Acknowledgements
I thank the 60 individual homeowners who granted property access and answered my questions. Johnny Narita, Sophia O’Hara, Kim Trask, Ryan Boyle and Elena Boyle helped count plants and measure area while I was on crutches. Marina Alberti, David Montgomery and Jan Whittington provided scientific guidance and commented on earlier versions of this manuscript. Richard Olmstead gave detailed advice on paper structure, accounting for differences in lawn area, and plant nomenclature. The Center for Statistics and the Social Sciences at the University of Washington consulted with me on statistics. Simone Des Roches and Karen Dyson commented on data visualizations. I thank the two anonymous reviewers and the associate editor for their suggestions that greatly improved the article.

Funding
The Bullitt Foundation partially funded this research, via the Priscilla Bullitt Collins Environmental Fellowship awarded to the author.

Conflict of interest statement. None declared.

References
Akbari, H., Rose, L. S., and Taha, H. (2003) ‘Analyzing the land cover of an urban environment using high-resolution orthophotos’, \textit{Landscape and Urban Planning}, 63(1): 1–4. https://doi.org/10.1016/S0169-2046(02)001
Barton, K. (2018) MuMIn: multi-model inference. R package version 1.42.1.
Beard, J. B., and Green, R. L. (1994) ‘The Role of Turfgrasses in Environmental Protection and Their Benefits to Humans’, \textit{Journal of Environmental Quality}, 23: 452–60.
Bertoncini, A. P. et al. (2012) ‘Local Gardening Practices Shape Urban Lawn Floristic Communities’, \textit{Landscape and Urban Planning}, 105: 53–61.
Bivand, R. et al. (2019) Spdep: spatial dependence, weighting schemes, statistics and models. R package version 1.1-2.
Blaine, T. W. et al. (2012) ‘Homeowner Attitudes and Practices towards Residential Landscape Management in Ohio, USA’, \textit{Environmental Management}, 50: 257–71.
Brede, D. (2000). \textit{Turfgrass Maintenance Reduction Handbook: Sports, Lawns, and Golf}. Chelsea: John Wiley & Sons.
Bremner, D. J., Keeley, S. J., and Jager, A. (2015) ‘Effects of Home Value, Home Age, and Lot Size on Lawn-Watering Perceptions and Behaviors of Residential Homeowners’, \textit{HortTechnology}, 25: 90–7.
Brenzel, K. N. (2007). \textit{Sunset Western Garden Book}, 8th ed. Menlo Park: Sunset Books.
Breyer, J., and Speerschneider, K. (2016) Likert: analysis and visualization likert items. R package version 1.3.5.
Cao, J., and Kang, J. (2019) ‘Social Relationships and Patterns of Use in Urban Public Spaces in China and the United Kingdom’, Cities, 93: 188–96.
Carpenter, P. J., and Meyer, M. H. (1999) ‘Edina Goes Green Part III: A Survey of Consumer Lawn Care Knowledge and Practices’, \textit{HortTechnology}, 9: 491–4.
Carrico, A. R., Fraser, J., and Bazuin, J. T. (2013) ‘Green with Envy: Psychological and Social Predictors of Lawn Fertilizer Application’, \textit{Environment and Behavior}, 45: 427–54.  
—— et al. (2018) ‘Household and Block Level Influences on Residential Fertilizer Use’, \textit{Landscape and Urban Planning}, 178: 60–8.
Chamberlain, D. et al. (2020) ‘Wealth, Water and Wildlife: Landscape Aridity Intensifies the Urban Luxury Effect’, \textit{Global Ecology and Biogeography}, 29: 1595–605.
Chowdhury, R. R. et al. (2011) ‘A Multi-Scalar Approach to Theorizing Socio-Ecological Dynamics of Urban Residential Landscapes’, \textit{Cities and the Environment}, 4: 1.
Christians, N. E., and Agnew, M. L., (2008). \textit{The Mathematics of Turfgrass Maintenance}. Hoboken: John Wiley & Sons.
Clarke, L. W., Jenerette, G. D., and Davila, A. (2013) ‘The Luxury of Vegetation and the Legacy of Tree Biodiversity in Los Angeles, CA’, \textit{Landscape and Urban Planning}, 116: 48–59.
