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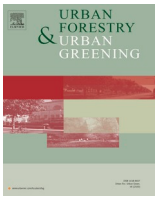

Landscaping preferences influence neighborhood satisfaction and yard management decisions

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ABSTRACT

Residential landscapes support human well-being and ecological functioning in urban ecosystems. Trees and native plants in yards and neighborhoods positively influence satisfaction, an important component of human well-being and quality of life. However, these patterns may not hold true in arid ecoregions, where the composition of desert vegetation contrasts the tall, broad-leafed trees of temperate regions. The effects of xeric, desert-like landscaping on satisfaction with the neighborhood environment are especially important to consider given the large amount of resources required to support people's propensity for grassy yards. Although place satisfaction is related to pro-environmental behavior, the multi-scalar relationship between yard management decisions and satisfaction with the neighborhood environment has yet to be established. Here, we test the social-ecological dynamics of landscape preferences, satisfaction with trees and desert plants, and management intensity in residential yards and neighborhoods throughout the desert city of Phoenix, Arizona, USA. We found that wealthy neighborhoods close to desert open space were intensively managed and supported the highest levels of satisfaction. However, there was no direct relationship between satisfaction and management intensity for people who preferred xeric landscaping. Instead, management intensity for people with xeric preferences was related to demographics, such as income and home ownership. There was a relationship between satisfaction and management intensity for people with mesic preferences, suggesting a resource cost to maintain satisfaction for lush, green landscaping in a desert city. Overall, our study supports the assertion that changing yard landscaping may not result in desired changes for high-input management practices.

1. Introduction

Residential landscapes—made up of privately-owned yards/gardens nested within neighborhoods—form an extensive social-ecological component of cities (Head and Muir, 2006; Cook et al., 2012). As a result, landscaping in residential yards and neighborhoods, such as tree composition and maintenance, can significantly impact urban sustainability (Pauleit et al., 2005; Ghosh and Head, 2009). For example, trees sequester CO_2 and their shade mitigates the effects of extreme heat in cities (Nowak and Dwyer, 2007). Other vegetation, such as herbaceous ground cover or lawns, can reduce storm water runoff and further mitigate heat through evapotranspiration (Coutts et al., 2013). In addition to citywide impacts on ecosystem functioning, residential landscaping also influences the subjective well-being of the people who live there (Elmendorf, 2008).

Measures of human well-being, such as satisfaction (Campbell et al., 1976; Diener, 2009), reflect how people experience their neighborhood environment (Diener and Suh, 1997). The biophysical environment of a neighborhood influences people through its function and appearance (Tress and Tress, 2001). However, the neighborhood environment is largely shaped by the decisions (or lack thereof) made by land managers—such as homeowners, developers, or homeowner associations—that scale up across individual parcels (Goddard et al., 2010). Satisfaction and other subjective evaluations also have the potential to influence management decisions that either shift or further reinforce the existing environment (Gans, 1968; Diener and Suh, 1997; Grimm et al., 2000; Antrop, 2000; Adriaanse, 2007). Our paper investigates the complexity of these social-ecological dynamics across scales by

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examining how landscape preferences predict the relationship between satisfaction and management decisions in residential yards and neighborhoods.

1.1. Satisfaction with the neighborhood environment

For our study, we define satisfaction with the neighborhood environment as a subjective measurement—that is, positive or negative evaluations—of environmental quality. Satisfaction with the environment is formed through a person's individual characteristics (e.g., demographics), as well as their perceptions of biophysical properties of their surrounding environment (Veenhoven, 2000; Van Kamp et al., 2003). Using this conceptual framework, we predict that a mixture of social and ecological factors will affect people's satisfaction with the biophysical environment of their neighborhood.

Social factors, such as demographics, are often related to people's perceptions and evaluations of their neighborhood environment (Andrade et al., 2019). For example, income and homeownership are positively related to perceptions of ecosystem services, such as the aesthetics of neighborhood vegetation (Brown et al., 2020). Although the mechanistic relationship is complex, income is positively associated with people's perceptions that their neighborhood supports a variety of ecosystem services related to tree and vegetation cover, such as mitigating extreme heat and providing habitat to support urban bird populations (Larson et al., 2019a, 2019b, Warren et al., 2019). Additionally, length of residency increases a person's familiarity with the landscape, which can foster positive evaluations (Herzog et al., 1982). However, perceptions also vary with the actual ecological factors of the neighborhood, such as the vegetative characteristics and spatial configuration of local forest patches.

Positivistic approaches predict that satisfaction depends on the objective, physical characteristics of the environment, including ecological factors and the built environment (Veenhoven, 2000). Trees seem to be a particularly important ecological driver of householder satisfaction with their neighborhood. In particular, the shape and size of forest patches in a neighborhood influence resident satisfaction (Ellis et al., 2006; Lee et al., 2008). The presence of shared open space, such as parks or nature preserves, also positively influences satisfaction Kearney, 2006), even for residents who do not physically visit the space (Kaplan, 1985; Kaplan and Austin, 2004). Likewise, Kearney (2006) found people living in subdivisions closer to preserved open space expressed stronger satisfaction with the natural environment of their neighborhood. In the same study, satisfaction was also related to local characteristics that a person could view from their home, such as trees or manicured landscaping (Kearney, 2006).

Landscaping features that are perceived as "natural" influence people's experiences, and thus satisfaction, with their neighborhood environment (Coley et al., 1997). Conceptualizations of what is natural are often based on people's perceptions versus actual ecological characteristics (Dallimer et al., 2012). For example, some people associate the color green with nature (Elliot and Maier, 2014). However, mesic landscaping would largely not exist without human development in desert cities (at least outside of riparian areas). As a result, grassy lawns and deciduous trees often require a higher baseline of resources, such as irrigation, provided by land managers to maintain these green landscapes. Conversely, xeriscaped yards that reflect the natural desert environment are not a lush, grassy landscape (Ibes, 2014). As a result, people who expect or desire nature to fit within a mesic motif are often disappointed by desert landscapes (Herzog et al., 1982). Based on varying frames of what is natural, we predict that people's satisfaction—even in similar environments—will vary based on factors such as latent expectations, which we measured through landscape preferences (Özgüner and Kendle, 2006).

1.2. Factors influencing yard management

People's landscaping preferences are operationalized through their yard management decisions and fortified by the existing landscape (Larson et al., 2009). For example, cultural legacies in Phoenix, Arizona have created the expectation of an "oasis" in the desert, resulting in people's expectations for mesic yards in an otherwise arid environment (Larson et al., 2017). Social norms related to mesic landscaping are further enforced by ordinances in historical neighborhoods, which codify expectations and shape preferences for grassy landscaping (Larson and Brumand, 2014). However, yard care decisions are also further constrained by a number of external factors, such as socioeconomic status of the householder, which are not solely based on a person selecting or maintaining an environment they prefer (Wheeler et al., 2020).

People do not have equal ability to realize landscape preferences in their residential yards and neighborhoods (Mustafa et al., 2010). Renters may not be able to make landscaping choices because they do not own the home, whereas home ownership supports increased vegetation cover (Ossola et al., 2018). Additionally, high turnover rates in tenancy encumber the growth of mature trees when new residents replace the existing landscaping (Kirkpatrick et al., 2012). In general, people with more resources are less constrained—at least by money or time—to plant and maintain the vegetation that they desire (Goodness, 2018). For example, Avolio et al. (2020) found that yards in affluent neighborhoods supported the greatest plant biodiversity in Baltimore, Maryland, which the authors attributed to the monetary resources required for yard care. However, yards are also a physical manifestation of the people who live there, which constrains even people with the required monetary resources from fully actualizing their preferences. Residents often signal social status and their role as a good neighbor or environmental steward through their well-maintained landscapes (Grove et al., 2014). Therefore, even in higher socioeconomic areas where people own their homes, yards may be managed to meet neighborhood expectations as opposed to householder preferences (Robbins et al., 2001).

In addition to management decisions that support the delivery of ecosystem services, such as planting native vegetation, yard maintenance also encompasses practices that negatively affect ecosystem functioning. Management practices, such as chemical application and water use, are tightly coupled with individual and household characteristics. For example, Groffman et al. (2016) found that fertilizer application increased as a function of household income, and that fertilizer use was positively related to resident satisfaction. Likewise, environmental awareness and concern are counterintuitively related to an increase in chemical use in San Francisco; likely as a demonstration of environmental stewardship (Templeton et al., 1999). Overall, the social factors that influence satisfaction also drive management decisions, which create or maintain the biophysical features of neighborhoods (Veenhoven, 2000; Van Kamp et al., 2003).

1.3. Linking satisfaction, preferences, and management decisions

Although conceptual linkages have been drawn, there have been relatively few studies that investigate the empirical relationship between satisfaction and yard care decisions. Or how landscape preferences may influence people's expectations, and thus their subjective evaluations and management practices. Here, our work draws from interdisciplinary urban ecology literature to investigate the relationship between preferences for xeric landscaping, satisfaction with the neighborhood environment, and management intensity in residential yards and neighborhoods. We focus on satisfaction with residential trees and desert plants due to the social and ecological importance of vegetation (Lerman and Warren, 2011; Avolio et al., 2015; Gobster, 2015; Conway, 2016; Konijnendijk van den Bosch, 2016; Ostoić et al., 2017) and recent initiatives to dramatically increase the urban tree canopy, especially in arid cities (Pincetl, 2010; Pincetl et al., 2013). Specifically, we ask: (1)

how do satisfaction and management intensity vary across Phoenix neighborhood typologies? (2) how are social and ecological factors associated with satisfaction with trees and desert plants, and to what extent are these relationships influenced by whether people prefer mesic (e.g., lush) or xeric (e.g., desert-like) landscaping in a desert environment? (3) how does the relationship between landscape preferences and satisfaction influence the intensity of yard management practices?

2. Methods

2.1. Study area

Our study takes place in Phoenix, Arizona, an arid city located in the Sonoran Desert region of the southwestern United States (Fig. 1). Cultural legacies of Phoenix as an "oasis in the desert" shape people's expectations of green, grassy landscapes in the arid environment (Larsen and Swanbrow, 2006). As a result, residents who have lived in Phoenix longer actually hold greater propensity for mesic and oasis landscaping than people who have recently moved to the area (Larson et al., 2017). Preferences and actual landscaping also follow socioeconomic and environmental patterns, where people who live in high-income neighborhoods closer to the desert have and prefer xeric landscaping (Larson et al., 2009). Cultural legacies have further fortified the ideal of the Phoenix oasis through the stark contrast between grassy, green suburban neighborhoods and the surrounding desert. As a result, residents of the area often feel like the desert is "out there" and that "desert landscaping is a different story from going out into the *real* desert" (Larson et al., 2009, pg 933). Preferences for green landscaping also increase over time, where people who have lived in the Phoenix metropolitan area for longer are more likely to prefer and install mesic yards (Wheeler et al., 2020).

2.2. Household survey administration

Survey questions related to satisfaction with the neighborhood environment and management practices were collected as part of the 2017 Phoenix Area Social Survey (Larson et al., 2019a, 2019b). The Phoenix Area Social Survey, known as PASS, is a long-term household survey of 12 neighborhoods in the Phoenix metropolitan area. The survey has been deployed four times since 2001, with the most recent survey in the summer of 2017. The 12 study neighborhoods were defined by U.S. Census block groups selected to represent the ecological and social variation in the metropolitan area, including centrally located neighborhoods in comparison to suburban and exurban areas (Fig. 1).

We sent surveys to 1,400 households, with more than a hundred people sampled in each of the neighborhoods. A portion of households, 188, were previous respondents for the 2011 PASS. An additional 1,212 addresses were randomly drawn from U.S. Postal Service addresses provided by the Marketing Systems Group. Four mailings occurred between May and September of 2017, including three full surveys with a Spanish-language option and postage-paid envelopes, and one reminder postcard for the second mailing. The response rate was 39% for a total of 496 householders. The sample size for neighborhoods ranged from a low of 22 respondents to a high of 56. See the Larson et al. (2019a, 2019b) data package for more details on survey protocol, response rate, and to access the raw household survey data. We processed and coded survey variables using the 'tidyverse' package in program R (Wickham, 2017; R Core Team, 2018).

The household survey was stratified across both social and ecological gradients in the metropolitan area (Fig. 2). As a result, the demographic composition of the sample varied somewhat from the broader region (Larson et al., 2019a, 2019b). The Census Block Groups in the areas where the household survey was administered had a higher household income ($87,135 in the neighborhoods, $60,774 in the metropolitan area). The surveyed neighborhoods also had a slightly younger population (median age was 35.6 in the neighborhoods, 38.7 in the

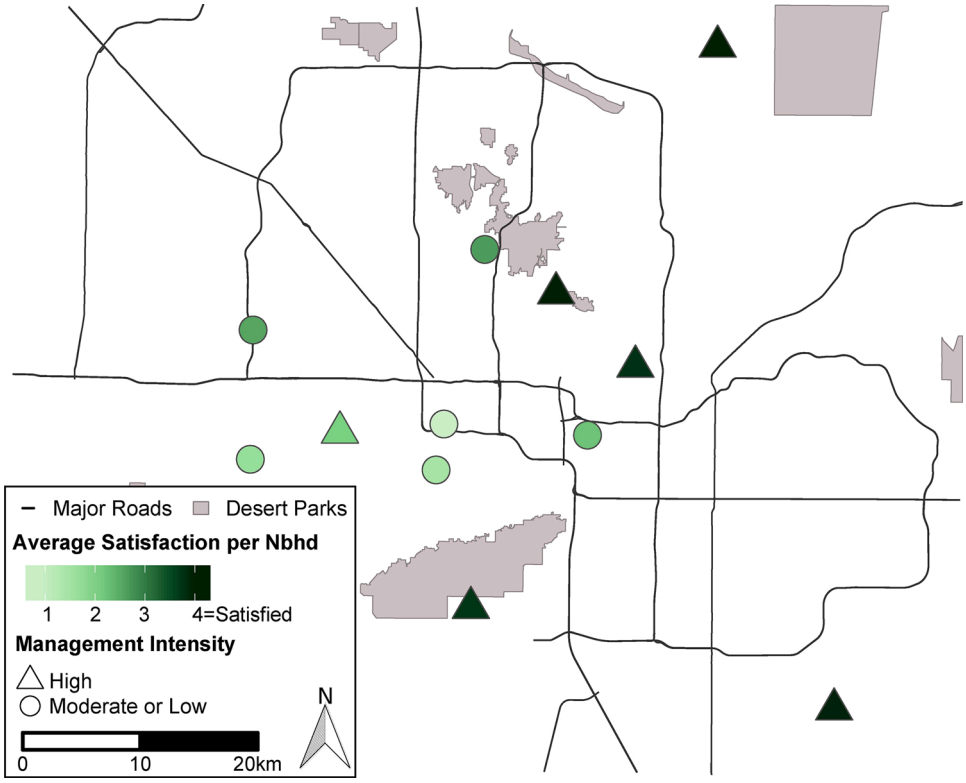

Fig. 1. Study area of the Phoenix Metropolitan region, an arid city located in the Sonoran Desert of Southwest United States. Points are locations where the Phoenix Area Social Survey was conducted. Average satisfaction with desert plants, the amount of trees, and trees that shade is represented by color gradient where lighter colors correspond to lower levels of satisfaction (1=strongly dissatisfied, 2=dissatisfied, 3=neither, 4=satisfied, and 5= strongly satisfied). Triangles represent neighborhoods with high management intensity, where greater than 50 % of the respondents in the neighborhood irrigate daily, use fertilizer, and have planted trees or desert vegetation in the last 5 years. Circles represent neighborhoods with low to moderate management intensity, where less then 50% of the respondents in the neighborhood irrigate daily, use fertilizer, and have planted trees or desert vegetation in the last 5 years.

metropolitan area). Our sample was also composed of a higher percentage of owner-occupied neighborhoods (70.3% compared to 60.5%). From the returned surveys (n = 496), the survey respondents were representative of the targeted neighborhoods in terms of their average age (51 years) and income levels ($80−100 K). Of the final respondents, 72% were homeowners. Given the survey sample and demographics, we advise caution when generalizing the results to the metropolitan region.

2.3. Dependent variables: satisfaction and management decisions

We used three survey questions that asked householders to indicate their satisfaction with the ecological attributes of the vegetation in their neighborhood environment. Specifically, respondents were asked: How dissatisfied or satisfied are you with each of the following features in and around your neighborhood… the amount of trees, desert plants, and trees that shade. Responses were collected on a five-point scale: strongly dissatisfied (1), somewhat dissatisfied (2), neither dissatisfied nor satisfied (3), somewhat satisfied (4), and strongly satisfied (5).

To measure how satisfaction was related to the intensity of yard management practices, we analyzed summer irrigation frequency, fertilizer use, and the addition or removal of trees and desert vegetation. To measure summer irrigation frequency we asked how often the respondent watered plants, trees, or grass in their yard, with the following responses coded: never (1), less than once per week (2), once per week (3), more than twice per week (4), and every day (5). Respondents were also asked how often they or someone else added fertilizer to their lawn or outdoor plants. The response options were never, less than once a year, every few months, monthly, more than once a month, not sure, and does not apply / do not have a lawn or outdoor plants. We coded fertilizer on a binomial scale; if a respondent fertilized more than once a year as (1), and less than once a year or never as (0). Finally, we captured vegetation changes respondents made by asking if they had added or removed any trees or desert plants in the last five years.

2.4. Explanatory variables: social and ecological factors

2.4.1. Social factors

We organized social factors into two categories measuring householder cognitions and demographics. We used responses from PASS to capture landscape preferences, ecological worldviews, and attitudes toward the desert (Table 1). Landscape preference was determined by asking the respondent which of a series of various typologies they would prefer as their front and back yard landscape. Following from previous research (Larsen and Harlan, 2006; Larson et al., 2009), we coded preferences for yard landscapes that were “a yard with grass, some shrubs, and leafy trees” and “a yard with some grass and some crushed stone with plants, shrubs, and trees” as mesic and oasis preferences. Xeric preferences were coded from the respondent selecting they preferred “a yard with crushed stone and native desert plants and trees”.

Ecological worldviews, also known as environmental value orientations, were measured with the 15-question New Ecological Paradigm (NEP) scale developed by Dunlap et al. (2000). The NEP scale has been widely used in previous research as a measure of broad-based beliefs about the relationship between people and the nature or the environment (Dunlap, 2008). In particular, ecological worldviews can be used to indicate the interaction between individual values and contextual, broad-based beliefs (Dunlap et al., 2000). We averaged the responses for the 15 items, with statements that related to anthropocentric values reverse coded for a final scale ranging from 1−5. Higher numbers reflected pro-ecological worldviews. Desert attitudes were measured by asking respondents the extent to which they agreed or disagreed (on a 5-point scale) with the following statements: the desert is an empty wasteland, the desert is a very special place to me, the desert should be developed, the desert is beautiful, the desert is a nice place to spend time. We then averaged the responses from the five statements to create

Fig. 2. Representative residential landscaping typologies (mesic versus xeric) of survey neighborhoods, stratified across socioeconomic (median household income) and development gradients in the Phoenix Metropolitan region.

Table 1
Descriptive statistics for dependent and explanatory variables for the Phoenix metropolitan area in 2017. Demographic and attitudinal data (social factors) were collected via responses from the Phoenix Area Social Survey (n = 496). Ecological factors were measured from satellite imagery georeferenced to each respondent's parcel.

Variables	Mean	Std. Dev.	Median	Minimum	Maximum
Satisfaction with… (5=strongly satisfied)					
Amount of Trees	3.4	1.3	4.0	1.0	5.0
Desert Plants	3.8	1.1	4.0	1.0	5.0
Trees that Shade	3.2	1.3	3.0	1.0	5.0
Management Intensity					
Irrigation Frequency (6=daily)	4.6	1.5	5.0	1.0	6.0
Fertilizer Use (1=at least once a year)	0.4	0.5	0.0	0.0	1.0
Vegetation Planting (1=plant vegetation)	0.5	0.5	1.0	0.0	1.0
Attitudes (Social Factors)					
Yard preference (0=oasis/mesic, 1=xeric)	0.4	0.5	0.0	0.0	1.0
Ecological worldview (5=very ecocentric)	3.7	0.7	3.7	1.5	5.0
Attitudes toward the desert (5=very positive)	4.0	0.8	4.2	1.0	5.0
Demographics (Social Factors)					
Respondent Age	51.0	51.0	18.0	18.0	96.0
Household income (5=$80,000−100,000)	5.3	3.2	4.0	1.0	11.0
Length of Residency (% of life in Phoenix)	0.5	0.3	0.5	0.0	1.0
Home ownership (0=rent, 1=own home)	0.7	0.4	1.0	0.0	1.0
Ecological Factors					
Yard landscape (0=oasis/mesic, 1=xeric)	0.3	0.5	0.0	0.0	1.0
Tree Cover	0.1	0.1	0.1	0.0	0.5
NDVI	0.2	0.1	0.2	0.0	0.5
Distance to desert open space (km)	2.6	2.2	1.6	0.0	8.7
Distance to urban park/ green space (km)	1.0	0.7	0.8	0.0	4.2

a single scale. The desert attitudes scale was expanded from earlier work (see Andrade et al., 2019 for details).

Demographics were collected from respondents reporting their birth year, income, length of residency in Phoenix, and if they owned or rented their current home (Table 1). We calculated the respondent's age by subtracting the year the respondent was born from 2017 (the year of the survey). Length of residency was calculated as a proportion of the respondent's life they lived in Phoenix. Income was coded as household income on an 11-point scale ranging from $20,000 and under (1) to more than $200,000 (11), increasing in $20,000 increments. Respondents were asked if they owned or rented their current home, which we coded as: own (1) and rent (0).

2.4.2. Ecological factors

We collected explanatory variables from both the PASS and remotely sensed imagery of the Phoenix metropolitan area to measure the ecological factors associated with satisfaction (Table 1). We defined these variables as *ecological factors*, to reflect to our focus on the natural (versus built) environment of neighborhoods. Ecological factors included xeric landscaping, tree cover percent, Normalized Difference Vegetation Index (NDVI), distance from the respondent's yard to desert open space, and distance from the respondent's yard to green space (including mesic parks, golf courses, and other heavily managed open space with cultivated vegetation). Xeric landscaping was the only ecological variable measured from the household survey. The rest of the variables were derived from the classification of satellite data from an online data repository associated with the study area. Detailed information on processing and classification methods are available with the associated data packages for the satellite imagery (Li, 2015a; Stuhlmacher and Watkins, 2019; Li, 2015b). Due to the resolution of satellite imagery available, our study was limited and could not distinguish between differently structured trees (e.g., their varying capacity to provide shade) or plant community composition in neighborhoods.

We calculated xeric yard landscaping from a question asking about front and back yard landscaping. A respondent was determined as having xeric landscaping when they indicated that they had "a yard with crushed stone and native desert plants and trees" or a combination of "a yard with crushed stone and native desert plants and trees" and "a yard with some grass and some crushed stone with plants, shrubs, and trees" between their front and back yard. We coded the yard landscaping variable as xeric (1) or mesic and oasis (0).

Survey respondents were geolocated based on their mailing addresses to match survey responses (n = 496) to ecological factors derived from satellite imagery. To match survey and satellite imagery we used the R packages 'rgdal' and 'rgeos' (Bivand et al., 2018; Bivand and Rundel, 2018). We used a 50 m buffer around the respondent's parcel using the gBuffer function in the R package 'rgeos' (Bivand and Rundel, 2018), then selected the pixels that fell within the buffer for variable extraction. We selected a 50 m buffer to encompass both the respondent's yard, as well as neighboring yards, for a comparable spatial scale as the survey questions that measured satisfaction with the neighborhood environment.

We used a land use and land cover (LULC) classification to calculate percent tree cover surrounding a respondent's parcel (Li, 2015a). The LULC classification was derived from satellite imagery provided by National Agricultural Imagery Program (NAIP). The LULC classification was established using a hierarchical image object network and land cover type, which was based on four-band aerial photography at a 1 m resolution. The resulting classification had an accuracy 91.86% and included 13 categories: building, road, soil, tree, grass, shrub, active cropland, inactive cropland, orchard, lake, canal, swimming pool, and seasonal river. Tree cover was calculated as the percent of pixels classified as "tree" land cover within a 50 m buffer of each respondent's parcel. We used the extract function in the R package 'raster' to calculate tree cover percent for each 50 m buffer (Hijmans, 2018).

The Normalized Difference Vegetation Index (NDVI) measures greenness and can encompass vegetation such as trees, grass, shrubs, and herbaceous group cover. NDVI was computed from the following equation of near-infrared (NIR) and red (RED) bands, (NIR-RED)/(NIR + RED), using NAIP satellite imagery at 1 m resolution during June (Stuhlmacher and Watkins, 2019). We then calculated NDVI for each respondent as the median value of the pixels within 50 m of the parcel. NDVI values were generally low (ranging from 0.00−0.49) but were confirmed using other studies in the same neighborhoods (e.g., Jenerette et al., 2011). We used the extract function in the R package 'raster' to calculate the median NDVI value for each 50 m buffer (Hijmans, 2018).

The two distance factors, distance to desert open space and distance to green space, were calculated using a land use land cover (LULC) classification derived from Landsat TM5 (Li, 2015b). We used Landsat imagery for these variables because it better captured the broad LULC types of green and desert open space than the fine resolution NAIP data. The original Landsat TM5 imagery had a 30 m resolution. The final classified image had a spatial resolution of 15 m. We used the classification scheme that had an accuracy of 95.83%, featuring 12 LULC categories. LULC included: unclassified, water, riparian vegetation, active crop, cultivated grass, high density mountain vegetation, mid density

mountain vegetation, low density mountain vegetation, undisturbed, soil, asphalt, inactive crop, and canal. We coded desert land cover as pixels classified as high density mountain vegetation, mid density mountain vegetation, low density mountain vegetation, or undisturbed. We coded green space land cover as pixels classified as cultivated grass. We calculated the distance to desert open space variable as the distance (m), from the parcel to the closest desert land cover. Similarly, we calculated distance to green space as the distance (m) to the closest cultivated grass land cover. We calculated distance metrics using the gDistance function in R package 'rgeos' (Bivand and Rundel, 2018).

2.5. Statistical analysis

To answer our first research question on the different neighborhood typologies, we first tested how satisfaction and yard management intensity varied across the 12 PASS neighborhoods. To do so, we first specified the following latent constructs: (1) satisfaction with desert plants, (2) satisfaction with trees (the amount of trees and trees that shade), and (3) management intensity (irrigation frequency, fertilizer use, and the addition or removal of trees and desert vegetation). We averaged the variables to create a single scale for each construct. Using a multivariate analysis of variance (MANOVA), we then tested how satisfaction and management varied across PASS neighborhoods grouped by income (high income: $140,000, middle income: $80,000, and low-income: $40,000) and location in the urban matrix (urban fringe, suburban, and urban core).

We used structural equation modeling (SEM) using the 'lavaan' package in program R (Rosseel, 2012) to answer our second and third research questions regarding the relationship between ecological and social factors with satisfaction and management intensity (Fig. 3). We used an SEM to test the association between our explanatory variables (social and ecological factors) and latent constructs (satisfaction with desert plants, satisfaction with trees, and management intensity), while considering the effect of landscaping preferences (Grace, 2006). We used a multiple-group analysis to split our survey respondents into two groups: (1) respondents who preferred xeric residential landscapes (xeric preferences), n = 201, and (2) respondents who did not prefer xeric landscapes (mesic/oasis preferences), n = 295. We specified preference groups to test whether the respondent's landscape preferences influenced the relationships between explanatory variables (social and ecological factors) and the latent constructs (satisfaction with desert plants, satisfaction with trees, and management intensity).

To answer our second research question on the relationship between social and ecological factors on satisfaction with trees and desert plants, we specified regression paths to test the relationship between demographics (resident age, home ownership, Phoenix residency, and income), attitudes (desert attitudes and ecological worldviews), and ecological factors (xeric parcel, tree cover, NDVI, distance to desert, and distance to green space) on the two latent constructs of satisfaction: satisfaction with desert plants and satisfaction with trees.

Finally we calculated the covariance between satisfaction with desert plants, satisfaction with trees, and management intensity to answer our third research question. We used covariance to specify our prediction that satisfaction would be related to—but not necessarily a driver of—management intensity, and that management intensity may also affect satisfaction over time. We considered demographic variables that have been established in the literature as drivers of management decisions (e.g., resident age, home ownership, Phoenix residency, and income) through a regression path.

We used the χ^2-statistic to test overall goodness of fit to determine if our model was valid (Hooper et al., 2008; Table 2). We also evaluated our model using the Comparative Fit Index (CFI), Tucker-Lewis Index (TLI), root mean square error of approximation (RMSEA), and root mean square residual (SRMR). We evaluated our use of the xeric preference group by testing for metric invariance (weak), scalar invariance (strong), and equal regression coefficients across the two groups. If measurement invariance cannot be confirmed, then latent constructs cannot be assumed to have the same meaning across groups, which results from survey questions that are biased against a particular subgroup (Meade and Lautenschlager, 2004).

3. Results

On average, residents were moderately satisfied with trees and desert plants in their neighborhood (Table 1). People were most satisfied with the desert plants in their neighborhood (3.8 ± 1.1), followed by the amount of trees (3.4 ± 1.3) and trees that shade (3.2 ± 1.3). We found that respondents who were satisfied with trees and desert plants in their neighborhood also intensively managed their landscapes (F=12.48, P < 0.0001; Fig. 4). People in high-income neighborhoods at the urban-

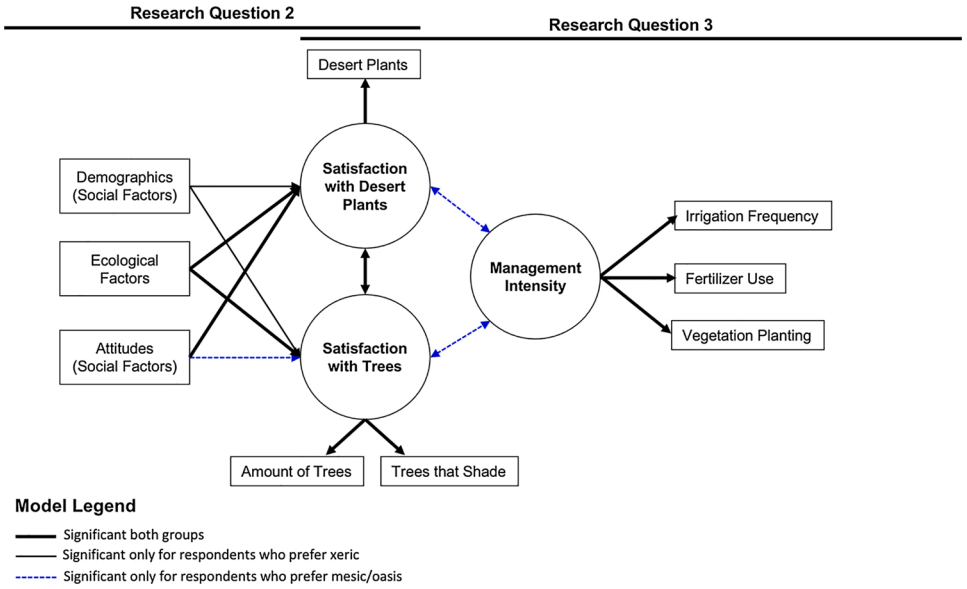

Fig. 3. Conceptual and empirical model specifying the relationship between social factors (demographics and attitudes) and ecological factors, satisfaction with trees and satisfaction with desert plants (Research Question 2). Research Question 3 tests the relationship between satisfaction and yard management intensity.

desert fringe were particularly satisfied with desert plants, but also more intensively managed their yards (Fig. 4). Lower-income respondents at the city-core had the lowest satisfaction overall, as well as lower satisfaction with desert-plants compared to satisfaction with trees (Fig. 4). Satisfaction with trees and desert plants were not significantly different in suburban, middle-income neighborhoods, which served as a midpoint of satisfaction and management intensity across the PASS neighborhoods (Fig. 4).

3.1. Drivers of satisfaction with trees and desert vegetation

The final SEM did not significantly deviate from the data (Table 2) and was therefore an acceptable representation of the data. Additionally, we established that there was measurement invariance between the two preference groups using weak metric invariance ($\chi^2_\Delta = 0.49$, $P = 0.92$), strong scalar invariance ($\chi^2_\Delta = 2.02$, $P = 0.57$), as well as equal regression coefficients ($\chi^2_\Delta = 31.43$, $P = 0.09$). Measurement invariance confirmed that differences between groups met statistical assumptions for the SEM and we could proceed with comparing differences predicted by people who had xeric landscaping preferences. We found that social and ecological factors associated with satisfaction varied between people with preferences for xeric landscaping and people with preferences for mesic landscaping (Fig. 5). Xeric preferences also shifted the relationship between satisfaction and management intensity.

3.1.1. Xeric preference model

Social and ecological factors explained satisfaction with desert plants and satisfaction with trees in the respondent's neighborhood for people who preferred xeric landscaping (Fig. 5a). Length of residency, income, xeric yards, and attitudes toward the desert explained 36% of the variation for satisfaction with desert plants. Length of residency in Phoenix for people who preferred xeric landscaping was negatively related to satisfaction with desert plants ($\beta = -0.22$, $P = 0.008$), whereas income was positively related to satisfaction with desert plants ($\beta = 0.21$, $P = 0.009$; Table 3). Xeric yards were also related, although weakly, to satisfaction with desert plants ($\beta = 0.15$, $P = 0.07$). The only link between attitudes and satisfaction for respondents with xeric preferences was between attitudes toward the desert and satisfaction with desert plants ($\beta = 0.28$, $P = 0.002$; Table 3).

Income, xeric yards, and the greenness (NDVI) explained 25% of the variation in people's satisfaction with trees (measured from satisfaction with tree amount and shade) for people who had xeric preferences (Fig. 5a). Satisfaction with trees was positively influenced by income ($\beta = 0.25$, $P = 0.009$) and the prevalence of xeric yards in the respondent's neighborhood ($\beta = 0.21$, $P = 0.03$; Table 3). NDVI (neighborhood greenness) was also important for satisfaction with trees in the neighborhood for people who preferred xeric landscapes ($\beta = 0.24$, $P = 0.006$; Table 3).

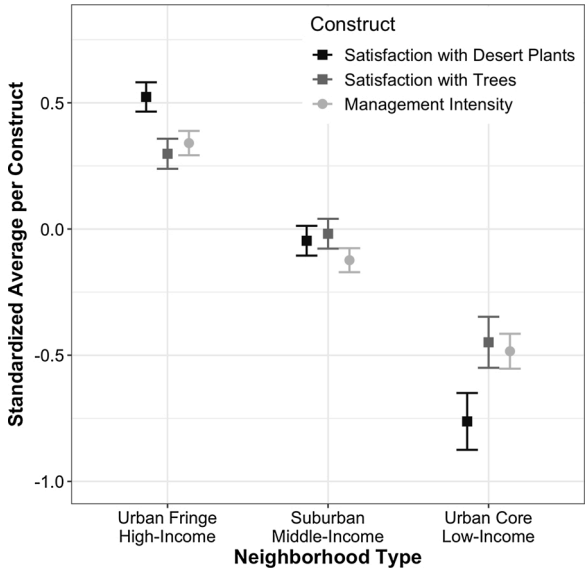

Fig. 4. Relationship between neighborhood types based on income and location with satisfaction and management intensity in the Phoenix Arizona Social Survey (n = 496 respondents in 12 neighborhoods). Values are standardized Z-scores to account for the variation in scales between satisfaction and management intensity.

Table 2
Goodness-of-fit test results. All model performance results were within suggested thresholds, indicating that the proposed model explaining the relationship between social and ecological factors, satisfaction with trees, satisfaction with desert plants, and yard management intensity was a valid fit for the data.

Fit Index	Chi-square	CFI	TLI	RMSEA	SRMR
Suggested Value	$P > 0.05$	> 0.9	> 0.9	< 0.05	< 0.05
Model Results	$P = 0.11$	0.97	0.95	0.03	0.04

3.1.2. Mesic and oasis preferences model

Attitudes, as opposed to demographics, emerged as an important social driver of satisfaction for people who preferred mesic or oasis landscaping (Fig. 5b). Xeric yards, attitudes toward the desert, and distance to desert open space explained 29% of the variation in satisfaction with desert plants for people with mesic or oasis preferences. Xeric landscaping ($\beta = 0.11$, $P = 0.06$), distance to desert open space ($\beta = -0.26$, $P = 0.0001$), and positive attitudes toward the desert ($\beta = 0.33$, $P = 0.0001$) were all positively related to satisfaction with desert plants (Table 3).

Tree cover, attitudes toward the desert, ecological orientations, distance to desert, and distance to open space explained 26% of the variation in satisfaction with trees for those with mesic or oasis preferences (Fig. 5b). The percent of tree cover in the respondent's neighborhood was positively related to the respondent's satisfaction with trees ($\beta = 0.25$, $P = 0.004$). Distance to green space ($\beta = -0.17$, $P = 0.06$) and desert open space ($\beta = -0.18$, $P = 0.03$) were both related to satisfaction with trees for people who preferred mesic or oasis landscaping (Table 3). People who held positive attitudes toward the desert were more likely to be satisfied with tree amount and shade ($\beta = 0.26$, $P = 0.002$), whereas pro-environmental orientations were negatively related to satisfaction with the trees in their neighborhood ($\beta = -0.17$, $P = 0.04$; Table 3).

3.2. The relationship between satisfaction and management

The relationship between management intensity and satisfaction with trees and desert plants was influenced by landscape preference (Fig. 5). For people who preferred xeric landscapes, there was no relationship between satisfaction and management intensity (Table 4). Instead, management intensity for irrigation, chemical use, and plantings were primarily related to the demographics of people who preferred xeric landscapes (Table 4). Significant factors included, income ($\beta = 0.43$, $P = 0.003$), home ownership ($\beta = 0.24$, $P = 0.05$), and age of the respondent ($\beta = 0.42$, $P = 0.001$). However, for people who preferred mesic or oasis landscapes, management intensity was positively related to satisfaction with trees ($cov(X,Y) = 0.30$, $P = 0.02$) and satisfaction with desert plants ($cov(X,Y) = 0.27$, $P = 0.01$). Management intensity for mesic preferences was also related to the following demographics: income ($\beta = 0.36$, $P = 0.001$), home ownership ($\beta = 0.20$, $P = 0.09$), and length of residency in Phoenix ($\beta = -0.22$, $P = 0.02$).

4. Discussion

Our study tested how social and ecological factors interact to influence people's satisfaction with trees and desert plants in their yards and

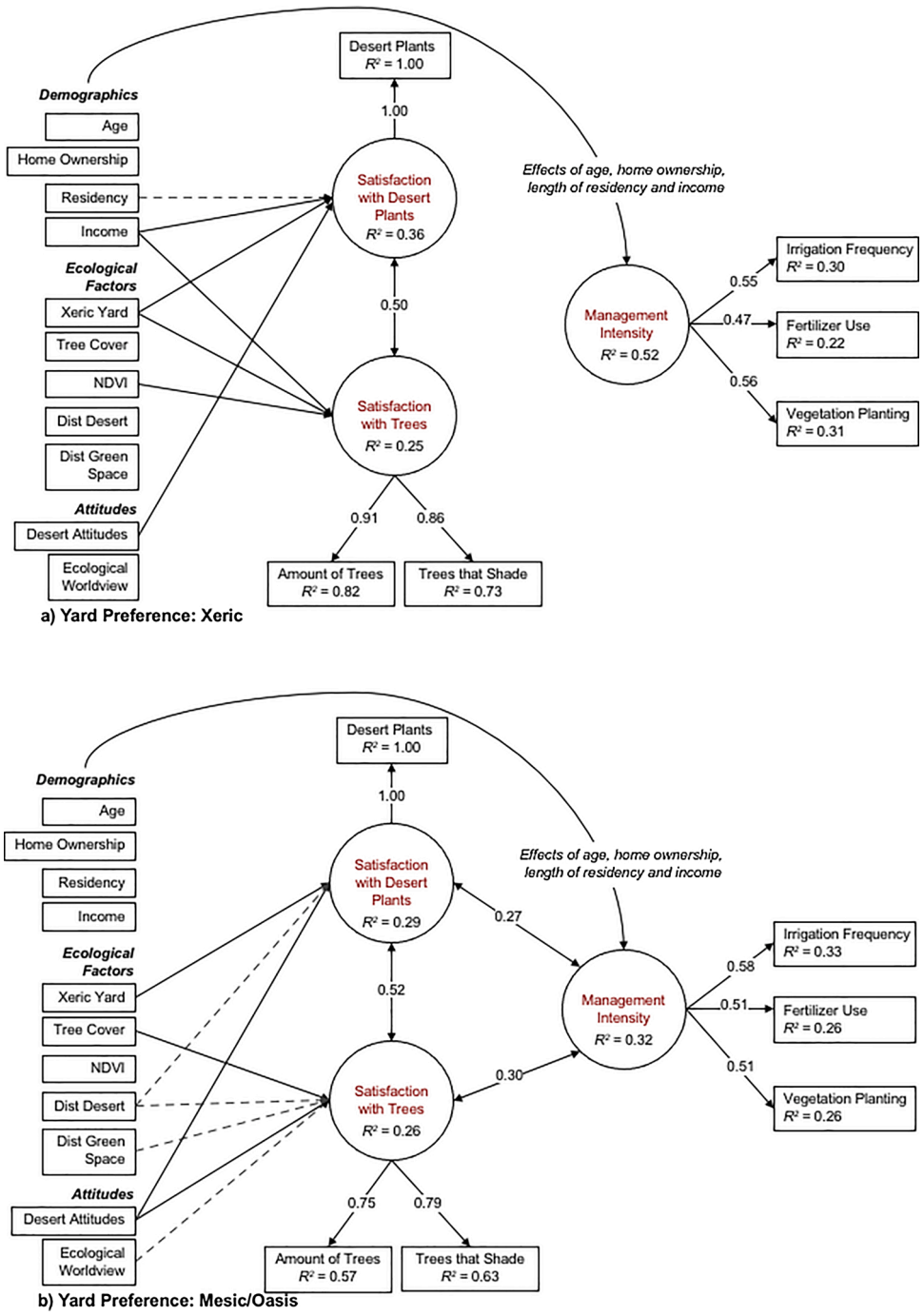

Fig. 5. Final structural equation model (SEM) explaining satisfaction with trees and satisfaction with desert plants in the neighborhood, as well as management intensity for people living in the Phoenix metropolitan area. Dashed arrows indicate a negative relationship. Standardized coefficients are reported. (a) Respondents who prefer xeric landscaping. (b) Respondents who prefer mesic landscaping.

neighborhoods. Ecological factors in neighborhoods that reflect the regional desert environment were positively related to satisfaction, even for people with mesic preferences. People in neighborhoods with xeric landscaping at the fringe of the city—closer to desert parks and preserves—as well as people in high income neighborhoods were largely satisfied with the trees and desert plants in their residential landscapes. However, people in these neighborhoods were also more likely to adopt intensive management practices compared with those in low-income neighborhoods in the city core. We also found that householder attitudes and demographics had varying degrees of influence on satisfaction depending on landscape preferences. The effect of preferences highlights how people have different experiences in neighborhoods with similar environmental conditions based on their expectations (Wilkie and Stavridou, 2013).

4.1. Landscape typologies in an arid city: mesic versus xeric

People had varying satisfaction with trees and desert plants in their neighborhood based on their landscape preferences. In particular, people with pro-ecological orientations appeared dissatisfied with the lack of trees in their neighborhood when they also preferred mesic landscapes. Similar to findings in Ostoić et al. (2017), the dissatisfaction of

Table 3
Standardized path coefficients of the relationship between social and ecological factors with latent constructs measuring satisfaction with… (1) desert plants, and (2) trees (tree amount and trees that shade). Respondent's landscaping preferences influenced the relationship between demographics and attitudinal variables with satisfaction. Starred estimates are significant at the $P < 0.05$** level and bolded values below $P < 0.1$.

Satisfaction with:	Desert Plants		Urban Trees	
	Landscape Preference			
Variables	Prefer Xeric	Prefer Mesic	Prefer Xeric	Prefer Mesic
Length of Residency	**−0.22****	0.01	−0.06	0.14
Household income	**0.21****	0.06	**0.25****	0.10
Tree Cover	−0.09	0.05	0.03	**0.25****
NDVI	0.10	−0.03	**0.24****	−0.06
Xeric Yard	**0.15***	**0.11**	**0.21****	−0.01
Distance to desert	−0.15	**−0.26****	−0.04	**−0.18**
Distance to green space	−0.05	0.02	−0.07	**−0.17****
Desert attitudes	**0.28****	**0.33****	0.05	**0.26****
Ecological worldview	−0.07	−0.02	−0.07	**−0.17****

[a] Householder age and home ownership were dropped in the final model as predictors of satisfaction with desert plants or urban trees.

Table 4
We tested the covariance between satisfaction with trees, satisfaction with desert plants, and management intensity. We included age of householder, home ownership, length of residency, and income as regression paths to consider the effects of demographics on management intensity. The respondent's preference for xeric versus mesic landscaping influenced the relationship of management intensity with satisfaction and demographics. Bolded estimates are significant at the $P < 0.05$.

Relationship with Management Intensity		Group Variable: *Landscape Preference*	
		Prefer Xeric	Prefer Mesic
Satisfaction with Trees	⇆Management Intensity	*cov(X,Y)* = 0.08 *P* = 0.590	***cov(X,Y)* = 0.30** ***P* = 0.016**
Satisfaction with Desert Plants	⇆Management Intensity	*cov(X,Y)*= -0.04 *P* = 0.771	***cov(X,Y)* = 0.27** ***P* = 0.014**
Age	→Management Intensity	***β*= 0.42, *P*= 0.001**	*β*= 0.06, *P*= 0.466
Home Ownership	→Management Intensity	***β*= 0.24, *P*= 0.045**	*β*= 0.20, *P*= 0.091
Residency	→Management Intensity	*β*= -0.09, *P*= 0.390	***β*= -0.22, *P*= 0.023**
Income	→Management Intensity	***β*= 0.43, *P*= 0.003**	***β*= 0.36, *P*= 0.001**

these pro-ecological respondents who preferred mesic landscaping was likely driven by the fact that vegetation fell short of their expectations of a "green" city, reflecting their desire for more trees and shade in their neighborhood. Literature has shown that the longer someone lives in the Phoenix region, the more likely they prefer and have grassy, mesic landscaping (Larson et al., 2017). However, we found that for respondents who lived in Phoenix longer—and who also preferred xeric landscapes—the legacy of the Phoenix Oasis appears to have decreased satisfaction, probably because people with xeric preferences wanted more desert landscaping. Both the positive relationship between pro-ecological worldviews and satisfaction for people with mesic preferences and inverse relationship between length of residency and satisfaction for people with xeric preferences reflects the importance of context when considering the effects of trees and vegetation in the neighborhood environment.

Different expectations were also highlighted in the relationship between ecological factors and satisfaction. We found that satisfaction for people who preferred mesic landscapes was related to tree canopy cover, whereas satisfaction for people who prefer xeric landscapes was associated with the greenness of overall vegetation present (NDVI). The effects of preferences on the relationship between ecological factors and satisfaction supported our initial prediction that people perceive and value the same environment in different and complex ways (Kendal et al., 2012). In summary, people with different landscape preferences have varying notions with regards to the ideal look and function of trees and other vegetation in a desert city.

4.2. Social-ecological dynamics in a Desert City

Another important finding in our study was the significance of desert open space. Distance to desert open space influenced satisfaction with the neighborhood environment, even for people with mesic preferences. People with mesic preferences may desire green landscaping in their yards and neighborhoods. However, living closer to desert open space was still associated with higher levels of satisfaction for both desert plants and trees for people with mesic preferences. The consistently positive effect of desert open space and xeric landscaping is interesting because it shows that desert typologies do not necessarily lead to lower satisfaction for people who have mesic preferences. Instead people with mesic preferences may respond positively to an increase in desert trees in their neighborhoods as landscaping trends shift away from the current grassy, non-native typologies to xeric alternatives.

The capacity for people with higher socioeconomic status to realize their landscape preferences has been linked to biodiversity patterns in affluent neighborhoods (Lubbe et al., 2010), as well as people's satisfaction with their neighborhood environment (Vemuri et al., 2011). Likewise, we found that income was positively related to satisfaction with the trees and desert plants for people with xeric preferences. Xeric landscaping in Phoenix, for the most part, is associated with newer development at the city fringe in higher income neighborhoods (Harlan et al., 2007). People in these newer, desert-fringe neighborhoods also tend to prefer xeric landscaping (Wheeler et al., 2020). It follows that people in more affluent neighborhoods closer to the desert would be more satisfied with their neighborhood environment based on their ability to actualize their landscaping preferences.

Another factor that could influence satisfaction with vegetation in high-income, xeric neighborhoods is the biophysical features of the neighborhood environment. In particular,

xeric landscaping in Phoenix tends to be greener and more diverse than the outlying desert, especially in high-income areas (Larsen and Harlan, 2006). Income in Phoenix is positively associated with overall plant biodiversity (Hope et al., 2003), reflecting global patterns of inequities in urban tree cover and open space (Gerrish and Watkins, 2018; Hoover and Lim, 2020). Additionally, local land managers in high-income areas often have more resources to plant and maintain trees, which often concentrates resources to the wealthy, already vegetated areas of a city (Locke and Grove, 2016). As a result, tree cover and the associated ecosystem services—such as heat mitigation—are coupled along socioeconomic gradients (Jenerette et al., 2011; Kirkpatrick et al., 2012). Tree cover patterns and inequities are especially pronounced in arid cities compared to temperate regions (Nowak et al., 2011), which is largely due to the fact that most trees in desert cities are planted by people (Nowak, 2012).

4.3. Implications for yard management: maintaining a green aesthetic

The consequences of people preferring lush, green landscapes in an arid city include intense resource inputs that are required to maintain these thirsty landscapes (Larson et al., 2009). People often dissociate their yards from broader perceptions of nature, and instead prioritize aesthetics, comfort, and leisure (Head and Muir, 2005). People with mesic preferences have expressed similar motivations for comfortable

and leisurely landscapes (Larson et al., 2009), and their satisfaction is achieved through the increased resources required to maintain these lush, green landscapes (e.g. Groffman et al., 2016). The positive relationship between satisfaction and management intensity for mesic preferences is likely due to the resource requirements needed to maintain mesic landscaping in an otherwise desert environment.

Numerous studies link demographics and landscaping choices to yard management intensity (Templeton et al., 1999; Robbins et al., 2001; Larsen and Harlan, 2006; Larson et al., 2010). Xeric landscapes *should* require less management than mesic landscapes in arid cities like Phoenix. However, we found that householders in neighborhoods at the urban-desert fringe with xeric landscaping often engaged in intensive yard management practices (Fig. 4). They were also the most satisfied with trees and desert plants. Satisfaction is positively related to place attachment, and people who are more attached to the natural environment often feel a degree of responsibility to care for it (Gobster, 2015).

The desire for people to care for their environment may lead to more intensive yard practices and resource inputs (Templeton et al., 1999; Robbins and Birkenholtz, 2003), despite the actual physiological needs of the trees and vegetation present (Balling and Gober, 2007). This could partially explain why xeric yards, which are often viewed as an "environmentally friendly" landscaping option in terms of resource inputs (Kaplan et al., 2014), can still be over-watered and over-managed at the scale of individual households (Martin, 2001). Similar to our study, Balling and Gober (2007) and Martin (2001) observed a decoupling of actual water use with climatic demand, suggestive of over-watering. In particular, Martin (2001) found that water use was higher by approximately 10 % on xeric landscapes than mesic or oasis landscapes in the months of December and January, with high variability in water use among individual households. Overall, these findings challenge the premise that encouraging native and regionally adapted landscaping will reduce chemical and water use without reciprocal changes in attitudes or behavior (Clark et al., 1997; Owens, 2000).

4.4. Future research directions

Our study connects multi-scalar dynamics in residential landscapes by considering how the neighborhood environment interacts with management decisions in yards. However, our study is limited in its focus on individual householders and the use of ecological factors that do not fully capture the structure and function of trees in residential neighborhoods. Species composition influences the benefits derived from the trees present in a neighborhood since ecosystem services vary with tree structure and age (Moser et al., 2015). Conversely, coarse measures of vegetation, such as tree cover percent, do not capture nuances in tree community assemblages. For example, Nowak et al. (2016) found that tree cover remained relatively consistent in Syracuse, New York between 1999 and 2009, but tree species shifted. In particular, buckthorn *(Rhamnus cathartica)*—an invasive tree species with smaller leaf area and stature—more than tripled in population during the same time period.

Focusing on specific types of trees could address interesting connections between multi-scalar management decisions. For example, landscaping ordinances in a Phoenix historic neighborhood prohibit residents from cutting down palm trees that line the streets to preserve the character of the community (Larson and Brumand, 2014). It is common for external forces—including developers, homeowner associations, and broader socio-cultural factors—to act as top-down constraints on yard management decisions and landscaping choices in residential landscapes (Roy Chowdhury et al., 2011; Daniel et al., 2016; Larson et al., 2020). While our study considers satisfaction and management in yards and neighborhoods, more research is needed that explicitly measures social-ecological dynamics across multiple levels. In particular, considering satisfaction across scales in combination with local plant community measurements, would better connect human well-being and management decisions to the neighborhood environment.

5. Conclusions

Our theoretical framework considers the complexity of satisfaction with trees and desert plants in residential neighborhoods, as well as the multi-scalar relationship with yard management decisions. Overall, xeric landscaping and desert preserves fortify neighborhood satisfaction, even for people who prefer mesic landscapes. Therefore, the preservation of desert open space and the conversion of yard landscaping to more drought-tolerant motifs carry benefits for people in addition to supporting ecological functioning in arid cities. We also found that there was a resource cost of maintaining satisfaction for people with mesic preferences. However, the presence of xeric landscapes alone does not automatically imply what management practices are undertaken by individual residents. In particular, our study supports other scholarly research that has found drought-tolerant landscaping does not necessarily lead to water-conserving behavior. Management programs, such as tree planting or xeriscaping initiatives, would benefit from considering the values, attitudes, and behaviors of the local community responsible for maintaining trees and other vegetation on privately held land.

CRediT authorship contribution statement

Riley Andrade: Conceptualization, Investigation, Methodology, Formal analysis, Writing - original draft. **David M. Hondula:** Conceptualization, Funding acquisition, Supervision, Writing - original draft. **Kelli L. Larson:** Conceptualization, Supervision, Writing - review & editing. **Susannah B. Lerman:** Methodology, Validation, Writing - review & editing.

Declaration of Competing Interest

The authors report no declarations of interest.

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