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Attitudinal and structural drivers of preferred versus actual residential landscapes in a desert city

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Abstract

Residential landscaping decisions can have important implications for water use and conservation in urban areas. Yard preferences are generally closely related to actual yard landscapes, but differences in the drivers of and constraints on preferences relative to actual landscaping have not been well explored. In this study, we conducted a resident survey to consider the relationship between preferred and actual yard grassiness in the desert city of Phoenix, AZ, where outdoor water use makes up over two-thirds of residential water consumption. Using a robust theoretical approach including both attitudinal and structural drivers, we examined the relative importance of various attitudes as well as social and parcel attributes as drivers of preferred and actual yard grassiness. We found that nearly half of surveyed residents had less grass than they would prefer, and that existing yard grassiness is best explained by structural characteristics out of the variables we considered. Yard preferences, however, were better explained by attitudinal and social characteristics. The mismatch between actual and preferred yard grassiness revealed a latent demand for grass in this arid city, which could lead to shifts in water-conserving landscaping if structural constraints on landscaping behavior change. Additionally, the relative importance of structural constraints in determining actual yard grassiness, and the differences in important predictors of yard preferences as opposed to actual yards, suggest that appeals to resident attitudes and values are unlikely to shift yard landscaping.

Keywords Turfgrass · Landscape preferences · Yard choices · Urban ecology · Environmental attitudes

Introduction

Residential yards are a ubiquitous part of cities, with residential land uses forming a large component of urban areas (Keys et al. 2007; Loram et al. 2007). Often, residential yards encompass lawns, by which we mean areas of regularly mown, maintained turfgrass, and which require irrigation, fertilization, and regular maintenance. Although lawns can provide a variety of ecosystem services, including recreational opportunities and cooling via evapotranspiration (Beard and Green 1994; Monteiro 2017), they come at the cost of high water requirements, the potential for water quality degradation through fertilization, and loss of wildlife habitat (Law et al. 2004; Goddard et al. 2009; Gober et al. 2012; Smetana and Crittenden 2014). Across the US, about 50% of water used in residential areas is for outdoor purposes such as irrigation (DeOreo et al. 2016), and in the desert city of Phoenix, Arizona, 74% is for outdoor uses (Mayer et al. 1999), making outdoor landscaping an important target for conservation goals. Due to the downsides of grassy landscaping, lawn alternatives are increasingly promoted in cities and suburbs (Larson et al. 2009a; Mustafa et al. 2010; Hayden et al. 2015).

Past research has shown that residents' preferences for particular types of landscaping are important drivers for actual yard types, but factors such as socioeconomic status, legacies of past land-management decisions, and neighborhood context also influence residential landscaping choices (Larsen and Harlan 2006; Yabiku et al. 2008; Nassauer et al. 2009; Larson et al. 2017b). To date, existing studies linking preferences and actual yard landscaping have focused on limited sets of

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variables (e.g., Larsen and Harlan 2006) or narrow populations (e.g., Yabiku et al. 2008). Research has not yet explored the relative influence of various drivers of both yard preferences and actual landscaping, despite evidence that residential landscaping does not always follow personal preferences (Larsen and Harlan 2006; Larson et al. 2017b). Thus, we ask the following questions: 1) to what extent are yard preferences realized in actual landscapes, and what is the nature of mismatches between preferred and reported yard types? And 2) what factors explain yard preferences compared to actual landscapes?

To address these questions, we surveyed residents in the Phoenix metropolitan area to determine how attitudinal and structural (social and parcel) characteristics related to preferred and actual yard types. We developed regression models to test the extent to which diverse factors influenced the actual and preferred amount of grass in residential landscapes. We also conducted cross-tabulations to examine the extent to which preferences are realized in actual, reported landscapes in metropolitan Phoenix. The results hold implications for outdoor water demand as well as other social-ecological outcomes.

Literature review

Our study draws from previous research on residential landscaping, as well as broader research in the fields of urban ecology and environmental attitudes and behaviors. In the sections that follow, we situate our research questions in the relevant scholarly literature.

Actual versus preferred landscapes (RQ1)

The lawn has been a defining feature of American suburbs since World War II and has become a symbol for social status, morality, and domesticity, enforced by normative pressures and a multi-million dollar industry (Jenkins 1994; Robbins 2007). However, recent trends show movement away from lawn-based American yards, with a rise in naturalistic, low water use, or environmentally-conscious yard choices, including xeric yards with a mixture of dirt, rock, paving, and low water-use plantings (Frost 2016) and artificial turf (Francis 2018). While lawns remain common in many cities (Blaine et al. 2012; Burr et al. 2018), lawn alternatives have been promoted for water conservation and other environmental purposes even in humid regions (Vickers 2006; Robbins 2007; Smith and Fellowes 2013). Still, it is not well understood what drives individual residents to adopt alternative landscape types.

While some studies have shown alignment between yard preferences and actual landscaping (Larsen and Harlan 2006; Larson et al. 2017b), numerous reasons explain mismatches between actual and preferred yards. The normative pressures of keeping a lawn have been widely credited with many Americans maintaining lawns despite ecological or personal harm or a desire for other landscapes (Jenkins 1994; Robbins 2007). Regardless of local norms, decisions made by developers and previous occupants can create a legacy of landscaping decisions, which the current resident may or may not choose to change (Larson et al. 2017b). Additionally, residents lacking time or money may be especially unlikely to make changes to their yards to match their personal preferences (Spinti et al. 2004; Mustafa et al. 2010).

Some previous research in residential spaces has focused primarily on landscape preferences (Zube et al. 1986; Yabiku et al. 2008; Larson et al. 2009a; Nassauer et al. 2009; St. Hilaire et al. 2010; Kurtz and Baudains 2012; Peterson et al. 2012; Hayden et al. 2015), while other work has a greater focus on the landscapes people actually have (Zmyslony and Gagnon 1998; Larson et al. 2010; Blaine et al. 2012; Burr et al. 2018). Relatively few studies (Martin et al. 2003; Larsen and Harlan 2006; Larson et al. 2017b) have considered both preferred and actual yards and the relationships between the two. These studies tend to focus on specific subsets of drivers such as legacy effects (Larson et al. 2017b) or landscaping regulations (Martin et al. 2003). Actual landscapes have been presented for comparison with preferences (Spinti et al. 2004; Larsen and Harlan 2006; Larson et al. 2009a), but combined drivers of these choices have not been explored. Yet some drivers of yard preferences and outcomes are likely shared, whereas others may be distinct or may be relatively more or less important.

Our work builds upon previous findings by considering a broad range of attitudinal and structural predictors for both preferred and actual yards. Based on the existing literature, we expect to see that most residents have the yards they prefer, with higher realization of preferences in back yards than in front yards.

Diverse drivers of landscape choices (RQ2)

We expect that landscaping choices, by which we mean both preferences and actual yards, are driven by a mixture of attitudinal and structural drivers. By attitudinal drivers, we mean personal evaluations and beliefs that influence decisions as people act to realize their values and ideals (Roy Chowdhury and Turner 2006; Larson et al. 2010). In contrast, structural drivers constitute the factors that drive and/or constrain decisions, including social attributes such as wealth and parcel attributes such as lot size. As further explained below, we respectively refer to these forces as social and parcel structure. Ultimately, we expect attitudes to have a greater influence on landscape preferences, whereas structural factors are more likely to constrain the actual landscapes people have.

Attitudinal drivers

The link between environmental attitudes and behavior has been frequently explored, with varying results (Stern 2000; Kollmuss and Agyeman 2002; Ives and Kendal 2014; Drescher et al. 2017). The New Ecological Paradigm (NEP), a commonly used scale for measuring broad-based environmental worldviews (Dunlap et al. 2000), has been used to evaluate the influence of environmentally-oriented values on yard management behavior and outcomes. Several studies have linked pro-ecological worldview (measured by NEP) with yard preferences (Yabiku et al. 2008; Kurtz and Baudains 2012; van Heezik et al. 2013), although in Phoenix, Arizona, contradictory relationships have been found between NEP and preferred versus actual yard grassiness (Yabiku et al. 2008; Larson et al. 2010). While broad ecological worldview can impact yard preferences, landscape-specific values and attitudes, such as attitudes toward the desert in the arid context of Phoenix, have been shown to better predict yard-management behaviors and landscape preferences (Larson et al. 2010; Kurtz and Baudains 2012). Given these findings, we expect to see significant effects of both general ecological worldviews and more specific attitudes on yard choices.

Less research has investigated how political attitudes relate to residential yard choices. Two studies—one in the US (Larson et al. 2010) and another in Canada (Drescher et al. 2017) found no effect of political affiliation on landscape preferences, irrigation practices, or private land conservation behavior. However, studies have shown political orientations do affect other environmental attitudes and behaviors (Larson et al. 2011; Feinberg and Willer 2013). Typically, conservatism is associated with tradition and resistance to change, which might lead to favoring the lawn over modern alternatives. Thus, we hypothesize that more conservative residents will have more grass than liberal residents, particularly given Phoenix's historic grassy, oasis-like character (Larson et al. 2009a, 2017b).

Structural drivers: social

Aspects of social structure may also influence yard choices. Similar to attitudes toward the regional landscape, acculturation to the local context of an area may lead to greater acceptance of landscapes incorporating native plants and regionally-appropriate features. In Phoenix, a popular narrative suggests that domestic immigrants from the humid east bring with them a preference for lush lawn-dominated yards, while longer-term residents have grown accustomed to the desert and are more likely to adopt xeric landscaping (Larson and Brumand 2014). However, this has been challenged in numerous studies that show longer-term residents in the southwest tend to prefer more grass or fewer desert plants in their yards (Martin et al. 2003; Spinti et al. 2004; Yabiku et al. 2008; Larson et al. 2009a, 2017b; St. Hilaire et al. 2010). In accordance with this work, we expect to see higher preferences for grass as the duration of residence in the Phoenix Valley increases.

Social status and lifestyles can also influence yard management (Grove et al. 2014). An extensive body of literature has investigated the effects of socioeconomic status, often characterized by income, on residential yard structure and ecological outcomes, typically with a focus on tree canopy cover (Iverson and Cook 2000; Grove et al. 2014) and biodiversity (Hope et al. 2003; Leong et al. 2018). Dubbed the luxury effect, higher income levels have been associated with more trees, vegetation, and bird biodiversity (Hope et al. 2003; Kinzig et al. 2005; Cook et al. 2012; Avolio et al. 2018). We therefore expect higher income residents to prefer more naturalistic landscapes, wherein xeric yards are seen as a cultural status symbol (Larsen and Harlan 2006; Mustafa et al. 2010).

Resident age may also affect yard choices, as low-maintenance needs become more important for older adults, while maintaining a space for children to play becomes less important (Martin et al. 2003; Bhatti 2006; Larson et al. 2009a, 2017b). As a result of this predicted relationship between lifestage and desired grassiness, we predict that older residents will have less grass in their yards.

When viewing the residential yard as part of the domestic sphere, gender roles become an important consideration (Bhatti and Church 2000). Caretaking responsibilities may lead women to be more concerned with creating hospitable recreational spaces for children, which may result in preferences for soft, grassy landscapes over rocky landscapes with thorny, possibly dangerous vegetation, or that may conceal dangerous animals (Larson et al. 2009a; Mustafa et al. 2010). We predict that women will be more likely to prefer grassier landscapes while men prefer less grass.

The relationship between ethnicity and yard management has not been well explored, although preferences have been shown to differ with cultural identity and ethnicity. In Canada, for example, Chinese, British, Portuguese, and Italian respondents preferred different landscape types (Fraser and Kenney 2000). In North Carolina, African-American respondents preferred grassier yards with fewer native plants (Peterson et al. 2012). In Phoenix, where the largest non-white ethnic group is Hispanic residents, primarily with Mexican origins (Larsen and Swanbrow 2007), a small negative correlation has been found between the proportion of Hispanic residents in a neighborhood and the amount of grassy landscaping (Balling et al. 2008). We explore the effects of identification as Hispanic on yard choices, with the expectation that Hispanic residents will more likely have xeric yards, if not prefer them.

Structural drivers: parcel

Parcel structure is likely to constrain what residents can or cannot do in their yard and, thus, may influence actual yards rather than preferences. Parcel characteristics, including lot size, have been shown to be more important than socioeconomic factors in determining residential tree cover (Bigsby et al. 2014). Lot size is likely related to the amount of effort required to manage a yard. We therefore expect to see more grass in smaller lots, where the yard may be more likely to be used and viewed as an extension of the home, while larger lots will have a smaller proportion of grass for ease of maintenance.

In Phoenix, outdoor swimming pools are relatively common in residential neighborhoods. Explorations of residential water consumption in Phoenix have found a small positive correlation between grassy landscaping and presence of a swimming pool (Balling et al. 2008), which has also been observed in Spain (Cubino et al. 2014). Neither of these studies considered how pools might affect preferences for grassy landscaping. We expect that the presence of a swimming pool may reveal an "oasis mentality" associated with grassiness, leading to a positive correlation between presence of a swimming pool and amount of grass. Alternatively, the presence of a pool may allow for cooling and outdoor recreation opportunities that make a lawn unnecessary, and so presence of a pool may be negatively correlated with the amount of grass.

Historical conditions and previous landscape choices can leave lasting impacts ("legacies") on current residential landscapes (Grove et al. 2017; Larson et al. 2017b; Roman et al. 2018). Residents often state a preference for low-maintenance yards, possibly indicating a lack of desire to do yard work, which may lead to the management of existing landscapes rather than changing landscapes to match preferences (Larson et al. 2010). In addition, residents may feel beholden to the neighborhood character and social norms, and feel pressured into maintaining the existing landscape (Robbins 2007; Larson and Brumand 2014). Phoenix is a relatively young city but was largely built as successive planned developments, and so legacies of original developer decisions are likely to be important for present-day landscapes. Differentiation in landscape design between new and old developments, moreover, may have led to more xeric yards in newer developments, due largely to developer decisions (Larsen and Harlan 2006). Thus, we hypothesize that older homes will have more grass than newer homes.

Methods

Research context

This study was conducted in the Phoenix metropolitan area, which is the focal study area of the Central Arizona–Phoenix Long-Term Ecological Research project (CAP LTER). The Phoenix-Mesa-Scottsdale metropolitan area (hereafter, "Phoenix") is the 11th largest in the U.S. with an estimated population of 4,561,038 (U.S. Census Bureau 2017, 2018a). The metropolitan area is rapidly growing, with a population increase of 544,141 residents from 2010 to 2017, amounting to the 7th largest increase of any U.S. metropolitan area over this time period (U.S. Census Bureau 2018b). Phoenix experiences high domestic immigration from the midwestern and northern regions of the U.S., with large influxes of new residents in search of a warm climate and a low cost of living. Due to its location near the southern border, about 30% of the population is Hispanic or Latinx (U.S. Census Bureau 2017).

Phoenix is located along the Salt River in the Sonoran Desert of central Arizona, located in the southwestern United States. The climate is hot and dry, with average seasonal temperatures ranging from 57 ° F (14 °C) in the winter to 93 ° F (34 °C) in the summer (1981–2010 seasonal normals for Phoenix Airport; National Climate Data Center 2019) and an average of 109 days per year with a maximum temperature over 100 ° F (38 °C) (1981–2010 average; National Oceanic and Atmospheric Administration 2019). Annual precipitation is low, with an average total of 8 in. (20 cm) distributed in a summer monsoon season and winter rainy season (1981–2010 normals for Phoenix Airport; National Climate Data Center 2019). As a result, outdoor irrigation is ubiquitous (DeOreo et al. 2016). Despite the arid context, Phoenix has historically been marketed as an oasis in the desert with abundant water and lush vegetation, and has a history of grassy landscaping (Zube et al. 1986; Larsen and Swanbrow 2007; Hirt et al. 2008). Lawn alternatives have become commonplace more recently, with desert-like xeriscaping widely adopted (Frost 2016). Residential development has typically occurred on former agricultural sites, resulting in little increase in overall water use in Phoenix with urban development, but continued development on desert sites as well as ongoing drought and water policy challenges in the Colorado River Basin create an urgent need for understanding and reducing urban water use (Hirt et al. 2008; Larson et al. 2009b; Sullivan et al. 2019).

Survey administration

Survey data were collected as part of the CAP LTER ongoing Phoenix Area Social Survey (PASS), which is a longitudinal survey of residents in the Phoenix metropolitan area intended to evaluate connections between the social and ecological dynamics of residential neighborhoods (Larson et al. 2017a). The PASS was first piloted in 2001 and then conducted again in 2006, 2011, and 2017. Here, we consider responses from the most recent 2017 survey administered by the University of Wisconsin Survey Center between May 31 and September 15.

A stratified sampling design was used wherein study neighborhoods, as defined by 2000 U.S. Census block group

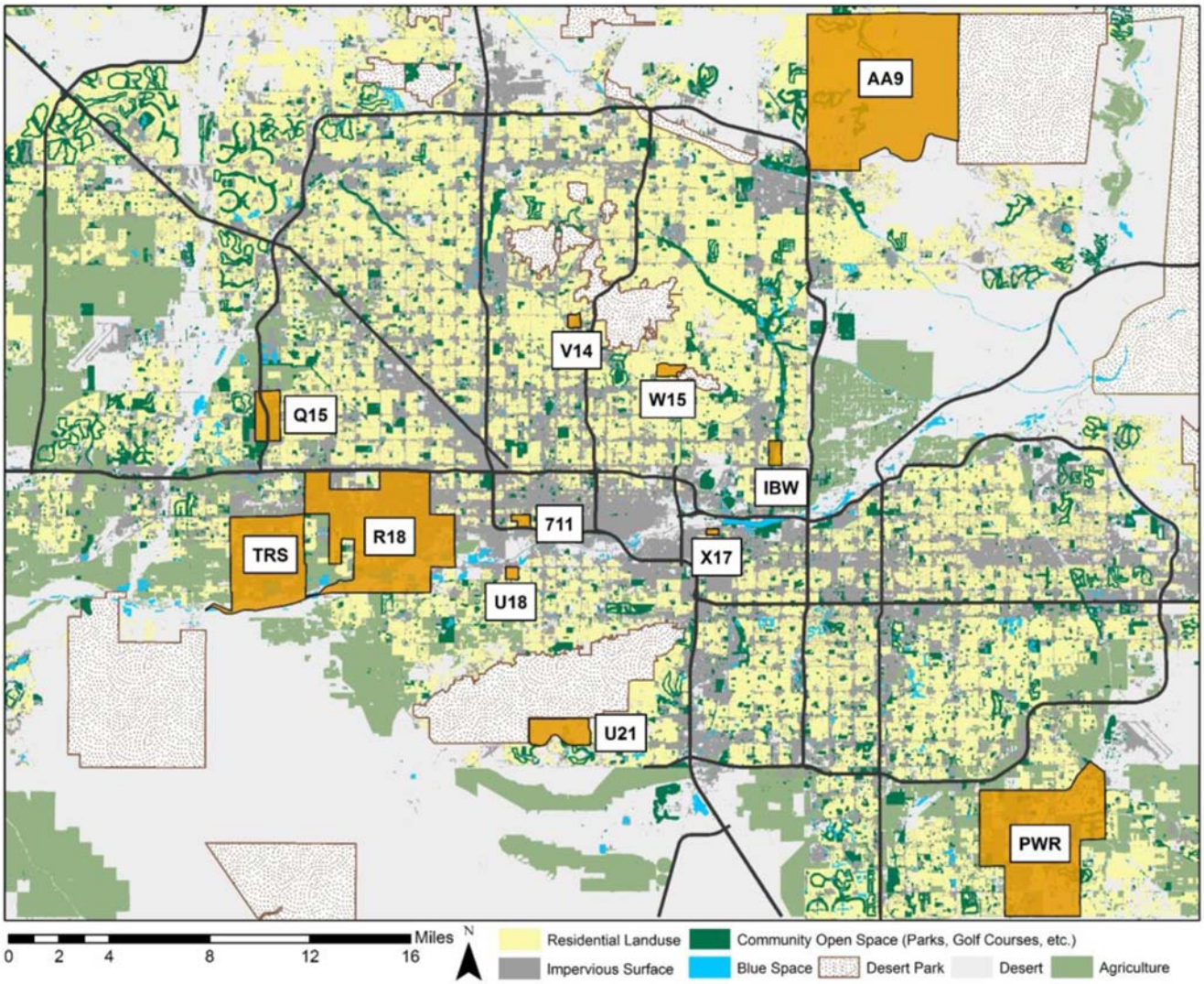

Fig. 1 Map of the study area in the Phoenix, AZ metropolitan area and specific neighborhoods surveyed (Larson et al. 2017a). Three-digit codes are unique neighborhood identifiers

boundaries, were selected to overlap with ongoing ecological sampling conducted by CAP LTER. In particular, 12 neighborhoods in the Phoenix valley (Fig. 1) were selected with the goal of representing a range of income levels and locations relative to the city. Within each neighborhood, we surveyed both addresses from which surveys were returned in previous years ($n = 188$) as well as new addresses. The total sample included 1400 addresses. 101 new addresses per neighborhood were provided by the Marketing Systems Group and generated from the U.S. Postal Service's Delivery Sequence, for a total of 1212 new addresses. 14 back-up addresses for each neighborhood were generated and used in case of undeliverable surveys or refusals.

Residents were contacted by mail only. The first mailing included the survey, a postage-paid card to request a Spanish survey, a return envelope, and a $5 incentive. All residents received a reminder postcard 1 week later, and non-responders received two additional mailings with the full survey packet—one sent 3 weeks after the initial packet and one sent 7 weeks after the initial packet. In addition to the $5 prepaid incentive, residents were assigned to one of fifteen completion incentive groups.[1] Incentive amounts for survey completion were $5, $25, or $40 and were given to either the respondent or a charity organization.

From the total sample of 1400, 496 surveys were completed and returned for a response rate of 39.4%. Due to our focus on privately managed outdoor landscaping, only the 381 respondents who reported living in single-family homes are included our analyses (77% of total responses).

[1] The fifteen random assignments were part of an experimental design by economist Kerry Smith, to test the impact of different incentives on survey response rates (Smith et al. 2016).

Survey questions and variables

Yard typologies

Respondents were surveyed about the ground cover and vegetation of their existing front and back yards, as well as what ground cover and vegetation they would most prefer in each their front and back yard. Specifically, respondents were asked: "Which of the following [yard descriptions] would you most prefer as a front yard landscape?" Next, respondents were asked: "Which one of the following [descriptions] most resembles your front yard?" These questions were then repeated using "back yard" in place of "front yard." Respondents were provided with the following 7 choices of yard descriptions:

- "a yard with grass, some shrubs and leafy trees" (which we call *mesic*);
- "a yard with some grass and some crushed stone with plants, shrubs and trees" (*oasis*);
- "a yard with crushed stone and native desert plants and trees" (*xeric*);
- "a yard with patches of bare soil and little or no grass and trees" (*bare*);
- "a yard with large areas of hard surface, such as flagstone or finished concrete, and plants and shrubs in containers" (*paved patio*);
- "a balcony or patio without plants, shrubs, or trees" (*bare patio*); and
- "a patio or balcony with garden area/flower beds/plants" (*garden patio*) (Table 1).

A write-in "other" option was also available. The above descriptions are modeled after previous research that has used a typology of mesic, oasis, and xeric to capture common types of yards in the region—that is, as characterized by all or mostly grass cover, a mix of grass and gravel, and all or mostly gravel cover (Larsen and Harlan 2006; Yabiku et al. 2008; Larson et al. 2009a, 2010, 2017b). The three patio options were added to represent courtyard-style yards that are popular in the U.S. and elsewhere as well as balconies and patios with either no vegetation or with garden areas, most common in multi-family housing. As expected, very few respondents in single-family homes—the focus of this study—chose the "balcony" options, though some did, given the inclusive "or patio" wording (Table 1).

The yard typology primarily captures the extent of grass versus other alternative groundcover types, partly because of our interest in the water-use implications of landscaping. To specifically address the grassiness of each yard, we reclassified survey responses based on lawn cover using the existing categories and free-response "other" values (Table 1). This ordinal variable for front and back yard typology included:

- mesic (3, all or mostly turfgrass);
- oasis (2, a mix of turfgrass and other ground cover types); and
- xeric (1, no turfgrass).

Remaining "other" responses which could not be classified were eliminated in subsequent analyses (2 existing and 2 preferred front yards removed, 4 existing and 4 preferred back yards removed), including unclear write-in responses as well as artificial turf. Yards with swimming pools were also left as "other" if other groundcover types (e.g., grass, rock, or patio) were not specified. In our simplified typology, the three patio types and bare yard type are combined with xeric landscaping since none of these includes grass as a component (Table 1). We verified our grass-based typology for actual yards via comparison with another survey question specifically about yard grass area, and then excluded the small number of respondents who gave contradictory answers (see Online Resource 1, Supplementary Methods for additional information).

Our simplified typology was applied to front and back yards separately and was used for both preferred and existing yards. A whole-parcel typology was developed based on the combined front and back yard simplified typologies for each parcel. The parcel-level coded variable is an ordinal measurement representing five levels of grassiness for entire parcels:

- all grass (5, mesic in front and back);
- mostly grass (4, one yard mesic, one yard oasis);
- about half grass (3, one yard mesic and one xeric OR both yards oasis);
- less than half grass (2, one yard oasis and one xeric); and
- no grass (1, both yards xeric).

When a respondent did not provide both a front and back yard type or when either yard could not be classified into the turfgrass-based typology due to unclear free (i.e., "other") responses, a parcel-level landscape type was not assigned and those cases were eliminated for subsequent analyses (6 existing and 6 preferred parcels removed). A total of 331 parcels had valid existing full parcel typologies (50 removed with invalid responses for one or both yards), while 369 had valid preferred full parcel typologies (12 removed with invalid responses for one or both yards).

Attitudinal variables

Respondent attitudes were captured in three ways. First, we used two composite survey scales to represent the environmental perspectives of residents: 1) a standard measure of

Table 1 Number of responses for each original and simplified yard typology, for front and back yards, preferred and existing. Single-family homes only, $N = 381$

Original typology	Simplified typology	Preferred front	Preferred back	Existing front	Existing back
Mesic	Mesic	92	115	31	39
Oasis	Oasis	86	115	53	107
Xeric	Xeric	147	62	228	80
Bare	Xeric	3	4	20	53
Paved Patio	Xeric	16	26	9	35
Bare Patio[a]	Xeric	5	3	1	9
Garden Patio[a]	Xeric	18	26	3	5
Other	Various, based on inclusion of turfgrass in description	13	25	26	49
Refused	Excluded	1	5	10	4

[a] Wording of answer choice was inclusive of both patios and balconies

broad-based environmental value orientations, and 2) a more specific measure pertaining to the study region, attitudes toward the desert (based on Andrade et al. 2019). A third measure captures political orientation, as further detailed below (Table 2).

Environmental value orientations, or pro-ecological worldviews, were measured using all 15 survey items from the New Ecological Paradigm (NEP) scale (Dunlap et al. 2000). The statements were given verbatim with one exception. Due to the outdated and somewhat awkward reference of the Earth as a spaceship, the item, "The earth is like a spaceship with very limited room and resources," was slightly reworded to "The Earth has limited room and resources" (Table 2). The 15 NEP items were combined into a reliable index (Cronbach's alpha = 0.86)[2] representing pro-ecological worldview. To create this index, responses for half of the items (see Table 2) were reversed to make the scale unidirectional before calculating individuals' average responses. The scale ranged from 1 to 5, where 1 is the most anthropocentric, 3 is neutral, and 5 is the most eco-centric.

To assess attitudes toward the desert, respondents were asked the extent to which they agree or disagree with the following four statements: 1) "The desert is an empty wasteland"; 2) "The desert is a very special place to me"; 3) "The desert is a nice place to spend time"; and 4) "The desert is beautiful". A five-point response scale was used (1 = strongly disagree, 2 = somewhat disagree, 3 = neither agree nor disagree, 4 = somewhat agree, 5 = strongly agree). The responses for the four questions were averaged to calculate an 'attitudes toward the desert' survey scale (Cronbach's alpha = 0.83), with one negatively worded item ("The desert is an empty wasteland") first reversed such that higher values of the scale indicate more positive attitudes toward the desert.

[2] Alphas calculated using the function alpha in R package psych v 1.8.4 (Revelle 2018).

Similar to previous research (Larson et al. 2011), respondents were asked to describe themselves politically on a seven-point scale wherein 1 = very conservative, 2 = conservative, 3 = slightly conservative, 4 = moderate, 5 = slightly liberal, 6 = liberal, and 7 = very liberal.

Social structural variables

Based on the scholarly literature and theory-driven hypotheses, the socio-cultural variables considered for this study were household income, respondent age, duration of residence in the Phoenix metropolitan area, gender, and identification as Hispanic and/or Latino (Table 3). For all questions, a refuse/prefer not to answer choice was provided.

For the income variable, respondents were asked to select a range representing the total combined income of all members of the household for 2015. The provided ranges were coded as follows: $20,000 and under (1), $20,001–$40,000 (2), $40,001–$60,000 (3), $60,001–$80,000 (4), $80,001–$100,000 (5), $100,001–$120,000 (6), $120,001–$140,000 (7), $140,001–$160,000 (8), $160,001–$180,000 (9), $180,001–$200,000 (10), more than $200,000 (11). Age was estimated by subtracting the respondent-provided birth year from 2017. Respondents were also asked for how many years they had lived in the Phoenix valley, and a percentage of life lived in Phoenix was calculated by dividing their response by their age in years. Where the number of years lived in Phoenix given was greater than the calculated age (usually by 1), the percentage of life in Phoenix was considered to be 100. For one respondent with a calculated age of 116, the calculated age was assumed to be in error and was converted to NA. Gender was considered as a binary variable coded as 0 for male or 1 for female. Regarding ethnic identity, respondents were asked whether they considered themselves to be Mexican, Mexican-American, Chicano, Hispanic, Latino, or of Spanish background. This wording was intentionally inclusive to capture both Hispanic

Table 2 Summary statistics for attitudinal variables

Explanatory variable	Mean (Std Dev)	Valid N
Pro-ecological worldview index (alpha = 0.86)	*3.70 (0.70)*	*372*
We are approaching the limit of the number of people the earth can support	3.42 (1.20)	377
Humans have the right to modify the natural environment to suit their needs (R)	2.28 (1.21)	378
When humans interfere with nature it often produces disastrous consequences	3.90 (1.09)	379
Human ingenuity will insure that we do NOT make the earth unlivable (R)	2.92 (1.26)	377
Humans are severely abusing the environment	4.11 (1.10)	379
The earth has plenty of natural resources if we just learn how to develop them (R)	3.45 (1.31)	379
Plants and animals have as much right as humans to exist	4.22 (1.03)	379
The balance of nature is strong enough to cope with the impacts of modern industrial nations (R)	2.35 (1.13)	378
Despite our special abilities humans are still subject to the laws of nature	4.40 (0.79)	377
The so-called "ecological crisis" facing humankind has been greatly exaggerated (R)	2.23 (1.27)	377
The Earth has limited room and resources	3.98 (1.09)	377
Humans were meant to rule over the rest of nature (R)	2.48 (1.41)	378
The balance of nature is very delicate and easily upset	3.81 (1.08)	378
Humans will eventually learn enough about how nature works to be able to control it (R)	2.40 (1.18)	376
If things continue on their present course, we will soon experience a major ecological catastrophe	3.75 (1.18)	377
Desert attitudes index (alpha = 0.83)	*4.10 (0.80)*	*370*
The desert is an empty wasteland (R)	1.56 (0.96)	376
The desert is a very special place to me	3.78 (1.09)	375
The desert is beautiful	4.39 (0.95)	373
The desert is a nice place to spend time	3.92 (1.11)	378
Politically liberal	*3.92 (1.64)*	*373*

The first two scales were measured using response options: strongly disagree (1) to strongly agree (5) with a neutral (3) option. Composite scales are oriented such that 5 = most pro-ecological worldview or most positive attitudes toward the desert. Political views are on a scale from 1–7 (1 = very conservative, 4 = moderate, 7 = very liberal). Reverse coded items are marked with (R) to indicate variables for which scales were reversed to create unidirectional indices for worldview and desert attitudes. The means shown are for the original response scale (not reversed). Alpha is Cronbach's alpha

(Spanish-speaking) and Latino (from Latin America). Given the population of metro Phoenix, we assume the majority of these respondents are from Mexico or of Mexican descent. The terms in the question reflect this, as well as the identification of some Mexicans or Mexican-Americans as Chicano. For whether the respondent was of Hispanic and/or Latino descent, no was coded as 0 and yes as 1.

Parcel structural variables

Three elements of physical parcel structure were assessed through the resident survey and additional publicly available data: presence of a swimming pool, lot size, and home age (Table 4). To integrate the lot size and home age variables with the survey data, respondent households were matched with data from the Maricopa County Tax Assessor records. Each respondent household was matched with its Assessors' Parcel Number (APN) by address, with manual assignments made for single-family homes with unit or lot numbers. Parcels were then matched by APN with tax assessor data to find total lot size and home age. The pool variable came from the PASS and was coded as 0 = no pool and 1 = pool.

Table 3 Summary statistics for social structural variables

Explanatory variable	Mean (Std Dev)	Range (Min – Max)	Valid N
Income	5.7 (3.2)	1–11	353
Age	52.0 (16.1)	18–92	375
% life in Phoenix	54% (31)	0–100	370
Female	62%	0–100 (% respondents)	379
Hispanic/Latino	24%	0–100 (% respondents)	369

See text for descriptions of variables

Analyses: yard grassiness models

We used ordinary least squares (OLS) and ordinal regression to identify significant predictors of increased yard grassiness. All models were run in R (version 3.6.1; R Core Team 2019). Existing yards and yard preferences were modeled separately to compare the drivers of each set of landscaping choices. We used OLS regression to model parcel-level grassiness, where our response variables were the preferred and existing amount of grass at the parcel level, from our calculated five-level grassiness variable. We then used ordinal regression with the polr function in R package MASS (version 7.3–51.4; Venables and Ripley 2002) to model front and back yards separately, using the three-level xeric/oasis/mesic simplified typology. For all response variables, higher values signify greater grassiness.

We tested three groups of predictors: personal attitudes (pro-ecological worldview, attitudes toward the desert, political orientation), social structural variables (income, age, percent of life lived in the Phoenix valley, gender, Hispanic/Latino identity), and parcel structural characteristics (parcel area, home age, presence of a swimming pool). All models were checked for multicollinearity by calculating the variance inflation factors (VIF) with the vif function in R package car (version 3.0–2; Fox and Weisberg 2011). VIF values for all predictors in all models were under 2. Standardized beta coefficients were used to determine relative predictor impact for OLS models, and were calculated with the lm.beta() function in R package lm.beta (version 1.5–1, Behrendt 2014).

Results

First, we discuss respondent realization of yard grassiness preferences, or in other words, the extent to which residents have their preferred yard types. Then, we present results of parcel-level grassiness models for preferred and existing yards, followed by results for front and back yards separately.

Realization of preferences

At the parcel level, less than half of survey respondents (46%) had their preferred landscape grassiness. An additional 46% had less grass than they would prefer. Only 15% of respondents who wanted yards with all grass had fully mesic parcels; meanwhile 42% of these grass-loving respondents had no grass at all (Table 5). Yet those with xeric preferences largely had their desired yard type, with only 11% of people who wanted no grass having any.

A larger portion of respondents had either their preferred front or back yards. About two-thirds (62%) of respondents had their preferred front yard and 59% had their preferred back yard, contrary to our expectation that realization of preferences would be higher in back than in front yards. Of respondents who preferred to have lawn-dominated yards, 21% who wanted mesic front yards and 28% who wanted mesic back yards actually had them (Table 5). Regarding xeric yards, 93% of those who wanted xeric front yards and 87% who wanted xeric back yards had them. Very few respondents who wanted a xeric yard actually had a mesic yard (2% in front and 3% in back).

Drivers of parcel-level grassiness

Overall, preferred grassiness was better predicted by our explanatory variables than was existing yard grassiness (Table 6). The models for both preferred and reported yard grassiness were statistically significant, but the existing yard model explained very little of the variance in responses. Specifically, the models explained 19% and 5% of the variance for preferred versus reported yard choices at the parcel scale, respectively (Table 6). As expected, the attitudinal and social structural variables most strongly explained preferred landscapes, whereas social and parcel structural variables better explained existing yards.

Attitudes most strongly explained yard preferences; specifically, people who view the desert negatively had preferences for more grassy landscapes compared to others (Table 6). Consistent with past research and our expectations, younger residents preferred lawns more so than did older residents, and people who had lived more of their life in the Phoenix Valley tended to prefer more grass than did relative newcomers. No parcel structural variables significantly predicted yard preferences.

Lot size and respodent age were the only significant predictors of existing yard grassiness, with more grass on larger lots managed by younger residents (Table 6). None of the attitudinal variables tested significantly predicted existing yard grassiness.

Table 4 Parcel characteristics from the PASS and Maricopa County Tax Assessor records

Explanatory variable	Mean (Std Dev)	Range (Min – Max)	Valid N
Lot size (square feet)	11,863 (9497)	2145 – 79,531	378
Home age (years)	30 (22)	1–89	378
Have pool (% respondents)	41%	0–100	381

Front versus back yard predictors

Similar to the predictors for preferred versus reported landscapes, the factors that significantly explained front versus back yards also varied (Table 7; Online Resource 1, Table S1). Attitudes toward the desert, which was a significant predictor of full parcel preferred grassiness, significantly predicted both front and back yard preferences. However, duration of residence in the Phoenix area only significantly predicted back yard choices and resident age only significantly predicted front yard choices—both for preferred and reported levels of grassiness (Table 7; Online Resource 1, Table S1). Similar to findings at the parcel level, lot size and resident age significantly predicted front yard grassiness. In addition, Hispanic/Latino residents and those with older homes had more grass in the front yard. Existing back yards shared no significant predictors with front yards.

Discussion

In this study, we examined the relationship between actual and preferred residential yard grassiness and the relative influence of attitudinal, social structural, and parcel structural drivers on yard choices. We observed significant differences between actual and preferred yard grassiness, with nearly half of all respondents having less grass in their parcel than they would prefer. Additionally, we found that attitudinal and social structural characteristics were most important in determining yard preferences, but social and parcel structural characteristics were more important for actual yard outcomes. The distinction between drivers of yard preferences and actual yard landscaping suggests different strategies for promoting the adoption of water-conserving landscapes, wherein lifestyles affect preferences and structural factors constrain the landscapes people actually manage in their yards.

While most residents had at least their preferred front or back yard, parcel-level preferences were less often achieved. Our observed mismatch between preferred and actual front or back yard landscaping is about the same as found in a 2002 survey of Phoenix residents, and the percentage of respondents preferring mesic landscaping in front or back yards has stayed nearly the same as well (Larsen and Harlan 2006). However, we observed a higher level of unachieved preferences at the parcel level, with almost half of respondents wanting more grass than they had. The large difference between preferred and actual yard grassiness indicates a latent demand for lawns in Phoenix, despite the current prevalence of xeric landscaping. While xeric landscapes have become more common over time, our findings indicate that uptake of these landscapes is driven by forces beyond shifting resident preferences, such as legacy effects of original developers' decisions or social norms and pressures. Given the large number of residents who would prefer to have more grass, changes in

Table 5 Respondent preferred and existing (a) front yard, (b) back yard, and (c) full parcel typology

a)	Existing front yard						
Preferred front yard		Mesic		Oasis		Xeric	*Total*
	Mesic	18 (21%)		11 (13%)		57 (66%)	86
	Oasis	8 (10%)		26 (33%)		46 (58%)	80
	Xeric	3 (2%)		10 (5%)		173 (93%)	186
	Total	29		47		276	352
b)	Existing back yard						
Preferred back yard		Mesic		Oasis		Xeric	*Total*
	Mesic	29 (28%)		25 (24%)		50 (48%)	104
	Oasis	4 (3%)		69 (58%)		45 (38%)	118
	Xeric	3 (3%)		12 (10%)		103 (87%)	118
	Total	36		106		198	340
c)	Existing parcel typology						
Preferred parcel typology		All grass	Mostly grass	Half grass	Some grass	No grass	*Total*
	All grass	8 (15%)	1 (2%)	12 (22%)	11 (20%)	23 (42%)	55
	Mostly grass	0 (0%)	5 (15%)	6 (18%)	9 (27%)	13 (39%)	33
	Half grass	1 (1%)	0 (0%)	24 (31%)	23 (29%)	30 (38%)	78
	Some grass	2 (3%)	2 (3%)	9 (13%)	37 (52%)	21 (30%)	71
	No grass	0 (0%)	0 (0%)	3 (4%)	6 (7%)	75 (89%)	84
	Total	11	8	54	86	162	321

Values shown are the number of respondents in each category. The given percentages are the percent of respondents with a particular preference who actually have each type of yard

these structural forces may result in the resurgence of water-intensive grassy landscapes in Phoenix.

Our sample of existing yards had limited variability in grassiness, with most parcels containing half or less grassy landscaping. While this presents a challenge for explaining the drivers underlying predominantly grassy landscapes, it may reflect a broad trend in the greater Phoenix area since neighborhoods have become increasingly xeric over time (Frost 2016; Warren et al. 2019). Preferences, however, showed much greater variability, with many more residents preferring entirely grassy yards than actually had them, thereby highlighting the disconnect between preferences and actual landscaping. This is significant as the discourse in the region often emphasizes rising preferences for desert-like landscaping that lead to increased uptake of these landscapes, and yet the empirical evidence does not support this claim.

Nearly half of our respondents had their preferred amount of grass, but the predictors of preferences and actual yard grassiness were not the same. The importance of parcel structure relative to social characteristics and attitudes in determining yard ecological outcomes has been found in other studies (Bigsby et al. 2014; Ossola et al. 2019), suggesting an important role of physical urban structure in residential landscape outcomes. If parcel structure is key to determining outcomes, then conservation priorities will need to be pursued at neighborhood to municipal scales. Moreover, special attention should be paid in future research to decisions made by developers in designing new residential spaces, as well as additional parcel attributes that were not available to us in this work, such as lot-to-house ratio. Additionally, structural attributes particular to front and back yards such as front/back yard area should be considered to further investigate structural drivers at the sub-parcel scale.

In addition to lot size, we found a significant effect of resident age on existing parcel grassiness, where younger residents had grassier yards. We expect that this may relate to the maintenance of grassy yards for children to play, which has previously been shown to affect yard management priorities (Larson et al. 2009a). However, we found that resident age affected front but not back yard choices, suggesting that normative factors may also be important. Our survey did not collect information on whether there were children in the household, so we suggest future more targeted research to investigate the effects of children and caretaking responsibilities on yard management decisions for both front and back yards.

Contrary to our hypothesis, we found that larger lots had more grass than did smaller lots. This could be the result of a developer legacy, whereby developments with smaller parcels also tend to put in xeric landscaping rather than lawns. We also saw evidence of legacy effects through the significant relationship between home age and front yard grassiness (but not full parcel grassiness). This is similar to the effect of home age found in other Phoenix studies (Larsen and Harlan 2006;

Table 6 OLS model results for preferred and existing parcel-level yard grassiness.

	Preferred yard			Existing yard		
Variables	Coefficient ± Std Error	Std Beta	P value	Coefficient ± Std Error	Std Beta	P value
Intercept	**5.6 ± 0.6**	**0.00**	**<0.0001**	**1.8 ± 0.5**	**0.00**	**0.0009**
Attitudinal						
Pro-ecological worldview	−0.1 ± 0.1	−0.06	0.27	0.1 ± 0.1	0.03	0.61
Desert attitudes	**−0.44 ± 0.09**	**−0.26**	**<0.0001**	−0.06 ± 0.08	−0.05	0.41
Politically liberal	−0.03 ± 0.05	−0.03	0.60	0.04 ± 0.04	0.06	0.38
Social Structural						
Income	−0.04 ± 0.03	−0.10	0.15	0.02 ± 0.02	0.06	0.41
Age	**−0.012 ± 0.005**	**−0.13**	**0.03**	**−0.010 ± 0.004**	**−0.16**	**0.02**
% life in Phoenix	**0.6 ± 0.3**	**0.13**	**0.03**	0.3 ± 0.2	0.09	0.16
Female	0.1 ± 0.2	0.03	0.54	−0.1 ± 0.1	−0.05	0.43
Hispanic/Latino	0.2 ± 0.2	0.07	0.22	0.1 ± 0.2	0.04	0.52
Parcel Structural						
Lot size	0.000010 ± 0.000009	0.07	0.27	**0.000017 ± 0.000008**	**0.14**	**0.03**
Home age	−0.006 ± 0.004	−0.09	0.11	0.003 ± 0.003	0.05	0.41
Have pool	−0.2 ± 0.2	−0.09	0.16	0.0 ± 0.1	−0.02	0.74
Model sample size	315			283		
Adjusted R squared	0.194			0.050		
P value	<0.000001			0.009		

Bolded values are statistically significant at the $p < 0.05$ level for the specified yard type

Table 7 Summary of ordinal regression models of preferred and existing front and back yard typologies

	Preferred		Existing	
Variables	Front yard	Back yard	Front yard	Back yard
Attitudinal				
Pro-ecological worldview	0.83	0.85	0.91	1.33
Desert attitudes	**0.49***	**0.64***	0.74	0.92
Politically liberal	0.95	0.98	1.05	1.07
Social structural				
Income	0.95	0.96	1.07	1.10
Age (scaled)	**0.70***	0.82	**0.57***	0.89
% life in Phoenix	1.28	**3.06***	1.04	**2.92***
Female	1.25	1.16	0.84	0.86
Hispanic/Latino	1.47	1.28	**2.44***	0.78
Parcel structural				
Lot size (scaled)	1.20	1.07	**1.36***	1.18
Home age (scaled)	0.83	0.86	**1.38***	0.90
Have pool	**0.56***	0.93	0.65	1.19
Model sample size	319	318	300	297

Values given are the modeled odds ratio, with predictors that are statistically significant at the $p < 0.05$ level shown in bold with an asterisk. Odds ratios greater than 1 correspond to positive correlations, and less than one to negative correlations. Values are for models with all predictors. Numeric values were scaled to give comparable odds ratio values across predictors. For detailed model results, see Online Resource 1, Table S1

Larson et al. 2017b), which again may suggest a developer effect due to initial uniform landscaping of front yards. Alternatively, the relationship between parcel size and grassiness could be due to landscaping changes made by residents. Since smaller parcels would be easier to change than larger ones, legacies of a grassy past may be removed at greater rates in smaller lots, independent of home age. More research on developer decisions in new housing developments as well as rates of landscaping change by residents will help clarify these relationships.

Front and back yards were driven by different predictors and had different levels of preferred grassiness, likely due to differing use of these spaces. Our findings follow previous work showing that front and back yards differ in preferences (Larsen and Harlan 2006), ecological outcomes (Ossola et al. 2019), and drivers of wildlife-provisioning behaviors (Belaire et al. 2016). Nevertheless, realization of preferences was similar in front and back yards, suggesting that privacy in the back yard did not lead to greater realization of personal preferences as indicated by past research (Larsen and Harlan 2006).

One of our structural predictors, presence of swimming pools, may be indicative of personal attitudes as well as structural constraints. Presence of a pool had some significant impact on preferences while no other parcel structural variables did, with pools linked to preferences for less grass in front yards. This may be because residents with pools in the back yard have less desire for a grassy front yard to provide cooling services or for leisure activities. However, swimming pools are a major source of outdoor residential water use along with irrigation, so a tradeoff of pools for grassy landscaping is unlikely to lead to major water savings.

In our study, more specific attitudes about the regional environment—in this case, toward deserts—were more influential to landscape preferences than were broader environmental worldviews. This is in alignment with previous findings showing greater effects of specific attitudes compared to centrally-held values on yard management behavior (Larson et al. 2010), in addition to theoretical expectations from the cognitive hierarchy model that suggests more specific attitudes are more likely to influence human decisions than are broader ones (Vaske and Donnelly 1999). However, attitudes had little effect on actual yard outcomes. As such, conservation programs must go beyond value-based promotional campaigns to address the constraints on resident decision-making and water conservation or other desirable environmental outcomes.

While existing yard grassiness was significantly predicted by lot size and resident age, it was poorly predicted by our models overall, indicating the importance of additional factors not included in this study. For these analyses, we used a survey that was developed with other research questions in mind, but that contained many variables allowing us to explore our attitudinal versus structural framework of landscape decisions. However, some factors that ideally would have been included in this framework were not addressed by survey questions. Some additional factors that we expect may be important include neighborhood norms, the presence of children and/or pets in the home, incentivization of turf removal by

municipalities, and regulations on yard grassiness by homeowners' associations. We suggest future exploration into these additional factors using our theoretical approach in order to more fully compare potential drivers of yard landscaping decisions.

Overall, our theoretical framework presents a more holistic approach to understanding residential landscape management decisions by combining attitudinal and structural drivers of resident behavior. The inclusion of both of these considerations combines approaches focused on personal attitudes, values, and beliefs (e.g. Larson et al. 2010; Kurtz and Baudains 2012) with those that emphasize broader structural and political-economic constraints (e.g. Robbins 2007). We evaluated the relative importance of these realms in predicting landscaping outcomes and found that structural drivers better predicted yard grassiness than did attitudinal drivers, indicating that appeals to resident attitudes and values may not motivate changes in residential conservation behaviors. The theoretical approach presented here could be fruitfully explored with a wider range of possible drivers, and could also be used to structure qualitative investigations into motivations of and barriers to land management decisions in residential spaces. We suggest that qualitative methods would yield a more nuanced understanding of the relationships that we have begun to explore through a quantitative survey design, and may offer more insight into behaviors such as water-conserving landscaping in residential yards.

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