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Research Paper

Plant biodiversity in residential yards is influenced by people's preferences for variety but limited by their income

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HIGHLIGHTS

- General plant variety was more important to residents than high plant biodiversity.
- Residents expressed an emotional connection to plant variety in their yards.
- More colorful yards had more flowering plant genera.
- Income enabled residents to achieve their preferences for plant variety.
- Lawn species richness decreased as income increased, nuancing the luxury effect.

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ABSTRACT

Residential yards are a unique component of the urban environment and harbor high cultivated plant biodiversity; however, why and how people create yards with so many plant species is not well understood. To investigate this pattern, we studied the relationships between residents' preferences, income, and yard plant biodiversity in the Salt Lake Valley, Utah, USA where most of the urban vegetation is intentionally cultivated. We conducted in-person interviews, distributed written surveys, and inventoried the biodiversity (i.e., genus and species richness) of ornamental herbaceous flowering plants and lawn plants in residential yards located in neighborhoods across income levels. We found that 95% of surveyed residents valued having 'plants that create variety in the yard' ('variety' left open to interpretation) and that 47% of interviewed residents expressed an emotional connection to variety. On average, general plant variety was more important to residents than high plant biodiversity (i.e., a specified type of variety), but they also exhibited a preference for neat monoculture lawns lacking in biodiversity and other types of variety. Residents' preferences for general plant variety, and biodiversity specifically, were not necessarily reflected in their yards. Higher income households had greater flowering plant variety in terms of number of different flower colors, inflorescence types, and genera, but lower lawn species biodiversity due to a reduction in weedy species. Overall, our study shows that most residents in this region prefer plant variety in their yards more than biodiversity specifically, and that people with higher incomes can better achieve these preferences.

1. Introduction

Residential yards compose a large proportion of urbanized land area. It is estimated that 26–41% of urban land is residential (Avolio et al., 2020; Cook et al., 2012; McIntyre & Hostetler, 2001) and that yards can compose nearly half of that residential land (Mathieu et al., 2007). Yards encompass all vegetated parts of residential property, such as lawns, herbaceous flowering plants, shrubs, and trees. Lawns alone were found

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to occupy 23% of urban and suburban land in and around Columbus, Ohio (Robbins and Birkenholtz, 2003). Residential yards provide important regulating ecosystem services such as carbon sequestration and microclimate regulation as well as cultural services that can improve human well-being such as recreation and sense of place (Cook et al., 2012; Larson et al., 2019). They also can provide provisioning ecological services such as harboring high plant biodiversity (Avolio et al., 2020; Pearse et al., 2018) and providing habitat for pollinators and other wildlife (Davies et al., 2009; Fornoff et al., 2017). The extent of residential yards throughout urban areas and the ecosystem services that they provide make the yard a potentially valuable site for conservation in cities (Goddard et al., 2010).

While the plant biodiversity in residential yards can be broadly affected by regional and local variables such as climate, city laws, and Homeowners' Association regulations (Cook et al., 2012; Jenerette et al., 2016; Martin et al., 2003; Padullés Cubino et al., 2019), yards are unique in that they are ultimately managed on a house by house basis by individual residents. Humans can alter the plant communities in yards by controlling availability of essential resources as well as introducing and removing certain species. For example, residents heavily invest in plant resources by applying, often in copious amounts, fertilizer and water to support growth of desired species, and pesticides to limit growth of undesired ones (Hobbie et al., 2017; Loram et al., 2011; Robbins and Birkenholtz, 2003). Residents across the United State and United Kingdom typically create yards that have higher species richness than surrounding natural areas, with gardens that are composed of mostly exotic ornamental species (Loram et al., 2008; Pearse et al., 2018). While the pattern of high ornamental species richness is common across many residential yards (Loram et al., 2008; Pearse et al., 2018), it is not clear why people create this high biodiversity. It is possible that residents intentionally choose different species to create variety (Lindemann-Matthies and Marty, 2013; Southon et al., 2017) or that they indirectly choose different species to create a more specific type of variety such as colorfulness (Dallimer et al., 2012; Hoyle et al., 2018). It is also possible that high biodiversity is a legacy of multiple past household residents or pre-urban conditions, and is not strongly related to the preferences of current residents (Avolio et al., 2018; Larson and Brumand, 2014). Regardless of the factors underlying high yard biodiversity, it has been demonstrated that people ultimately experience greater psychological benefits from urban vegetation with greater biodiversity (Fuller et al., 2007; Lindemann-Matthies and Marty, 2013; Southon et al., 2018), although the benefits of urban vegetation are not enjoyed equally across socioeconomic and racial gradients in cities (Schell et al., 2020).

Within cities, neighborhoods of higher socioeconomic status have been found to have a greater diversity of trees, shrubs, and herbaceous perennials (Avolio et al., 2020, 2018; Martin et al., 2004; Wang et al., 2015) and greater vegetation cover (Jenerette et al., 2013; Leong et al., 2018). The positive relationship between plant biodiversity and income has been termed the *luxury effect* (Hope et al., 2003). The luxury effect has been documented globally (Kuras et al., 2020), with especially strong correlations in arid environments (Chamberlain et al., 2020). However, the effect of income on biodiversity can also be overwhelmed by other factors such as disturbances, infrastructure, policy, and human preference (Kuras et al., 2020). The mechanism of the connection between peoples' preferences, income, and realized yard biodiversity is still not well understood. A person's income can be correlated with their preferences for urban greenspace landscaping and management (Avolio et al., 2015; Larsen and Harlan, 2006; Locke and Grove, 2016), as can many other demographic and socioeconomic variables such as profession, education, ethnicity, gender, age, marital status, and personality type (Avolio et al., 2015; Ho et al., 2005; Hofmann et al., 2012; Jim and Shan, 2013; van den Berg and van Winsum-Westra, 2010; Wang and Zhao, 2017; Yabiku et al., 2008). The *ecology of prestige* hypothesizes that those with higher income use their yard as an expression of wealth or a societal cue that they belong (Grove et al., 2006). While positive relationships have been demonstrated between income and yard plant biodiversity, it is unclear whether socioeconomic status is associated with preferences for higher biodiversity and vegetation cover, or if socioeconomic status enables residents to achieve their preferences for their yards.

Higher income is associated with greater plant biodiversity, although this likely does not apply to lawns. In North America, a common preference is for lawns to be essentially monocultures, composed of only a few turfgrass species (Jenkins, 2015; Wheeler et al., 2017). Lawn greenness has been positively correlated with total lawn care expenditures in Baltimore, Maryland, which in turn were positively correlated with income (Zhou et al., 2009), suggesting that wealthier residents spend more money to create a greener lawn. It is therefore also probable that wealthier residents create a monoculture in their lawns by reducing weeds and ultimately reducing total species richness. However, the relationship between income, preferences for lawn, and lawn biodiversity has not been directly tested and is a knowledge gap.

While many studies have assessed the residential yard as a single unit, there is strong evidence that people have different preferences for their front and back yards (Larsen and Harlan, 2006; Larson et al., 2009; Locke et al., 2018a, 2018b). Many people view the front yard as more public and manage it to fit certain aesthetic norms, while the back yard is more private and its management is more in line with personal preferences, a pattern that has been called the *landscape mullet* (Larsen and Harlan, 2006; Locke et al., 2018b). The differences between front and back yards' purposes and management likely result in more aesthetically pleasing plants, such as ornamentals, and greater flower area in front yards than back yards, while back yards have more functional plants such as edible food plants and shade-providing trees (Avolio et al., 2020; Dorney et al., 1984; Vila-Ruiz et al., 2014).

In order to understand the mechanism of the links between people's preferences and yard plant variety and biodiversity, we used open structured interviews and written self-administered surveys on resident preferences and inventoried the lawn species richness and herbaceous flowering plant genus richness in residential yards in the Salt Lake Valley, Utah, USA. We use the following terms to describe plant variety in residential yards: we defined biodiversity for residents as the number of species or genera (i.e., richness). We did not define variety, but left it open to interpretation by residents, to include any type of aesthetic plant variety such as colorfulness, shapes, and biodiversity. We had three objectives. First, we aimed to characterize what types of plant variety residents preferred and why variety appeals to them. We hypothesized that residents would prefer ornamental herbaceous flowering plants (hereafter flowering plants) that create variety in the yard and a homogeneous monoculture for the lawn. Our second objective was to assess whether higher resident income is associated with preferences for more yard plant variety such as high biodiversity and other more novel metrics like colorfulness, or if income enables residents to achieve their preferences for their yards. We hypothesized that income enables residents to realize their preferences better than other household variables such as property age or elevation. We also hypothesized that residents would have different expectations and uses for their front versus back yards. Our final objective was to examine how the effect of income plays out across different yard plant types (lawn and flowering plants) and locations (front and back). We hypothesized that flowering plant genus richness would increase with income while lawn species richness would decrease, and that we would find higher flowering plant genus richness in front yards versus back yards. Overall, with this study, we address the knowledge gap on the mechanism of why residential yards have high biodiversity (personal preference or enabled by income?) and utilize novel resident-based metrics to assess plant variety.

2. Methods

2.1. Study site

This study was conducted in neighborhoods of Salt Lake City and surrounding Salt Lake County, Utah, located in the Salt Lake Valley, USA. This region is surrounded by mountains on three sides, with the Great Salt Lake to the north. Salt Lake Valley's annual rainfall is 397 mm and the mean annual temperature is 11.5 °C (PRISM Climate Group, Oregon State University, Corvallis, Oregon, USA). Prior to European colonization, Salt Lake Valley was Great Basin Desert shrubland and inhabited by Shoshone, Paiute, Goshute and Ute people. In 2014, when most of the research in this study was conducted, Salt Lake County was a metropolitan urbanized area with over 1 million residents (U.S. Census Bureau, 2020) and residential yards that consisted of mostly intentionally cultivated vegetation (Avolio et al., 2018).

2.2. Study design

For this study, we collected three total datasets over the course of two data collection campaigns (Appendix A Fig. 1, Appendix A). For the first data collection campaign in October 2013, we conducted semi-structured in-person interviews with household heads of 30 homes in Salt Lake Valley in order to gain a preliminary, but in-depth understanding of how residents perceive and value their yards. We selected the interviewees by mailing 300 residential households in total, asking to visit their houses to conduct interviews. The households that we mailed were in neighborhoods categorized as high or low socioeconomic status based on the Claritas PRIZM market classification system. Of those that responded yes to our letter, we interviewed one to two household heads from 15 homes of lower socioeconomic status (PRIZM classes 14, 15, 18, 54) and 15 homes of higher socioeconomic status (PRIZM classes 1, 2, 3, 6, 7). Most (90%) of the interviewees owned their homes; it is unknown whether the other 10% owned or rented.

In 2014, we conducted the second data collection campaign, collecting two datasets: surveys on resident preferences and yard plant biodiversity and variety inventories at single-family homes across income levels, property ages, and elevation. These homes were independent of the households interviewed in 2013. This research included written self-administered surveys for the residents on their yard plant preferences and in-person inventories of the lawn and flowering plant variety at a subset (81) of the survey participants' residential yards. With the surveys and inventories, we would be able to systematically assess how income, property age, elevation, and resident preferences influence types of yard variety such as biodiversity and colorfulness. We designed the study to assess the surveys and inventories at the level of average values per neighborhood. We identified neighborhoods using a typology developed in a larger study by Jackson-Smith et al. (2016) which included 608 total neighborhoods defined by census block boundaries. To limit confounding variables, we focused on neighborhoods in the valley floor (<1524 m elevation) with similar precipitation (<653 mm annual) and yard size (<0.70 acres, 90% in the range 0.1–0.34 acres). To improve the likelihood that we would interact with residents that were managing their yards, we also used the criteria of <35% renter occupancy and >65% single-family residences.

We chose nine neighborhoods that met the above criteria, using a cross-factor design of three income classes to assess income effects and three property age classes to assess legacy effects. Each neighborhood represented a unique income-age classification (Appendix A Table 2), using the Jackson-Smith et al. (2016) typologies based on census block boundaries. We based the income groupings on the range of neighborhood medians of household annual income from the Jackson-Smith et al. (2016) typologies, which was $33,000–$178,000, with a median of $68,000. The income groupings used in this study were low (<$45,000), medium ($45,000–85,000), and high (>US$85,000). The median household income was $62,000 in 2014 (U.S. Census Bureau, 2015). We based the property age groupings on the range of neighborhood medians for household year of construction from the Jackson-Smith et al. (2016) typologies, which was pre-1939 – present, with a median of 1976. The property age groupings used in this study were new (1985–2005), middle (1951–1970), and old (before 1939). We excluded households built after 2005 in order to decrease legacy effects of housing developers (Larsen and Harlan, 2006). More detailed methods are also published in Avolio et al. (2018), in which the data on resident preferences for trees and yard tree biodiversity is reported from the surveys and biodiversity inventory. Overall, our study is a balanced design to tease apart the effects of home age and residential income on patterns of yard plant diversity.

We mailed the 100 surveys, hereafter neighborhood surveys, to each of the nine neighborhoods (900 total), with an average response rate of 31% (278 returned). Higher income neighborhoods typically had higher response rates. Nearly all (96%) of the survey respondents owned their houses, while 4% said they did not own. See Appendix A for further explanation of study design and the neighborhoods assessed. At the end of the neighborhood survey, residents were asked if they would like to participate in the yard biodiversity portion of the study. With resident permission, we visited the yards of 9 houses from each of the 9 neighborhoods (81 total) in July and August 2014 to collect data on types of plant variety such as biodiversity and colorfulness. For neighborhoods with low response rates, we walked door to door asking residents to complete the neighborhood survey and for permission to assess their yards.

2.3. Data collection

2.3.1. Resident preferences: interviews

The 2013 interviews were guided by a collection of open-ended questions on resident perceptions of nature, preferences and uses of their yards, and values of different yard aspects. For the full interview protocol, see Appendix B. A subset of the questions was analyzed to better understand common themes in preferences and yard work. These questions covered interviewee motivations for decisions they made in their yard, descriptions of their ideal yard, if they hired yard care workers, the purposes of their front and back yards, and their opinions on their lawns, variety in the yard, and water scarcity. For a list of this subset of the interview questions, see Appendix C. We intentionally left the word "variety" open to interpretation by interviewees, in order to understand their perceptions of it without interviewer bias.

The recorded interviews ranged from 27 to 90 min long and were an average of 50 min, and were later transcribed. Interviewees were also asked who cared for their yards in order to determine the connection between the interviewees' preferences and the person(s) performing yard work. A majority of the interviewees (90%) were involved to some degree in yard work, decisions, or delegation while the other 10% had a significant other in the household who was responsible for the yard.

2.3.2. Resident preferences: neighborhood surveys

The 2014 neighborhood surveys asked residents about their opinions on variety and biodiversity in landscape design, water use and availability, and fertilizer use. We intentionally left the word "variety" open to interpretation in order to understand how residents think about it without bias. There were optional questions on resident socioeconomic information (Appendix D for full survey). Questions were presented with multiple-choice answers, accompanied by an "Other" category that respondents could fill in. Technical or ecology-specific terminology was typically avoided in the surveys, however, when it was used, it was defined. For example, a question on biodiversity was presented as "*How important is it to you to have high biodiversity (*i.e.*, many different plant species) in your yard?*"

2.3.3. Biodiversity inventory

We conducted yard plant biodiversity inventories in 2014 at a subset of the households (81) that responded to the neighborhood surveys in order to assess multiple types of variety in residents' yards, including lawn species richness and flowering plant genus richness (i.e., biodiversity), as well as colorfulness and number of inflorescence types. We inventoried both the front and back yards. Lawn species richness and average percent cover were assessed using four 1 m^2 quadrats, two in the front yard and two in the back (Wheeler et al. 2017). Data on flowering plants was collected at the genus level for the front and back yard of each house. Flowering plants were identified to genus because of the high prevalence of hybrids, intraspecific cultivars, and interspecific similarities within many genera. Per genus and yard location (front/back), the number of individual flowering plants, total number of flowering stems, and average number of individual flowers per three stems were counted. The individual flower face was photographed, oriented next to a U.S. quarter coin for scale. We used novel methods described in detail by Avolio et al. (2020) for measuring additional flowering plant variety metrics that might be important to residents and landscapers, but are typically overlooked by ecologists. These metrics include number of colors, flower area, number of different inflorescence types (i.e., solitary, raceme, corymb, spike, panicle, umbel, compound umbel, cyme), and water requirements.

2.4. Data processing

2.4.1. Resident preferences: interviews

We used inductive reasoning to identify themes in the 2013 interview responses and then quantified the households that described those themes. First, keywords were identified from the responses, for example, "color," "family," and "low-maintenance." Next, broader themes were determined based on the keywords, such as Aesthetic (e.g., color), Social (e.g., family), and Maintenance (e.g., low-maintenance). This method was used for questions on interviewee motivations, their ideal yard, lawn likes and dislikes, and opinion on variety and the purposes of the front and backyard.

Several of the interview questions also had a valuation or work intensity component, which were coded using a numerical rating scale. These questions were about the importance of variety, lawns, and water scarcity, as well as the intensity of yard work done by household members and/or hired workers. For example, a scale of 0 to 4 was used on the question of lawn importance: 0- Not important; 1- Somewhat Unimportant; 2- Somewhat Important; 3- Important; 4- Very important. For descriptions of how each of the selected interview questions were coded, see Appendix C.

2.4.2. Resident preferences: neighborhood surveys

The 2014 neighborhood survey consisted of closed-ended multiple-choice questions. Answers were coded for analysis using a Likert scale. Respondents' rankings of the importance of different plant traits and types of variety were quantified.

2.4.3. Biodiversity inventory

In the 2014 yard plant biodiversity inventory, lawn species were characterized as a turfgrass (Wheeler et al., 2017) or weed, nitrogen-fixer or not, and native or non-native. Flowering plant genera were characterized as native or non-native and given a water-requirement grade on a scale of 0 to 3 based on plant moisture needs (0- no irrigation needed, 1- little to moderate water, 2- regular water, 3- regular to ample water). Genus water-requirement was determined using Sunset's Western Garden Book (Brenzel, 2001). If the water requirement varied per species within a genus, then each recorded individual in the genus was identified to species. The USDA PLANTS database (http://www.plants.usda.gov) was used to determine native status for flowering plant genera and lawn species, and nitrogen-fixer status for lawn species. A flowering plant genus was classified as native if all species listed in the database were native to Utah. If only some species of a genus were native (ex. *Achillea, Campanula*), then each recorded individual of that genus was further identified as a native or non-native species using field photos.

To calculate area of all individual flowers, we used the same methods as Avolio et al. (2020). First, we used the program ImageJ (Version 1.52a) to measure the width and length of every photographed flower, using the photographed U.S. quarter for scale. We then multiplied together the length and width for individual flower area. The area was multiplied by total number of flowers (average number of flowers per stem × total number of flowering stems) for total flower area per genus and house. To determine color area, we started by assigning one to two colors to each flower, using a standard color wheel with 12 colors in order to reduce bias. Grouped by color, the flower areas were added together for total area of each color. If a flower had one color, then 100% of the flower area was assigned to that color for the summation. If a flower had two colors, then 50% of the flower area was assigned to each color.

2.5. Statistical analysis

All analyses were performed in R (Version 3.5.3; R Core Development Team) and an alpha of 0.05 was used to determine statistical significance. First, to determine if preferences varied by income, we assessed correlations between neighborhood median income and neighborhood average preference for biodiversity and flower color variety from the neighborhood surveys; this calculation used Pearson's coefficients. Next, to determine the degree to which people's yards represented their preferences, we assessed the correlation between a resident's preferences expressed in the neighborhood survey and their actual yard traits from the biodiversity inventory; this calculation used Kendall's Tau coefficients.

To determine whether neighborhood median income or home age affected lawn or flowering plant communities, we conducted multivariate analyses of community composition (based on the biodiversity inventory data). We used the adonis function in the vegan package (Oksanen et al., 2019) to determine whether centroid means differed by income or home age, and the betadisper function in the vegan package (Oksanen et al., 2019) to determine if the dispersion around the centroid mean was affected by income or home age. To visualize these relationships, we performed a Non-metric Multi-Dimensional Scaling (NMDS) using the metaMDS function in the vegan package, using Bray-Curtis dissimilarity. We summed community data per neighborhood block, with each block containing three inventoried houses, and compared across 27 blocks total (3 blocks per neighborhood × 9 neighborhoods). Lastly, analysis of variance (ANOVA) was used to test the relationship of income and plant type (flowering plant vs. lawn; weed vs. turfgrass) with biodiversity as well as income and yard location (front or back) with flowering plant biodiversity and color variety, based on the biodiversity inventories.

Lastly, we compared the lawn and flowering plant variety metrics from the biodiversity inventories to average neighborhood elevation, neighborhood median income, and neighborhood median property age using multiple regressions. Other environmental and socioeconomic variables were initially measured, but ultimately excluded from the models as they were highly correlated and best predicted by elevation. For details on these correlations, see Avolio et al. (2018) Appendix C. Lawn species and flowering plant genus richness were calculated using the community_structure function in the codyn package (Hallett et al., 2019). The correlation between average flowering plant genus richness per neighborhood and average number of flower colors per neighborhood, from the biodiversity inventories, was determined using Pearson's correlation coefficient.

All data will be available upon publication in Mendeley Data and code is available at github/allieblanchette/SLC-2014-Yards.

3. Results

3.1. Resident preferences: interviews

Residents most commonly described their ideal yard in the 2013 interviews as one that is of a certain maintenance level, is aesthetically pleasing, and serves a function (Table 1). In the maintenance theme, a majority of responses referred to a yard being simply "low-maintenance", but other more specific responses included "cheap to maintain" and tolerant to drought or sun. Common aesthetic keywords included "colorful" and "attractive" and functions included "privacy" and "shade [provision]". Other response themes that residents used to describe their ideal yards were variety (28% of interviewees), emotional (12%), and size (8%). In the variety theme, residents described ideal yards with a variety of plant types, sizes, shapes, and textures. In the emotional theme, residents described ideal yards that were "tranquil" and a "sanctuary" (i.e., evoked calming emotions). In the size theme, residents described yards that were a specific size or shape, such as "medium-sized" and "flat surface". Throughout the interviews, interviewees gave responses within multiple themes (e.g., emotional and aesthetic), causing the percentage of responses to be greater than 100%. For further information on response themes in the interviews, see Appendix C.

The three themes of maintenance, aesthetics, and function were also the most common themes that residents used to describe their motivations for the choices they made in their yards. Interestingly though, while maintenance, aesthetics, and function each were mentioned at similar frequencies when residents described their ideal yards, maintenance was a much more common theme than aesthetics or function when residents described their actual motivations. There was little variation in the importance of maintenance, aesthetics, and function between residents of higher socioeconomic status and residents of lower socioeconomic status. Other themes in resident responses for their motivations behind their yard decisions were social (24%) and variety (4%). In the social theme, residents were influenced by what they liked or disliked in their neighbors' and family members' yards. In the variety theme, the interviewee was motivated to "see different kinds of flowers".

A majority (79%) of the residents interviewed in 2013 said that they liked variety in their yard plants, which was consistent when grouped by high (73%) and low (86%) socioeconomic status. When probed about why they liked variety, the most common response that interviewees had (47% of all interviewees) was to describe an emotional reaction to it. The emotional responses were typically energetically uplifting, using the words *"exciting," "fun," "discovery," "happy," "uplifting," "rejuvenating," "freedom," "warm," "welcoming," "stimulating,"* and "*interesting*," or energetically relaxing, using the words *"peaceful," "relaxing," "comforting," "luxury,"* and "*restful*." One interviewee described a faith-based spiritual connection to having variety in their yard, stating "*I think it makes you peaceful. It is beautiful. It is like art. It is God's art."* Some interviewees also expressed that they liked variety because it is aesthetically pleasing (20%) and "natural" (20%), while others were unable to explain exactly why they liked variety (33%). To further understand residents' preferences for variety, we asked them specifically whether color variety alone would suffice. For example, "*What if you only had roses, but they were all different colors. Would that be enough variety?*". Most of the interviewees (79%) responded that it would not and they described many other types of plant variety that they would still desire in their yards, including different plant types, shapes, sizes, textures, bloom times, and spatial placement in the yard.

We also asked interviewees about their lawn preferences. The majority of them valued their lawns, with 83% saying that having a lawn was either Somewhat Important, Important, or Very Important. The most common positive aspects of a lawn that interviewees described were that it is low-maintenance, green, and attractive. The most common negative aspects were weeds, brown patches, and "nothing" (no negative aspects). There was little variation in residents' preferences for their lawns between households of higher and lower socioeconomic status.

When asked about water scarcity in Salt Lake Valley, 72% of the interviewees expressed concern about water scarcity. However, only 31% mentioned trying to use water conservatively. Lastly, interviewees were asked if they thought their front and back yards had different purposes; 70% of residents said that yes, they do serve different purposes. Specifically, these residents saw the front yard as being for curb-appeal (aesthetics), and the back yard for personal enjoyment. Residents' responses on both water scarcity and the purposes of the front and back yard were consistent across high and low socioeconomic status households.

3.2. Resident preferences: neighborhood surveys

In the 2014 neighborhood surveys, residents were asked their opinions on the importance of general variety: "*How important is it to you to have plants create variety (*e.g.*, color variety) in your yard?*". Nearly all (95%) answered that variety is either 2- Somewhat Important or 3- Important; the average answer was 2.54 (SE $\pm$ 0.04) on a scale of 0–3. They were also asked their opinions on biodiversity (i.e., a specific type of variety): "*How important is it to you to have high biodiversity (*i.e.*, many different plant species) in your yard?*". Most residents (71%) responded 2- Somewhat Important or 3- Important; the average answer was 1.95 (SE $\pm$ 0.06). On average, residents rated the importance of having general plant variety higher than having high biodiversity or species native to Utah (Fig. 1A). Flower color variety was the most highly rated type of plant trait variety as compared to other traits such as height, shape, and leaf texture (Fig. 1B). Neither biodiversity nor flower color variety preferences varied significantly by neighborhood median income (Fig. 1C & 1D). However, it should be noted that significantly more wealthy households used a lawn care company than those of lower income ($r = 0.842$, $p = 0.004$).

3.3. Biodiversity inventory: data summary

At the 81 houses that we inventoried yard plant biodiversity for in 2014, we identified 123 flowering plant genera from 45 families, and recorded 2,686 flowering plants in total. The most abundant flowering plant genus was *Petunia* and the most abundant family was *Asteraceae*. Fifty-seven different flower color combinations were recorded, the most common being Red-Purple. Total flower area for all the yards assessed in this study was 101.8 m^2. There were few native flowering plant genera; 19 were native out of the total 123 identified, with ranges of 0 to 6 native flowering plant genera per house. The average flowering plant's water requirement on our scale of 0–3 was 1.77, which roughly translates to needing 'moderate to regular watering.'

Nearly all houses inventoried had a front lawn (94%) and nearly all had a back lawn (92%). Across all of these lawns, a total of 59 different lawn species were recorded. Only five of these species were intentionally planted turfgrasses, but on average these turfgrasses covered 89% (SE $\pm$

Table 1
Top three responses for what motivated the decisions residents made for their yards and how they would describe their ideal yards, from the 30 open-ended interviews in 2013. Responses were categorized into broad themes. The top three most common themes (% of interviewees that included the theme in their response at least once) are presented. Many residents described more than one theme in their responses, attributing to the sums of responses being greater than 100%.

Yard Characteristics	Ideal Yard	Motivation for Yard Decisions	Keyword Examples
Requires a certain level of maintenance	52%	60%	Low-maintenance, Cheap, Drought-tolerant, Professionally maintained, Convenience
Has a certain aesthetic	48%	40%	Colorful, Lush, Neat, Plant shape, Pretty, Beauty, Bright, Looks healthy
Provides a certain function	48%	16%	Shade, Privacy, Food, Aroma, Soft grass, Attracts wildlife, Space to play

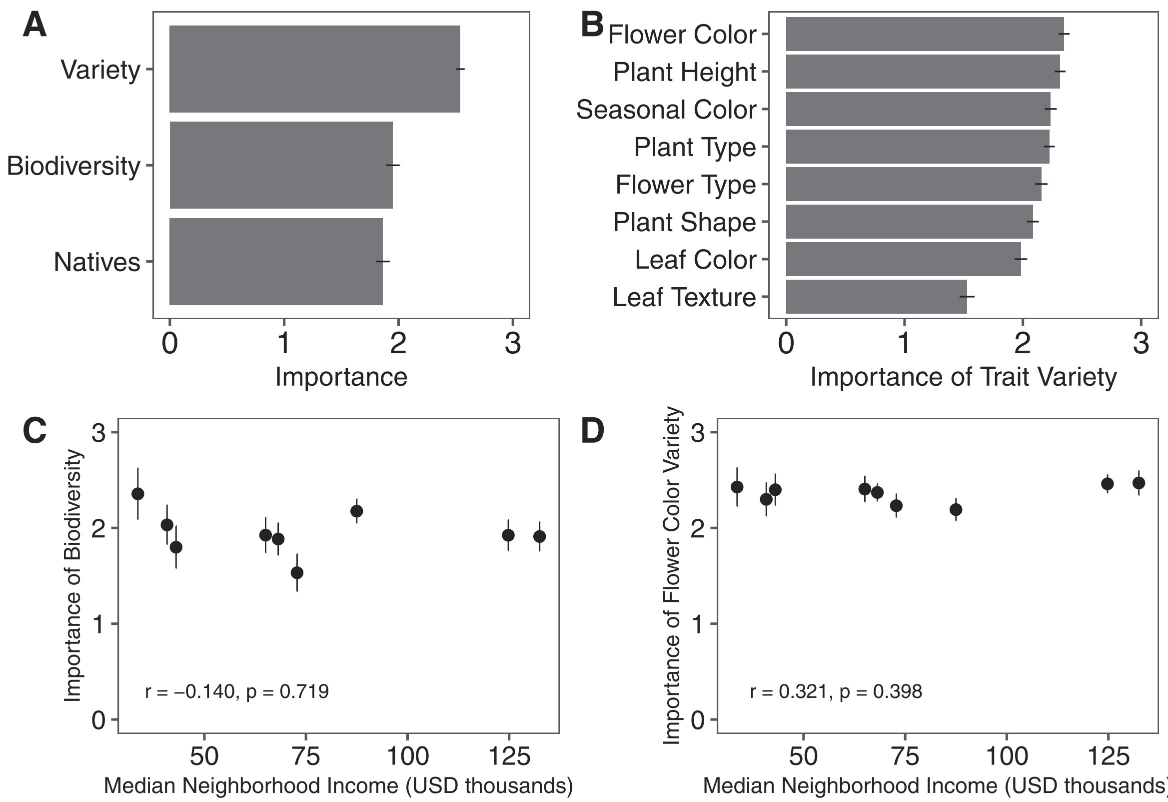

Fig. 1. Average resident perceptions on the importance of having different types of plant variety in the yard, across all of the 2014 neighborhood surveys (0- Unimportant, 1- Somewhat Unimportant, 2- Somewhat Important, 3- Important; N = 278 neighborhood surveys). Average perceptions on having in the yard (A): general variety (i.e., plants that create variety), high biodiversity (as one type of variety), and plants native to Utah. Average perceptions on having in the yard the listed types of variety (B). Average importance (±SE) of high biodiversity (C) and flower color variety (D) per neighborhood along a gradient of neighborhood incomes, tested with Pearson's correlation coefficient.

3) of a house's lawn. These species included *Poa pratensis* (most abundant)*, Lolium perenne, Festuca rubra, Festuca arundinaceae,* and the native *Bouteloua dactyloides* which was being used as a turfgrass at one house. The other 54 species recorded were weeds and comprised an average of 19% (SE ± 3) cover of the lawns (most lawns had over 100% coverage). The most abundant weed was *Taraxacum officinale* (Dandelion). Only five of the lawn species were nitrogen-fixers (e.g., *Trifolium repens*) and only 12 species were native (11 of which were weeds).

3.4. Biodiversity inventory: analyses

Resident preferences were weakly, if at all, correlated with the plant floral trait variety and biodiversity in their yards when the neighborhood survey and biodiversity inventory were directly compared at each individual house that had both a completed survey and yard inventory (Appendix E, Appendix A Table 2). Specifically, there was no correlation between any of the following: importance of flower color variety and number of flower colors (Tau = 0.178, p = 0.091), importance of biodiversity and genus richness of flowering plants (Tau = 0.156, p = 0.119), importance of native plants and species richness of native flowering plants (Tau = 0.117, p = 0.293), importance of native plants and percent cover of native lawn species (Tau = 0.004, p = 0.972), and importance of water scarcity and average flowering plant water requirements (Tau = -0.149, p = 0.106). While there was variation in the amount of plant trait variety and biodiversity across yards, there was minimal variation in resident preferences.

High and mid-income yards had different flowering plant communities than lower income yards, and low and mid-income yards had different lawn communities than high income yards (Table 2, Fig. 2). We found that property age had no effect on plant community composition (Table 2). Multiple regressions showed that income had a stronger relationship with most variety metrics assessed for flowering plants and lawns than property age or elevation did (Table 3). There was a significant positive relationship between income and flowering plant genus richness, plant abundance, flower area, number of different flower inflorescence types (e.g., panicle, solitary, etc.), and native species abundance (Table 3, Fig. 3). The number of flower colors had a marginally significant positive relationship with income (Table 3) and a highly significant positive relationship with flowering plant genus richness (Fig. 3B). The only variety metrics that did not have a noteworthy income relationship were flowering plant water requirements, which was significantly affected by property age and elevation, and lawn native species cover, which was not affected by any of the predictor variables (Table 3).

While number of flowering plant genera was positively correlated with income, the opposite was observed of lawn species richness. As

Table 2
Effect of median income (high, medium, low) or property age (new, middle, old) on flowering plant or lawn community composition. Results from PERMANOVA (difference in means) and PERMDISP (difference in dispersion) tests are shown. Community compositions are based on flowering plant genus richness and abundance, and lawn species richness and cover data, summed across 3 houses per block. There were 3 blocks per each of the 9 neighborhoods for a total of 27 blocks that were compared.

Driver	Community Type	Difference in means		Difference in dispersion	
		F	*p*	*F*	*p*
Income	Flowering Plant	1.831	0.003	0.847	0.430
	Lawn	2.073	0.019	2.395	0.112
Property Age	Flowering Plant	1.370	0.062	0.132	0.885
	Lawn	1.481	0.125	3.170	0.073

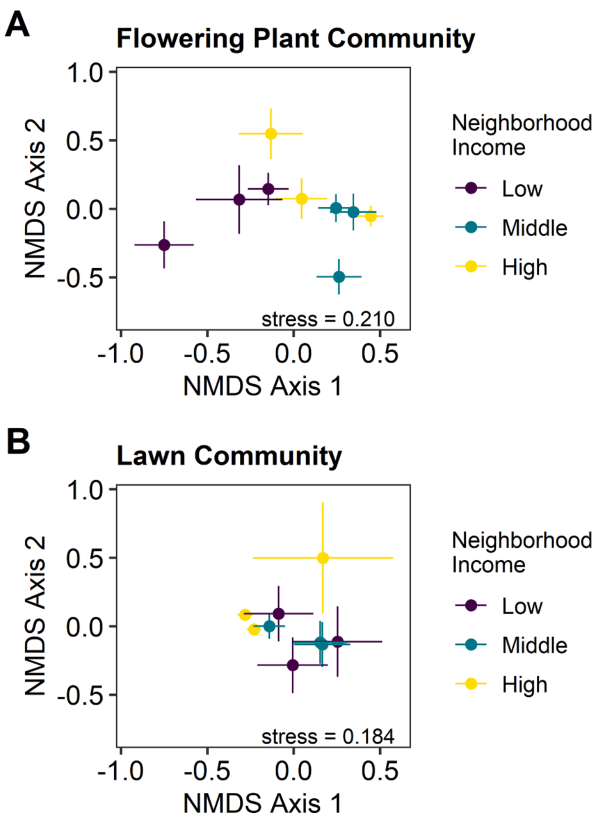

Fig. 2. Comparison of flowering plant and lawn community composition across neighborhoods of three different income levels. Community composition of flowering plant genus richness and abundance (A), and lawn species richness and cover (B) are summed across 3 houses per block. Each point is the mean nonmetric multidimensional scaling (NMDS) value for a neighborhood, averaged across three blocks per neighborhood (±SE). For PERMANOVA and PERMDISP values, see Table 2. Color version of this figure is available in the online version of this article.

income increased, flowering plant genus richness increased and lawn species richness decreased (Table 4, Fig. 4A). A closer inspection of lawn species, categorized as weeds or turfgrasses, shows that the decrease in lawn species with income was significantly due to a decrease in weeds (Table 4, Fig. 4B). Lastly, there was an interaction between flowering plant variety and yard location, which was consistent across income levels (Table 4); the front yards consistently had more flowering plant genera and colors than the back yards.

4. Discussion

We found that regardless of income, most residents in the Salt Lake Valley have similar yard preferences – mainly for low-maintenance yards with high plant variety and neat monoculture lawns. On average, residents rated general plant variety (i.e. “plants that create variety”) as more important than plant biodiversity, a type of variety, and expressed an emotional connection to plant variety overall. However, residents’ preferences did not correlate with the total flowering plant variety observed in their yards. Instead, income was positively correlated with multiple types of observed flowering plant variety, suggesting that a higher income enabled residents to plant and manage a variety of species as well as maintain several other types of plant variety. Income also enabled residents to better achieve common preferences for a monoculture turfgrass lawn with low species richness due to a lack of weeds. This modifies our current understanding of the effect of income, to also include the ability to remove undesirable plants. Overall, we found that residents valued plant variety over biodiversity, we identified

Table 3
Results of multiple regressions on the relationship between flowering plant and lawn variety metrics and median neighborhood income, median neighborhood property age, and neighborhood average elevation. Separate regressions were run for each variety metric as a response variable and income, property age, and elevation as predictor variables. Each variety metric was calculated per house and averaged across 9 houses per neighborhood. Neighborhood averages were compared across the 9 neighborhoods in the regressions. Multiple R^2 values are reported as well as partial R^2 for income, property age, and elevation. † signifies p-value < 0.1, * signifies p-value < 0.05, **signifies p-value < 0.01.

Response Variable			Predictor Variables Partial R^2		
Plant Type	Variety Metric	Multiple R^2	Income	Property Age	Elevation
Flowering	Genus richness	0.735†	0.701*	0.431	0.001
Flowering	Number of flowers	0.496	0.295	0.362	0.011
Flowering	Number of plants	0.782*	0.776**	0.004	0.087
Flowering	Total flower area	0.766*	0.761*	0.0004	0.141
Flowering	Number of flower colors	0.537	0.511†	0.165	0.011
Flowering	Number of inflorescence types	0.739†	0.738*	0.088	0.012
Flowering	Native species abundance	0.781*	0.671*	0.665*	0.009
Flowering	Water requirements	0.618	0.011	0.570*	0.486†
Lawn	Species richness	0.861*	0.781**	0.153	0.315
Lawn	Native species cover	0.148	0.044	0.045	0.006

an emotional connection to variety, and determined that income is a key resource that enables residents to achieve common preferences.

4.1. Resident preferences for variety

In our study, across income levels, there was a modest amount of variation in Salt Lake Valley residents’ preferences for their yards. Most of the interviewed residents wanted their yards to 1) be low-maintenance, 2) be aesthetically pleasing, and 3) provide functions such as shade and privacy, which closely mirrors the preferences of people across the United States (Larson et al., 2016). Interestingly, the interviewed residents in this study were much more frequently motivated by maintenance concerns than aesthetics or function when making decisions. Maintenance is an important factor to many residents when selecting yard trees (Avolio et al., 2018) and has been suggested to influence lawn management regimes (Harris et al., 2012), indicating that the importance of maintenance to a particular resident could have stronger impacts on their yard’s plant biodiversity than other preferences.

In this study, residents across all income levels reported in the neighborhood survey that high plant biodiversity and general variety were important to them. However, on average general variety was rated higher than biodiversity. The most highly rated type of plant trait variety was flower color variety, and there was little variation in the importance of flower color variety across incomes. While some studies have determined that people can perceive and prefer highly biodiverse landscaping designs (Lindemann-Matthies and Marty, 2013; Southon et al., 2017), there is also evidence that most people interpret flowering plant biodiversity based on flower colorfulness rather than true species richness (Hoyle et al., 2018). We found a strong positive correlation between color variety and biodiversity in yards, which supports the argument that humans are largely influenced by color variety, rather than by ecological definitions of biodiversity (i.e., species richness). This suggests that urban residents may be indirectly creating high plant biodiversity in their yards to achieve a more general aesthetic variety.

In addition to color variety, residents often desired a variety of plant types, shapes, and textures, both in the interviews and in the

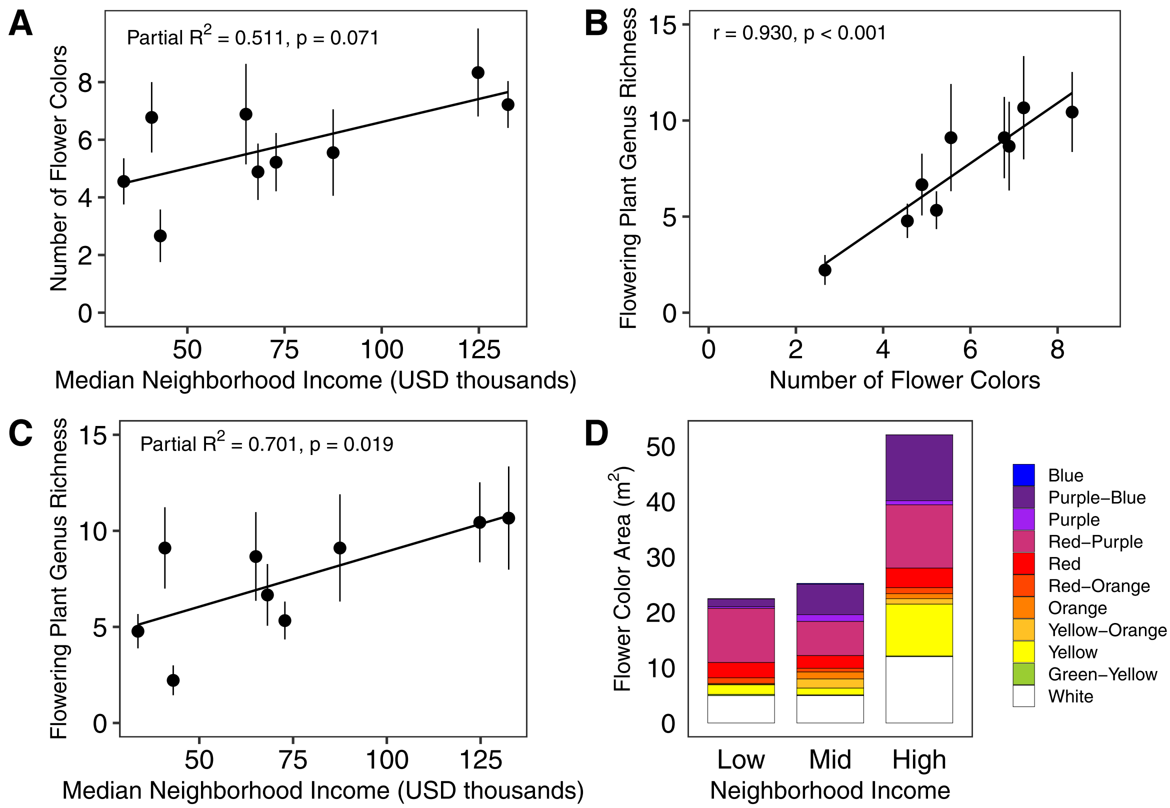

Fig. 3. Correlations between neighborhood income and flower color variety (A & D), flower color variety and flowering plant genus richness (B), and neighborhood income and flowering plant inflorescence type variety (i.e., number of different inflorescence types) (C). Partial R^2 and p-values in panels A and C derived from multiple regressions that were run with neighborhood median income, property age, and elevation as potential drivers (see Table 3). Correlation coefficient (r) and p-value in panel C are derived from Pearson's correlation coefficient test. Each point is the mean neighborhood value (±SE) averaged across 9 replicate houses per neighborhood. Color version of this figure is available in the online version of this article.

Table 4
Results from two-way ANOVAs on the relationship of income and plant type (flowering plant or lawn species) or income and yard location (front or back) with plant biodiversity and color. Richness and number of colors were determined per house and averaged across 9 houses per neighborhood. Neighborhood averages were compared across the 9 neighborhoods in the ANOVAs. F-values and p-values are reported.

Response Variables		Factors					
Metric	Variable	Income		Plant Type		Income × Plant Type	
		F	*p*	*F*	*p*	*F*	*p*
Richness	Flowering plant genera and lawn species	0.260	0.618	7.847	0.014	17.282	0.001
Richness	Turfgrass species and weed species	15.860	0.001	17.031	0.001	12.248	0.004
Metric	Variable	Income		Front/Back Location		Income × Location	
		F	*p*	*F*	*p*	*F*	*p*
Richness	Flowering plant genera	11.270	0.005	13.908	0.002	0.336	0.571
Number of colors	Flowering plants	11.427	0.004	14.257	0.002	0.515	0.485

neighborhood surveys. Interviewees described positive emotional connections towards plant variety in the yard using many different terms, with two overarching patterns. There was a pattern of uplifting emotions, with words such as "*exciting*" and "*warm*," and a pattern of calming emotions, with words such as "*peaceful*" and "*comforting*." Urban greenspaces have often been linked to improved mental health (Matsuoka and Kaplan, 2008) and plant biodiversity has been positively linked with psychological benefits (Fuller et al., 2007). Similar to our study, residents in New Zealand also described their gardens as "*peaceful*" and "*comforting*" (Freeman et al., 2012). These emotional connections to nature, biodiversity, and variety have important implications for urban landscaping and management (Restall and Conrad, 2015), as they have been foundational for urban nature conservation projects such as the High Line in New York City and a wetland in Cape Town with significance in apartheid history (Erixon Aalto and Ernstson, 2017). Finally, while we found similar preferences across all neighborhoods, our study was not designed to probe differences in neighborhood yard cultures, and further work could shed light on cultural differences across the city.

4.2. Flowering plant variety and income

While most residents had similar preferences for a variety of plant colors and species in their yards, their preferences were not consistently realized in the actual composition of their yards. There were no significant correlations between residents' preferences in the neighborhood

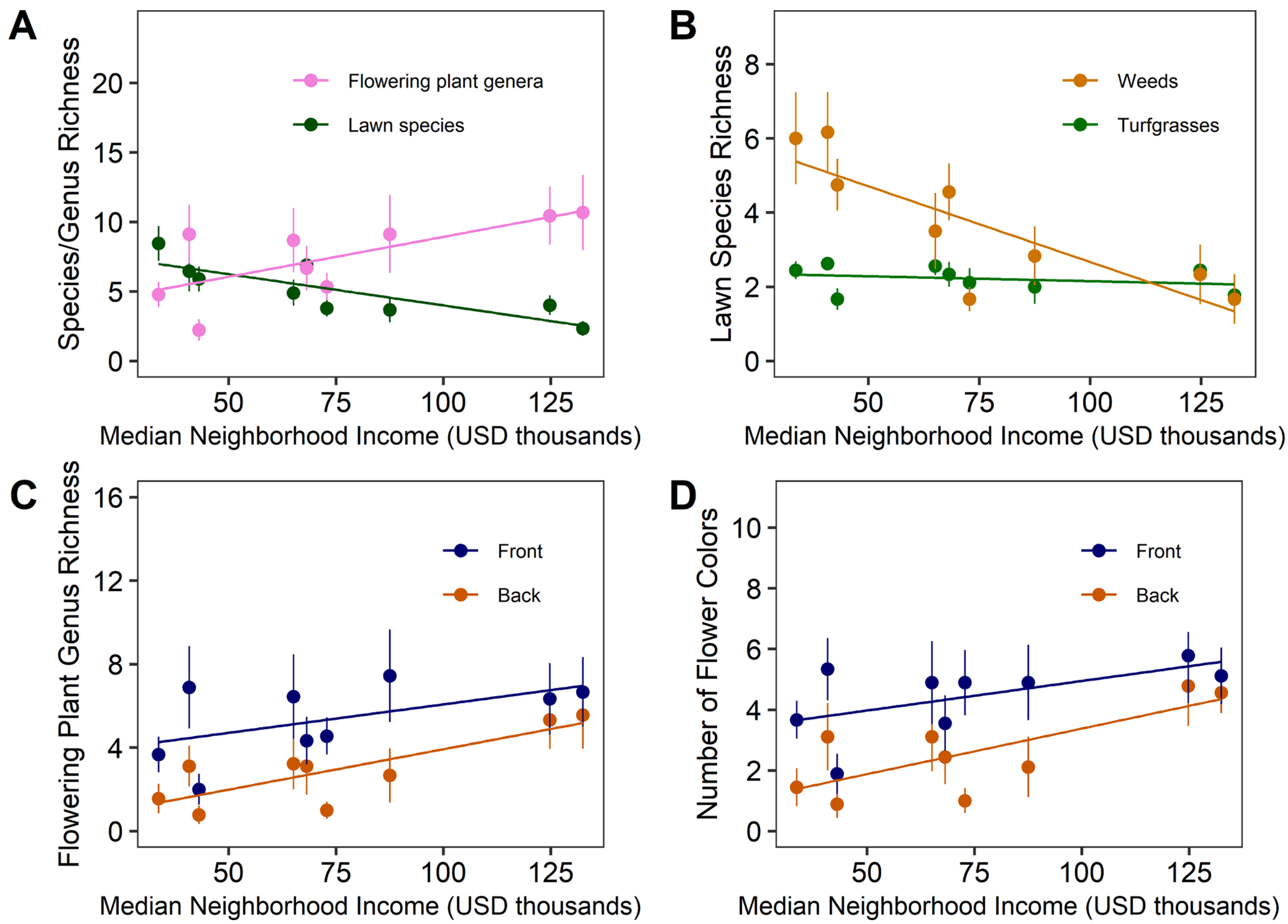

Fig. 4. Relationship between income and plant species richness/genus richness, separated by plant type (A) and lawn species type (B). Relationship between income and flowering plant genus richness (C), and number of flower colors (D), separated by front and back Yard. ANOVA F-values and p-values reported in Table 4. Each point is the mean neighborhood value (±SE), averaged across 9 replicate houses per neighborhood. Color version of this figure is available in the online version of this article.

survey and their yard composition in terms of flower color variety, plant biodiversity, native plants, or plant water usage. This may be due, in part, to the fact that residents typically shared similar preferences, rating most yard traits as Somewhat Important (2) or Important (3). However, it has been previously documented that about one-third of residents have landscaping practices that differ from their preferences (Harris et al., 2012; Larsen and Harlan, 2006). Several factors may be causing this inconsistency, including intensity of maintenance required to achieve their preferences and a lack of time, resources, and knowledge to carry out that maintenance, as well as social pressures and Homeowner Association restrictions (Harris et al., 2012; Hooper et al., 2008; Larson and Brumand, 2014).

Flowering plant variety was correlated with neighborhood median income. There were significantly greater numbers of flowering plants, flowering plant genera, and inflorescence types in higher income households. Income had a marginally significant positive relationship with number of flower colors, which becomes significant when one of the lower income neighborhoods is excluded which had unusually high numbers of flower colors at two-thirds of its houses. This neighborhood was one of the oldest neighborhoods visited and its high color variety may be due to a legacy effect in that colorful flowering plants have accumulated over time. Overall, our findings on the important role of income in multiple types of flowering plant variety reinforce the luxury effect concept: neighborhoods of higher income and socioeconomic status have greater tree, shrub, and herbaceous perennial biodiversity, which is one type of variety (Avolio et al., 2020, 2018; Hope et al., 2003; Martin et al., 2004; Wang et al., 2015). Additionally, the positive effect of income is stronger in arid environments, like Salt Lake Valley, than mesic (Chamberlain et al., 2020). It is important to note that our study was designed on an income gradient, rather than Salt Lake Valley's proportional demographics, and is not intended to be representative of Salt Lake Valley's specific population.

The positive relationship with income in our study was applicable in front and back yards, although front yards consistently had more flowering plant genera and colors, aligning with the landscape mullet theory that people manage their front and back yards differently (Locke et al., 2018b). There was no interaction between yard location (front/back) and income, indicating that the landscape mullet theory applies to households of all incomes and likewise that income affects both the front and back yard. Compared to income, property age had relatively few significant relationships with flowering plant variety. While previous studies in Salt Lake Valley have found that tree biodiversity and canopy cover can be driven by property age (Avolio et al., 2018; Lowry et al., 2012), one key difference between our results on flowering plants and others' results on trees is that trees are long-lived and accumulate over time, while the flowering plants in our study can be more easily added or removed over a shorter time frame. Overall, based on our major results that higher income homes had more flowering plants and higher numbers of several variety metrics, we conclude that higher income enables residents to plant and manage more plant variety. Wealthier residents can purchase more plants and plant resources (e.g., soil, fertilizer, irrigation systems, etc.) (Harris et al., 2012; Robbins et al., 2001), shop at nurseries with a greater diversity of species for sale (Avolio et al., 2018), and invest more in professional yard care services.

There have not been many other studies on yard plant variety metrics that humans commonly perceive, such as flower colorfulness (Avolio et al., 2020). In addition to number of flower colors and number of different inflorescence types, other variety metrics that were correlated with income were area of flower colors and abundance of native flowering plant species. These results suggest that humans are responsive to aesthetic variety traits such as flower color and shape (e.g., inflorescence type). By assessing multiple aesthetic plant traits that humans are receptive to, rather than solely biodiversity, our study demonstrates a mechanism for why residential yards have high biodiversity and how income enables humans to create their desired yards. More focus should be put on these types of aesthetic plant traits in future socioeconomic research, so that city planners and policy makers can better understand how to enhance biodiversity in urban environments in a way that appeals to people.

Based on the results of this study, we recommend that urban planners and landscapers use vegetation that appeals to residents' preferences for aesthetic plant variety when designing greenspaces to ensure that residents enjoy and utilize the benefits and ecosystem services of greenspaces (Bolund and Hunhammar, 1999; Goodness et al., 2016). These greenspaces would be particularly beneficial in lower income neighborhoods that have lower yard plant biodiversity (Avolio et al., 2018, 2020; Hope et al., 2003; Martin et al., 2004; Wang et al., 2015). Based on our findings that residents value variety more than biodiversity or native species, city managers can also institute educational programs through greenspaces and local nurseries to demonstrate how selections of biodiverse and native plants can also fulfill residents' desires for variety (Goodness et al., 2016; Hooper et al., 2008).

4.3. Lawn preferences and biodiversity

Residents expressed that biodiversity and variety in the yard were important to them, however this preference did not apply to lawn species. A majority of the households in the biodiversity inventory had turfgrass lawns, and most of the interviewed residents responded that their lawns were important to them. Specifically, interviewees preferred a green monoculture turfgrass lawn with *no weeds*, which was consistent for households of high and low socioeconomic status. However, only households of the highest income category that we assessed in the biodiversity inventory attained a near monoculture, as the number of weedy species significantly decreased as income increased. Furthermore, significantly more high-income than low-income households indicated on the neighborhood survey that they hired professional lawn care companies. As with flowering plants, we hypothesize that this relationship between income and weed suppression is due to an income effect that enables residents to continually seed their lawns and apply more inputs to their lawns (e.g., fertilizer, pesticides, irrigation systems, professional lawn care services). Thus, we suggest there is nuance to the luxury effect (Hope et al., 2003) because income does not consistently result in an increase in biodiversity in all yard cover types.

5. Conclusions

Urban residential yards are a small-scale yet abundant representation of ecosystems at the forefront of human-environment interactions, with each yard influenced by individual resident preferences and actions. In this study, we find relatively uniform resident preferences for plant variety in general, in that residents valued general aesthetic variety more than biodiversity (species richness) in their yards. Residents expressed positive emotional connections to variety and strong preferences for color variety. We conclude that residents may indirectly create biodiverse yards as an artifact of striving for the color variety they prefer and that income was a key determinant of the level of plant variety and specifically biodiversity in residential yards. Overall, this study highlights the importance of how common resident preferences are for flowering plant variety and lawn monocultures, as well as the role of money in realizing these preferences to structure biodiverse cities. In order to construct successful sustainable greenspaces and cities, urban planners should focus on incorporating vegetation that not only provides ecosystem services, but also meets residents' shared preferences for aesthetic variety, especially in lower income neighborhoods.

CRediT authorship contribution statement

Allison Blanchette: Data curation, Formal analysis, Writing - original draft. **Tara L.E. Trammell:** Conceptualization, Investigation, Methodology. **Diane E. Pataki:** Conceptualization, Funding acquisition, Methodology, Resources, Supervision. **Joanna Endter-Wada:** Conceptualization, Methodology. **Meghan L. Avolio:** Conceptualization, Investigation, Methodology, Project administration, Validation.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.landurbplan.2021.104149.

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