

Article

Attitudes toward Residential Trees and Awareness of Tree Services and Disservices in a Tropical City

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Abstract: Attitudes toward urban residential trees and awareness of their ecosystem services and disservices may play an important role in management decisions of private residential green spaces with important consequences to urban sustainability. In 2011, 397 household surveys were conducted in six locations of the Río Piedras Watershed (San Juan, Puerto Rico) to evaluate residents' attitudes toward residential and neighborhood trees and their association with household socio-demographic factors, how awareness of services and disservices relate to the spatial proximity of trees (home versus neighborhood), and whether attitudes are associated with yard management (tree abundance). Most residents self-reported positive attitudes toward trees in general and these appeared to be more frequent than self-reported negative attitudes. Respondents recognized more tree services (emphasizing shade, lower temperature, food, and ornamental/aesthetics) and fewer disservices (emphasizing maintenance hardship, property damage, and power line obstruction). Not all tree services and disservices were equally recognized, and differences in the spatial context of trees and residents may contribute to the variation in residents' awareness of tree ecosystem services or disservices. Variation in positive attitudes partially explained the current variation in yard tree abundance, along with residents' age, housing tenure, yard size, and watershed location. Results have direct implications for urban forest planning and management in residential contexts.

Keywords: attitudes; awareness; green infrastructure; green spaces; urban socio-ecological systems; urban trees; yards; ULTRA

1. Introduction

1.1. Background

Green infrastructure, a key component of urban social–ecological systems, is becoming more important in urban sustainability and planning discussions [1–4]. Within cities, the term green infrastructure refers to a network of natural and constructed multifunctional green spaces that should be planned, developed, and maintained [5,6]. Elements of urban green infrastructure include many features of the city landscape, such as green roofs, parks, green corridors, isolated green patches, abandoned land, residential yards, churchyards, school grounds, and even cemeteries [7]. Urban forests, defined here as all the trees and associated vegetation present in a city [8], are a dominant

feature of green infrastructure and urban forestry management strategies are incorporated into green infrastructure planning due to the commonality of the two approaches [9]. It is generally accepted that these green networks, and trees specifically, can provide a variety of ecosystem services that directly or indirectly impact human well-being in urban socio-ecological systems [10,11]. On the other hand, green spaces may inadvertently cause perceived or realized disservices that may affect human well-being (i.e., structural damage to private or public infrastructure, sources of pollen allergens) [12] if not planned adequately. Managing for ecosystem disservices may facilitate the optimization of outcomes for well-being rather than just managing ecosystem services alone [13]. One possibility is that the interplay between perceived services and disservices of green infrastructure within urban spaces could also be influencing management decisions about these spaces and changing them over time [13–15]. If so, urban planning with sustainability as a goal must address the links between human attitudes and behaviors toward green spaces and how these factors may influence the planning, development, and management of urban green infrastructure [16–19].

Residential green infrastructure has earned visibility as an important component of urban landscapes for its potential to provide multiple ecosystem services. Green infrastructure in the form of residential yards comprises a significant portion of urban space [20,21] and can also contribute to the general provision of ecosystem services [17,22,23]. In addition, private yards can improve human health and well-being by providing physical and psychological benefits, facilitating connections with other people and with nature [16], and by providing services that go beyond their utilitarian value (e.g., emotional, physiological, spiritual) [24–27]. Private yards are managed green spaces, and as such, their condition and dynamics will be greatly influenced by both social and ecological drivers, warranting an integrated multi-scalar, social–ecological approach to develop understanding of these systems [17,28–32]. In that regard, many studies emphasize that anthropogenic factors could dominate over non-anthropogenic ones in determining the characteristics of green infrastructure elements at the residential scale [17,29,33,34]. For example, in residential areas, socio-economic and social–psychological characteristics (e.g., household income, formal education, values, attitudes) are considered bottom-up drivers of biodiversity through their influence on garden management, which complement (or dominate over) top-down drivers (e.g., landscaping policies, local regulations, city-level strategies and management decisions) [29,34,35]. Ultimately, urban yards are likely to reflect (at least in part) individuals' choices that may be motivated by social drivers displayed as a variety of psycho-cultural and socio-economic traits [17,36–38], meriting an exploration of anthropogenic and non-anthropogenic interactions as possible drivers of household decisions.

Environmental psychology theories can help conceptualize relationships between humans and the environment and how these relationships might shape human actions. For example, theories like the Ajzen's Theory of Planned Behavior and Stern and colleagues' Value–Belief–Norm Theory link cognitive factors such as values and attitudes to human behavior, which can be useful to identify specific cognitive factors that can be linked to behavioral intention [39,40]. Others, like Rokeach's Cognitive Hierarchy Theory, provide a hierarchical relationship between these concepts to help understand how values can indirectly influence behavior through attitudes [41,42]. Building from this model, Homer and Kale proposed a value–attitude–behavior hierarchy model, where they emphasize that attitudes play a mediating role between individual values and behaviors, which has since been applied to environmental issues [42,43]. Attitudes are then defined as negative or positive evaluations of a specific object (i.e., preference, liking, or disliking) [44] and can be used a measure to evaluate behavior toward objects, such as a tree [45–48]. It has been documented that people hold strong positive attitudes toward urban trees [45,49–56], which, based on the value–attitude–behavior hierarchy model, can be used to explore potential behavioral outcomes in urban spaces, such as residential yards. For example, specific attitudes of individuals toward a set of objects may influence explicit decisions [57] and flora found in residential yards may likewise be a reflection of people's preference toward certain plant characteristics, such as large flowers or green foliage [37]. Residents' attitudes toward certain tree attributes (e.g., large canopy, tree height, low maintenance), ecosystem services (e.g., shade, beauty), and even a tree genus

(e.g., *Acer*), can also be positively correlated with urban yard composition (number of trees containing the attributes) [58]. Thus, human attitudes could be an important psychological driver influencing the composition of urban residential yards.

Human attitudes are an important component of urban social–ecological systems that relates to the actual interactions of people with urban green space. Studies documenting human attitudes toward trees are more frequently used in the literature to understand the relationships between residents and urban trees [49,59–63]. Research suggests that these people–environment interactions consist of complex and dynamic exchanges that enrich and shape one’s knowledge of the environment, while shaping the environment as well [64]. These interactions may include experiencing ecosystem disservices that lead to detrimental human–nature relationships [14]. Experiencing disservices can influence negative attitudes, some examples include allergies produced by city trees [51], street trees blocking visibility [65], damaging sidewalks [52], producing debris [63], or roots of yard trees damaging house walls [56]. Studies that look at tree planting and removal motivations in residential private spaces are scarce [66,67], but some studies in western cities have also documented perceived risks to property and management hardships (e.g., processing of vegetation debris) as stated reasons behind tree removal decisions [58,66–70]. The characterization of ecosystem disservices and how they vary along with socio-economic factors is an understudied area of research when using ecosystem services approaches [14,33,71,72]. Scientists argue that studies evaluating green infrastructure within an ecosystem services framework need to incorporate ecosystem disservices, as these may very well influence human attitudes and behavior toward green infrastructure [13,61,71] and may pose challenges toward the implementation of green infrastructure policies in cities [73].

Attitudes are context dependent [74,75] and have been understudied in Latin American cities relative to cities in other regions of the world within the context of green infrastructure planning [76–79]. Moreover, studies about attitudes toward green infrastructure in Latin American cities have focused on public or common green spaces and less so on private spaces (Medellín, Colombia: [80]; San Juan, Puerto Rico: [81,82]). For this study, we present a case study that builds upon prior work on the social–ecological processes driving residential vegetation dynamics in the Río Piedras Watershed (RPWS) located in the city of San Juan, in the Caribbean island of Puerto Rico. The objectives are to evaluate: (1) how household demographics and watershed location (site) drive positive and negative attitudes toward urban trees located in two referenced green spaces (residential yards and neighborhoods); (2) whether awareness of ecosystem services and disservices differs according to spatial proximity of the tree (home versus neighborhood); and (3) whether attitudes may drive yard management outcomes (tree abundance) within the Río Piedras Watershed in the San Juan Metropolitan Area (SJMA). We hypothesize that attitudes toward trees would vary between different demographic groups (defined by residents’ age and housing tenure status) and watershed location based on prior work showing a positive relationship between these variables and tree abundance [34]. Likewise, we hypothesize that residents may recognize tree services and disservices differently when trees are located inside their yards relative to when they occur in their neighborhood (i.e., small-scale context-dependent attitudes) and that there is a relationship between attitudes and yard tree abundance. Residents reporting positive attitudes (preference, trees as beneficial) would have more trees and residents reporting negative attitudes (trees as problematic) would have fewer trees. Our results contribute to the growing work on the use of social–ecological research to support the application of ecosystem service approaches in Latin American cities and the methods can also serve as model of inquiry for other insular cities in the Caribbean region, where the nature-based solutions may be seen as a strategy for climate change adaptation.

1.2. Social Drivers of Green Infrastructure in San Juan, Puerto Rico

The SJMA is the largest urban area on the island of Puerto Rico. In the 1900s, it experienced rapid urbanization that led to the loss of forest cover [83], a loss that has been linked to socio-economic, governance, and physical–spatial disparities in some neighborhoods [84]. In the municipality of San Juan, a 42% green cover was estimated for 2002, with the highest amount located on the northern part

as isolated small patches of forest, most of which occur in private yards [85]. Within the Río Piedras Watershed (RPWS), residential yards vary in the amount of green and tree cover [86], found to be partly associated with variation in yard size, with some differences moderately explained by housing tenure, age, and geographic location [34]. Considering these factors have not been able to explain all the variation in yard vegetation cover, one hypothesis is that these associations are also partly driven by differential attitudes toward residential vegetation and their services across social groups and sites within the watershed [31,85]. At least two studies conducted in the San Juan Metropolitan Area (SJMA) of Puerto Rico have shown that while urban dwellers are able to identify many of the ecosystem services provided by urban green infrastructure, green spaces may also generate disservices [81,82]. The combined results of these studies also indicate that perceptions of services and disservices may differ across short geographic ranges within a tropical city like San Juan [81] and shape the preferences of users for particular green infrastructure designs [82]. For example, visual aesthetics (or scenic value) was the ecosystem service most frequently mentioned by visitors of Plaza de la Convalecencia, a small town square in San Juan [82], but it was only the eighth most commonly recognized service for residents of the Río Piedras Watershed (RPWS) when asked about urban forests patches [81]. Thus, it is possible that values and perceptions of urban vegetation are influenced by the degree of interaction between residents and green spaces, or their sense of ownership of these spaces [87–90].

In San Juan, the protection of trees is being recognized by state and city local institutions in various ways. The Puerto Rico Forest Action Plan of 2016 includes an urban forest section, which describes the benefits of urban forests for well-being and define urban forests as priority landscapes, although it does not define specific guidelines to these effects [91]. A goal of the plan is to enhance the public benefits associated with trees and forests and some of the priorities outlined in the plan include the need for information related to ecosystem services and other related services of public and private lands. Article 9 of the Puerto Rico Forest Act (Law No. 133 of 1975) prohibits cutting and damaging public or private property trees that have characteristics indispensable or necessary for forestry use, that are at risk of extinction, located in plazas and parks, or that are indispensable for some purpose of essential use (not explicitly defined). A permit is required by the Puerto Rico Department of Natural and Environmental Resources (DNER) for cutting or grooming said trees (Puerto Rico Planning Board Regulation No. 25). The Municipality of San Juan does not have a specific urban forestry or management plan in place but there are several independent tree giveaway campaigns driven by local public and private entities. A collaboration from the Municipality's Office of Planning and Territorial Management, the Puerto Rico Department of Natural and Environmental Resources (DNER), and the San Juan ULTRA (Urban Long-term Research Areas) Network led to public seminars on the importance of green spaces in flooding risk management in the Río Piedras river. This collaboration was followed by municipal resolution OPOT-2015-1, which called for the creation of The Río Piedras Alliance (*Alianza del Río Piedras*) as a unifying network for stakeholders of the Río Piedras Watershed and the development of a green infrastructure plan for the Municipality of San Juan in coordination with corresponding offices and agencies, although the plan is pending preparation. The San Juan Bay Estuary Program (SJBE; <http://web.estuario.org>), which is the only tropical estuary in the U.S. National Estuary Program, a non-regulatory program of the U.S. Environmental Protection Agency, is also developing a green infrastructure plan for the SJBE basin. Residential areas comprise a considerable proportion of the landscape in the San Juan Metropolitan Area [92]. Therefore, yard spaces could contribute to the overall green infrastructure of the city. Beyond what exists at the state level, there are no specific laws that regulate tree management in private households, but a few gated communities do regulate their planting practices.

2. Materials and Methods

2.1. Study Site

We conducted this research in the Río Piedras Watershed (RPWS) located in the San Juan Metropolitan Area, the largest urban area on the island of Puerto Rico (Figure 1). This urban watershed

covers an area of 67,000 m² and the Río Piedras river has been extensively modified due to anthropogenic activities [83]. Based on Holdridge's life zone system it is classified as a subtropical moist forest zone [93] and presents a mean annual precipitation that ranges from 1509 mm to 1755 mm and a mean annual temperature of 25.7 °C, with a rainfall season that coincides with the hurricane season from June to December and a dry season from January to April [83]. The RPWS is part of the San Juan Bay Estuary for which residential land use has been estimated at 36% as the dominating land use [61]. The RPWS and the island suffered the impact of two intense hurricane events during the 2017 season, with considerable impacts to grey and green infrastructure [94,95]. An assessment of tree cover losses for the San Juan Municipality has been estimated to be as high as 24.8% of the total tree cover [96].

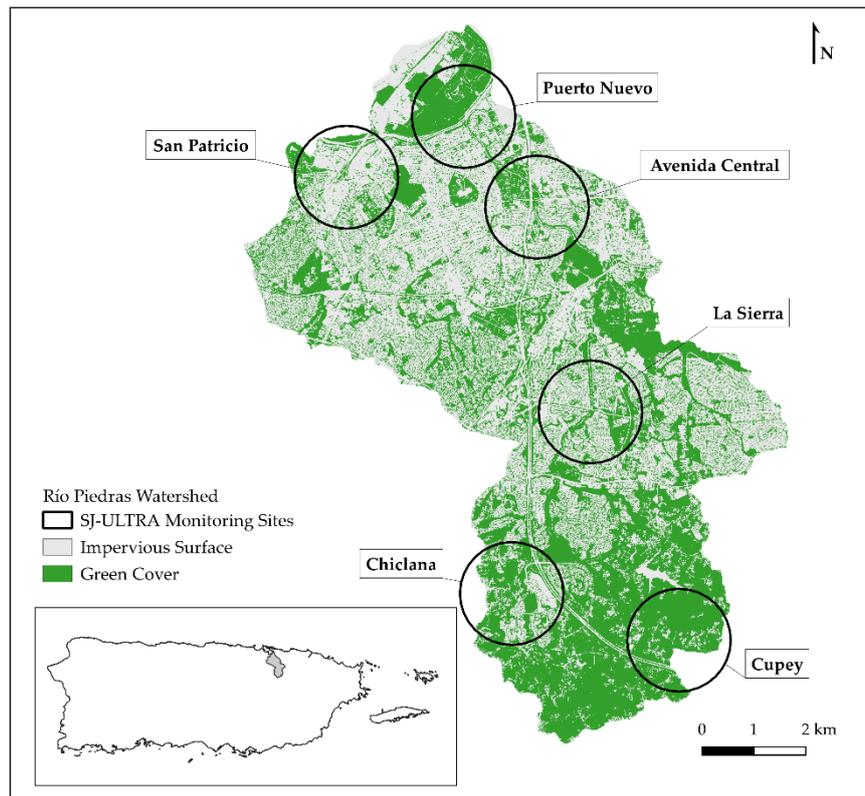


Figure 1. Location of the Río Piedras Watershed with its six monitoring sites and green area cover. Source: Martinuzzi et al., 2018 [97].

2.2. Sampling Design

We collected data through household and yard surveys via a convenient-based recruitment at six permanent monitoring locations within the Río Piedras Watershed (RPWS) based on the San Juan Urban Long-Term Research Area (ULTRA) Collaborative Network stratified sampling scheme [31,34,86,98]. The six sites have been studied to address a variety of social–ecological questions at residential scales since 2011 [26,30,31,82,86,98,99] and lie across a rural–urban and elevation gradient of grey coverage (Table 1). At each site a circular buffer zone of 1 km radius was overlaid on aerial photos of San Juan and a street vector file of access roads using ArcGIS v. 9.3 software [100]. Roads were selected by generating a random sample in Microsoft Excel with road codes, and surveys were administered depending on willingness to participate and availability of residents by visiting each household on a selected road. The survey was carried on different days of the week during daylight hours, the majority during weekends from 9:15 am to 14:30 pm. Surveys were conducted face-to-face by Spanish speaking students and faculty from the University of Puerto Rico Río Piedras Campus. Surveyors received training on how to conduct surveys and obtained certificates upon successful completion of the National Institute of Health web-based training course “Protecting Human Research Participants”.

All research protocols with human subjects were designed and implemented in accordance with University of Puerto Rico Institutional Review Board (IRB) requirements (IRB #1011-013). A consent form was provided to all participants explaining the voluntary nature of the survey, a privacy and confidentiality clause, and contact information for principal investigators and the respective IRB office. The minimum sampling size was six households per street and a maximum number of 80 households were sampled per buffer zone.

Table 1. Site descriptions and number of single-family residential units for each site included in the study (N = 397).

Site	N	Urban Cover	Housing Density	Watershed Location	Elevation (m.a.s.l.)
San Patricio	43	high	high	low	7
Puerto Nuevo	63	high	high	low	0
Avenida Central	78	high	high	mid	3
La Sierra	72	intermediate	intermediate	mid	20
Chiclana	64	low	low	upper	59
Cupey	77	low	low	upper	157

2.3. Social and Vegetation Surveys

We conducted field surveys from January 2011 to July 2011, with an additional survey in October 2011. The survey consisted of a combination of open-ended and multiple-choice questions about perceptions and behavior toward green areas, as well as socio-demographic characteristics. We pre-tested the questionnaire to ensure an appropriate question format, wording, and order. To assess attitudes, residents were asked if they preferred to have trees in their properties (or not) and the reasons why, if trees were perceived as beneficial and/or problematic, followed by open-ended questions about the perceived benefits or problems trees generated (Table S1). From the survey we also gathered the following information on households' socio-demographic and economic variables: the respondent's age, gender, marital status, years of formal education, combined annual household average income (US dollar), and housing tenure. We used deductive coding for each open-ended question and benefits and problems responses were classified into ecosystem services or disservices using categories from available literature. The coding scheme was agreed upon through discussion meetings with two lead surveyors (ecologist and social scientist) and two coders. Ecosystem services were classified according to the Millennium Ecosystem Assessment (2005) framework [10] into Regulation (R), Support (S), Provision (P), and Cultural (C) services. Likewise, responses to the question about tree problems were classified following von Döhren and Haase's (2005) [71] classification for type of ecosystem disservices developed from a comprehensive review of available publications according to economic, ecological, health, and psychological impacts. The social survey was complemented with available data on yard vegetation surveys that were used to extract the following variables: number of tree stems and yard area. All woody plants of over 2 cm diameter were included in the survey, habit and species were determined, and photographs of each individual were taken to confirm identification in laboratory. Yard area was estimated from aerial imagery using Google Earth Pro v. 7.0.

2.4. Statistical Analyses

2.4.1. Preferences and Attitudes Versus Household Socio-Economic Variables

We ran binomial logistic regressions to evaluate the relationships between household socio-economic variables and the likelihood that residents would (1) prefer trees on their property, (2) express positive attitudes toward trees on their property or in their neighborhood (trees as beneficial), or (3) express negative attitudes toward trees on their property or neighborhood (trees as problematic). Household socio-economic variables included: gender, housing tenure, civil status, age, years of formal education, annual family income, and household size. Only observations that did not have any missing values

were considered. This resulted in a smaller sample for each model. Qualitative variables were coded as binary variables as follows: gender (female = 1, male = 0), housing tenure (owner = 1, renter = 0), civil status (married or living with partner = 1, not married or divorced = 0). Response variables related to the preference for trees, trees as beneficial or problematic, were also coded as binary variables (yes = 1, no = 0). The variable site (categorical) was also included as an explanatory variable in logistic regression analyses with site = 'Cupey' as the reference category. We performed a McNemar's Test with continuity correction to test if the proportion of responses of whether home trees are beneficial or problematic significantly increased or decreased when asked about neighborhood trees. For samples of fewer than 25 records of discordant cells (cells that reflect difference in scale responses, "yes" to one scale and "no" to the other, and vice versa) a binomial distribution was used.

2.4.2. Services and Disservices Awareness Versus Scale

We evaluated the frequencies of responses of specific ecosystem services and disservices to determine those most commonly identified by residents. New variables that represented whether a resident mentioned a specific service or disservice when referring to home trees and neighborhood trees were created for each of the six most frequently indicated services (shade provision, food provision, lower temperature, oxygen production, aesthetic value, air purification) and the four most common disservices (maintenance hardship, reduced structural integrity, power lines obstruction, induces pests). McNemar's Tests were used to test whether the proportion of affirmative responses of each specific service or disservice by home trees changed when asked about home versus neighborhood trees. Tests were performed by site and using the pooled data for all sites. All the above analyses were run using SPSS v.24 [101].

2.4.3. Tree Attitudes Versus Yard Tree Abundance

We used spatial regression analysis to test for the effects of tree preferences (yes = 1, no = 0), trees as beneficial (yes = 1, no = 0), trees as problematic (yes = 1, no = 0), total number of services and disservices at the household scale, on the number of yard tree stems (a yard structure variable). Household socio-economic variables (age and housing tenure) and yard size were also included, building on previous work on the role of these variables on yard tree abundance [34]. For this analysis, we eliminated all cases that contained missing values in any of the variables, as well as a case whose coordinates were inconsistent between the social survey and the vegetation survey, yielding a total of 359 observations. Following Anselin et al. [102], ordinary least squares regression models (OLS) were generated to test relationships with each of the dependent variables. We used Moran's I statistics and Lagrange Multiplier test statistics to detect spatial autocorrelation. Akaike information criterion was used to select the best fit model for the prediction of the number of yard trees. Spatial analysis was run using GeoDa v.1.12.

3. Results

3.1. Household Socio-Demographic Profiles

The majority of respondents were females (60.6%) and the average respondent's age was 56.6 years. More residents surveyed were married or living with a partner (56.5%) rather than single or divorced (43.5%), and the large majority owned their properties (Table 2). Respondents had an average of 14.7 years of formal education, indicating that on average residents had at least completed a high school diploma and had spent at least two years pursuing a university degree. The average household size was 2.9 persons, with an annual household mean income of \$33,110. Although there is a natural skewedness in the San Juan population toward females and older residents, when compared to official U.S. Census data for the year 2010 these variables were overrepresented in our sample. Our sample was overrepresented by single household owners living within the boundaries of the RPWS and considerations need to be made when interpreting the data, since representativeness was not assessed.

Table 2. Descriptive statistics for the seven socio-economic characteristics of 397 households in the RPWS.

A. Categorical	Variable	Class	Frequency
1	gender	female	238
		male	155
2	civil status	single or divorced	171
		married or living with partner	222
3	ownership	owned	341
		rented or other	56
B. Continuous	Variable	Descriptive Statistics	Value
4	age (years)	mean \pm se	56.64 \pm 0.956
		max	96
		min	18
5	household income	mean \pm se	\$33,110.80 \pm \$1390.5
		max	\$80,000
		min	\$5,000
6	years of formal education	mean \pm se	14.73 \pm 0.185
		max	23
		min	6
7	household size (persons per household)	mean \pm se	2.95 \pm 0.081
		max	15
		min	1

3.2. Socio-Demographic Profiles and Attitudes toward Trees

Most respondents within the watershed (85.3% of 395 responses) preferred having trees on their property. Likewise, many residents responded that their home trees provide benefits (89.2% of 397 responses); the same pattern was observed when asked about neighborhood trees (88.7% of 397 responses). At the same time, 35.4% (out of 395) of respondents indicated that home trees caused problems, and a similar percentage (34.5% out of 397) indicated that neighborhood trees did. An exact McNemar's test using pooled watershed data found no significant differences across scales (home versus neighborhoods) in the proportion of residents that identified trees as beneficial, nor the proportion of residents that identified trees as problematic (Figure 2). When differences in the proportion of residents that identified trees as beneficial or problematic were also evaluated at each watershed location (site), none of the tests reflected differences across sites (all $X^2 < 3.2$, $p > 0.06$).

Logistic regression yielded no significant associations between household-level socio-economic variables and the likelihood of preferring home trees, and recognizing home trees as beneficial or problematic. However, the likelihood as to whether home trees were identified as beneficial (or problematic) was somewhat related to location (site) within the watershed (Table 3). In the Puerto Nuevo and Avenida Central sites (lower watershed sites), residents were less likely to perceive household trees as beneficial when compared to residents in Cupey (upper watershed). Also, the odds of finding home trees problematic was found to be 2.45 times higher for La Sierra (mid-watershed) residents versus Cupey (upper watershed). Models did show that residents' age and gender were factors associated with the likelihood of identifying neighborhood trees as beneficial (Table 3). Males and older residents were less likely to identify benefits derived from neighborhood trees than females and younger residents. In addition, residents from San Patricio, Puerto Nuevo, Avenida Central, and Chiclana were less likely than those from Cupey to acknowledge neighborhood trees as beneficial. None of the socio-economic or site variables were related to the likelihood of recognizing trees as problematic at the neighborhood scale. Overall, model variation in positive and negative attitudes toward home and neighborhood trees considering socio-economic and site factors was small and always below 19% of the total explained variation.

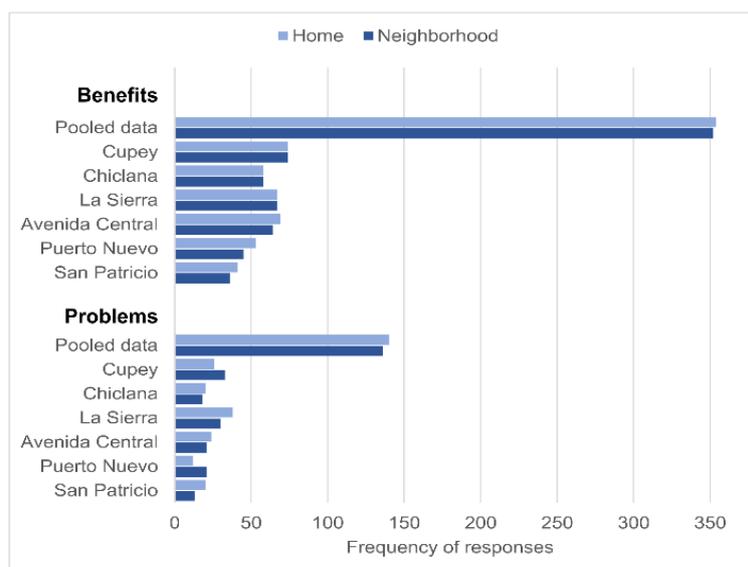


Figure 2. Frequency of resident affirmative responses (yes) to the question of whether trees provide benefits or problems for total responses and per site, a comparison between home and neighborhood trees. No significant scale differences were found for exact McNemar’s tests in either the pooled data or the site data (all $p > 0.05$).

Table 3. Regression coefficients from binomial logistic multiple regression analyses testing the relationship between household socio-economic variables and the likelihood of positive or negative responses by residents of the RPWS on whether they prefer trees in their property, and perceive benefits and problems from trees at the property and their neighborhoods. Significant values in bold.

Independent Variables	Prefer Trees on Property	Property Trees as Beneficial	Property Trees as Problematic	Neighborhood Trees as Beneficial	Neighborhood Trees as Problematic
gender (1)	-0.139	-0.234	0.039	-0.739 †	-0.244
age	-0.009	-0.002	0.005	-0.025 *	-0.001
civil status (1)	0.264	-0.034	0.410	-0.375	-0.238
years of formal education	0.116	0.021	-0.010	0.065	0.03
annual average income	0	0	0	0	0
ownership (1)	0.972	-0.448	-0.351	0.032	0.266
household size	0.163	0.018	-0.003	0.107	-0.071
site					
(1) San Patricio	-1.482	-0.031	0.576	-2.061 *	-0.808
(2) Puerto Nuevo	-1.051	-2.563 **	-0.781	-1.851 *	-0.146
(3) Avenida Central	-1.198	-1.616 †	-0.153	-2.433 **	-0.668
(4) La Sierra	-0.957	-1.306	0.895 *	-1.392	-0.106
(5) Chiclana	-0.546	-1.307	-0.052	-1.432 *	-0.583
χ^2	19.339	25.556	24.304	33.586	10.241
df	12	12	12	12	12
Nagelkerke R ²	0.098	0.141	0.093	0.183	0.04
N	345	347	345	347	347
p	0.081	0.012 *	0.018 *	0.001 **	0.595

† $p = 0.05$, * $p < 0.05$, ** $p < 0.01$.

3.3. Awareness of Ecosystem Services

Residents mentioned a total of 43 different ecosystem services when we pooled responses about why residents preferred trees and why they offered benefits (Table S3). Services were distributed by type as follows: 16 cultural, 11 support, 8 regulation, and 7 provision. Shade (22.43%), temperature reduction (18.45%), food provision (15.44%), aesthetic value (12.38%), oxygen production (11.66%), and air purification (6.58%) were the most commonly indicated ecosystem services. Less than two percent of the residents mentioned services that included habitat for flora and fauna, several regulation

services (natural hazard moderation, erosion control, carbon sequestration, noise reduction), and cultural services (privacy, relaxation, spiritual).

Statistically significant differences across scales (home versus neighborhood trees) were evident for at least four services (food provision, air purification, aesthetic services, and shade provision, Figure 3). However, these scale differences in the identification of certain services was more evident for food provision, where residents were twice as likely to indicate food provision as a service from home trees than from neighborhood trees (Figure 3). This trend was significant using pooled responses, and in all but two sites located in the lower watershed (Puerto Nuevo and San Patricio). The proportion of residents who mentioned shade as an ecosystem service was higher for home trees than for neighborhood trees, but this was significant when using the pooled data and only for the Cupey site when each site was analyzed independently (Figure 3). In contrast to food provision and shade, air purification and aesthetic value were recognized more often for neighborhood trees (Figure 3). These tendencies were only significant when evaluated using the pooled data, but not when evaluated for individual sites. Neither oxygen production nor temperature reduction were associated with significant differences in perception for home or neighborhood trees when using the pooled data (Figure 3). However, residents of San Patricio and La Sierra mentioned temperature reduction more frequently as a service from neighborhood trees than from home trees (Figure 3).

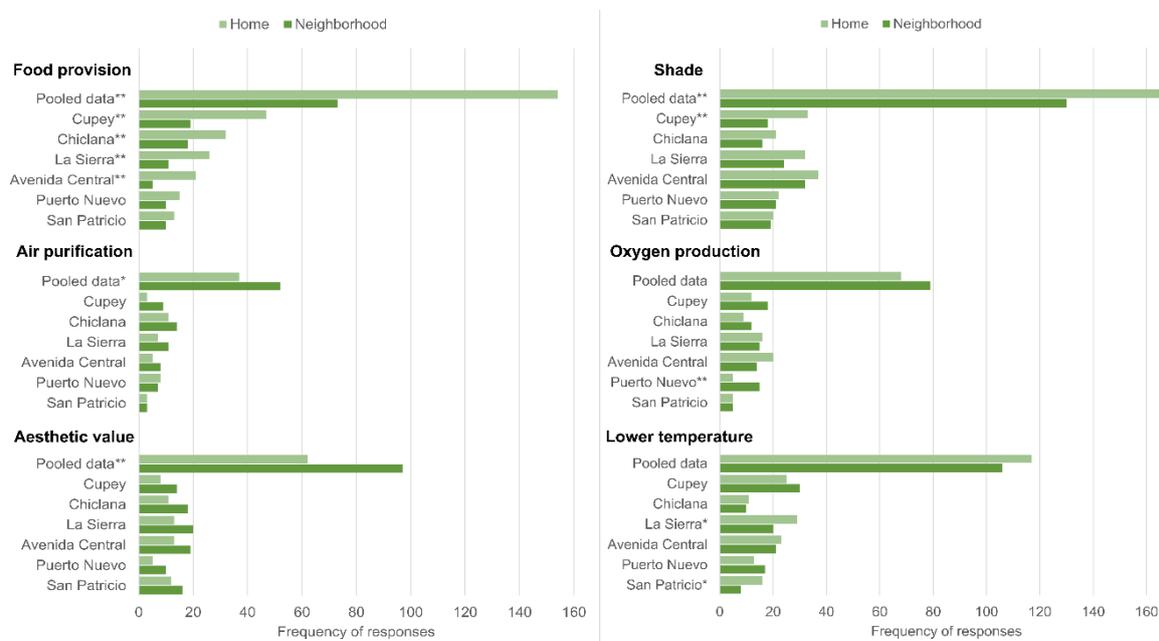


Figure 3. Frequency distribution of responses of the six most common services between home versus neighborhood trees (per site and aggregate). Symbols indicate significant differences using McNemar's tests (* $p < 0.05$, ** $p < 0.01$). X^2 values for significant McNemar's tests ranged from 4.083 to 52.893.

3.4. Awareness of Ecosystem Disservices

Residents identified a total of 18 ecosystem disservices (Table S3) including 8 economic, 2 health, 6 psychological, and 4 related to ecological impacts. The most frequently mentioned disservices were those related to economic impacts: maintenance hardship (37.11%), reduced structural integrity (21.91%), and power lines obstruction (10.82%). They were followed by an ecological disservice, inducing pests (7.73%). Together, these disservices represent over three-quarters of all pooled responses. Other disservices mentioned were: leading to neighbor disputes (4.64%), increased risk to personal injury (3.09%), and potential for property damage due to natural hazards (4.38%). In terms of differences in the proportion of responses considering disservices between home and neighborhood trees, reduced structural integrity was mentioned significantly more often at the home scale when using pooled resident data, but differences were not significant for any given site (Figure 4). Likewise, powerline

obstruction was mentioned more often as a disservice for neighborhood trees than for home trees in Cupey; results were not replicated in pooled watershed data (Figure 4). Neither maintenance hardship nor induced pests showed differences in the rate of responses across scales (home versus neighborhood trees).

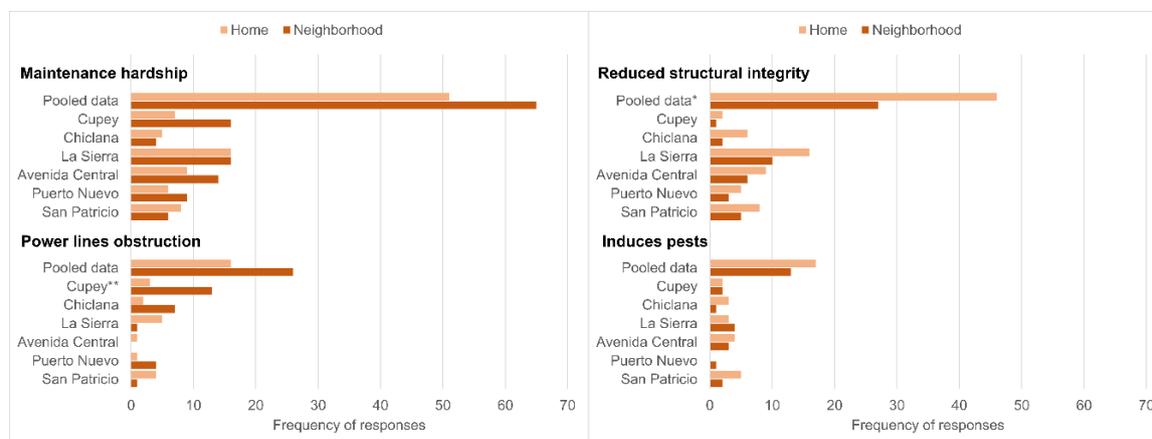


Figure 4. Frequency distribution of responses of four more common disservices from home versus neighborhood trees (per site and aggregate). Symbols represent significant values for McNemar’s test (* $p < 0.05$, ** $p < 0.01$). X^2 values for significant McNemar’s tests were both 6.75.

3.5. Relationships between Overall Respondent Profile and Yard Vegetation

Multiple regression analysis (Table 4) showed that the number of tree stems was positively associated with some of the seven variables in the model ($p < 0.001$). The model explained 46% of the total variation and the strongest regression coefficients were yard area, tree preference, and ownership (housing tenure). Recognition of home trees as beneficial showed a lower regression coefficient, which approached acceptable levels of significance, while trees viewed as problematic was not a factor contributing in a significant way to the variation in the number of trees per yard in this system.

Table 4. Regression coefficients from ordinary least squares (OLS) multiple regression analyses testing the association between household social variables and total number of tree stems. Coding for ownership as follows: owner = 1, renter and other = 0. Both number of tree stems and yard area were transformed to $\text{Log}_{10}(N + 1)$ and cases with missing values were excluded from the analysis for a total of $N = 359$. Significant values in bold.

Independent Variables	Tree Stems
ownership	0.217 **
age	0.005 **
site	0.059 **
preference trees	0.230 **
home trees as beneficial	0.177 *
home trees as problematic	-0.025
yard area	0.604 **
Whole Model Statistics	
F _{OLS}	44.974
df	351
AIC	375.516
R ²	0.473
Adjusted R ²	0.462

** Significant values $p < 0.001$; * Significant value $p < 0.05$.

4. Discussion

In this work, the goal was to understand residents' attitudes toward residential and neighborhood trees and their association with household socio-demographic factors, residents' awareness of trees' ecosystem services, and disservices in relation to the trees' proximity to the resident (home versus neighborhood), and if residents' attitudes toward trees could influence yard management using tree abundance as a yard management proxy. The study had three main findings. First, most residents self-reported positive attitudes toward trees in general and these appeared to be more frequent than the self-reporting of negative attitudes. Second, not all tree services and disservices were equally recognized by residents, but variation in their awareness of tree ecosystem services or disservices may be influenced by the spatial proximity of trees relative to the resident (home versus neighborhood). Finally, results suggest that positive attitudes toward trees might be more influential than negative ones in yard planting decisions when the study was conducted. Below, we discuss the significance of these findings, considering other studies and the implications for the use of an ecosystem services framework for urban forestry and green infrastructure planning with an emphasis on green residential spaces.

4.1. Drivers of Attitudes toward Trees

The fact that most residents had positive opinions toward trees rather than negative ones is consistent with the literature [45,49–56], but most of these studies evaluated attitudes toward trees in public spaces (but see [45,52,56]). Our results are consistent with these findings but add to the idea that there is complexity as to what may drive attitudes toward trees. For example, this study showed that proximity of trees to a resident (home versus neighborhood) is not likely to influence the frequency of self-reported positive attitudes. On the other hand, results also suggested that self-reported negative attitudes (i.e., viewing trees as problematic) among residents may indeed be influenced by their proximity to trees as well as the socio-economic profile of the resident. Specifically, men and older residents were more likely to view trees as problematic, but this result was only evident for neighborhood trees, not home trees. Other studies have alluded to the complexity of factors that may drive attitudes toward trees, but with different results. In Lohr et al. [51], most respondents strongly agreed on the importance of city trees, but men and lower income younger residents with less formal education were less likely to strongly agree. Avolio et al. [52] also found that a higher income level (\$150,000 or more) was strongly correlated with the importance of yard trees, but not public trees. While our findings found attitudes toward trees by gender to be significant, the relationship was weak (i.e., $R^2 < 18\%$ for models including gender) relative to those found in other studies, reinforcing the need to avoid generalization of the way social groups may self-report their attitudes toward trees and the importance of local information to understand the social constructions on their environment.

Due to the face-to-face and self-reporting nature of our recruitment strategy, positive attitudes might be overrepresented due to the enhancement of social desirability bias. Face-to-face self-report surveys can be affected by what respondents consider to be socially acceptable, to be viewed favorably by others [103]. A reason for caution in assuming most people have a positive attitude toward trees is the argument that negative attitudes might be stigmatized by prevailing normative discourses of trees as being “universally good” and “should be loved by everyone” [67,104]. We strived to minimize social desirability bias by including open-ended questions on tree benefits and problems and by explaining the voluntary and confidential nature associated with participation. Future studies might address social desirability bias using more in-depth qualitative analysis (e.g., semi-structured interviews) or mixed methods approaches that give subjects more space to discuss their attitudes and perceptions toward trees in more detail.

4.2. Awareness of Ecosystem Services and Disservices

The most frequently mentioned services were shade, lower temperature, food provision, and ornamental/aesthetics. The most frequently mentioned disservices were maintenance hardship,

property damage, and power line obstruction. The recognition of shade and temperature regulation is not surprising given the tropical environment of San Juan, which has been shown to exhibit a strong urban heat island effect [105] and temperatures and extreme heat episodes have been on the rise for the past 40 years as a result of climate change [106,107]. Awareness of shade is consistent with previous temperate city studies of residents ranking shade along with aesthetic value (i.e., ornamental, beauty) as the most important services of urban trees [49,51,52,58,63,65], in addition to oxygen supply in Morelia Mexico, [53] and fruit provision in South Africa [56]. Our findings are also consistent with previous studies where residents ranked damages to structures (e.g., sidewalks) and maintenance problems (e.g., fallen debris) higher than other disservices [49,52,53,56,63,65]. However, the extent of awareness of all ecosystem services and disservices was not necessarily uniform across cities in the cited studies. It is particularly notable that food provision and power line obstruction were frequently mentioned by respondents in the Río Piedras Watershed, but these were not prevalent in resident responses in most studies of attitudes toward residential trees. While evaluating the effect of those differences is beyond the scope of this study, these deserve future consideration when designing studies seeking to evaluate ecosystem service awareness. First, there were methodological differences on the exploration of attitudes between our study and other studies. Most studies provided a list of specific services and disservices to be ranked by residents, where food provision (a benefit) or power lines (a problem) were seldom included. Studies also differed in the metrics employed to evaluate services and disservices (e.g., scales, ranking values, attitude statements, visual scenarios) or the spatial and numerical context of the reference trees (e.g., one tree or many, yard street or street tree, private or public tree), factors which may influence attitude responses.

Variation in attitudes toward residential trees and their related services and disservices have been found to differ according to the location of the tree relative to the resident's property [49,65] or whether they are located in private or public property [52]. They have also been linked to variation in resident experiences across spatial scales and social-ecological contexts [13–15]. Our results suggest these relationships as well for resident awareness of tree services and disservices. Even when positive attitudes toward trees were not dependent on the proximity of trees, the results supported that the awareness of tree services and disservices did vary when asked about home trees versus neighborhood trees and that awareness of all services and disservices was not uniform across sites. Ecosystem services related to provision (mostly food) were more often acknowledged for home trees (trees in a private space). Ecosystem services related to cultural services, mainly aesthetic or ornamental values, were more often acknowledged for neighborhood trees (trees in private and public spaces). Likewise, reduced structural integrity, which is related to damages to residents' properties, was more frequently mentioned for home trees, while power line obstruction was more frequently acknowledged for neighborhood trees, particularly at the upper watershed (Cupey). At this site, public and private places tend to be more heavily forested than other sites within the watershed [85]. In Cupey, where heat vulnerability indexes are low [107], shade (and not temperature reduction) was more commonly perceived as a home service, while in San Patricio (lower watershed), where heat vulnerability is high and there is more grey infrastructure, temperature reduction was highly perceived as a home tree service (more than a neighborhood service). This suggests that variation in the climatic conditions experienced by residents may influence the awareness of services by residents, which is consistent with other studies [49]. In Los Angeles, residents experiencing hotter climates were more likely to value shade trees than those in cooler ones [52]. In Curitiba, Brazil people associated feelings of thermal comfort directly with street trees [90]. In Hong Kong, residents placed a high value in the heat stress functions of trees, particularly if they anticipated an increasing trend of occurrence of adverse weather events, like rising temperatures [108]. The combined results of these studies suggest that residents may visualize different types of spaces differently when it comes to the provision of services, and vice versa, making a stronger case for the importance of considering perceptual differences in urban green planning strategies.

4.3. Tree Attitudes and Yard Tree Abundance

A previous study considered the potential role of household socio-economic variables but not variation in attitudes and preferences for trees as factors that could influence yard tree abundance [34]. Our findings suggest that positive attitudes and expressed preference toward trees might be more influential in tree abundance than expressed negative attitudes. As hypothesized, variation in positive attitudes and expressed preference toward trees (but not expressed negative attitudes) partially explained the current variation in yard tree abundance, along with resident's age, housing tenure, and yard size. This relationship between positive attitudes toward trees and the number of trees in residential yards was also found by Shakeel and Conway [60], but in that study available planting space, a property characteristic, also influenced yard tree abundance. In our study, yard size, a property level variable, was the most important factor associated with tree abundance, which is something that was already stated by the previous study. When adding attitudes and preferences, our current model captured a larger percentage of the variation in yard tree abundance. Nevertheless, more than half of its variation was still unaccounted for in the new model. Other factors that have been suggested as contributing to the presence and composition of yard trees in San Juan in separate studies include plant gifts through social networks (i.e., family members, neighbors), historical process of urban development, homeowner association regulations, length of house tenancy, and natural dispersion [17,26,68,84,86]. Studies elsewhere have found that the acknowledgement of tree services and disservices could motivate tree planting and removals [58,66–69]. In some studies, visual aesthetics, shade provision, wildlife habitat provision, and privacy enhancement are the main reasons for tree planting decisions, while in others, removal decisions were related to tree condition (diseased, advanced age, poor health, dead or dying), maintenance problems, and damages to infrastructure by roots or potential hazards (fallen limbs, danger) [58,66–69]. This study did not evaluate the relationship between the awareness of specific services or disservices and tree management in an explicit way, but the fact that positive attitudes explained (at least in part) yard abundance suggests that evaluating the relationship between awareness and preferences for specific tree ecosystem services and plant abundance could help us understand yard planting decisions in San Juan if they reflect the residents' preferred plant ecosystem services [58]. Further research could address tree planting motivations specifically and utilize value research approaches that allocate more space or time for respondents to clearly articulate thoughts about trees, leading to a deeper understanding of their motivations.

4.4. Potential Implications for Green Infrastructure Planning

Tree planting is marketed as a go-to solution to increase ecosystem services provision [109], mitigate and adapt to extreme events (climate change, increasing temperatures, extreme flooding) [9,110–112], and biodiversity conservation [113–115]. In this study, residents were aware of many services, but did not always align with most of these goals. For example, benefits related to thermal and air regulation (i.e., shade, temperature reduction, oxygen production, and air purification) were more frequently mentioned relative to other regulating services of importance in the region (natural hazard moderation, flood control, erosion control, carbon sequestration, noise reduction). Residents' awareness of shade provision and temperature regulation services may be an asset in the incorporation of green infrastructure planning prescriptions, but the authors note that other services just as important for climate change adaptation, such as flooding and soil erosion control are not as recognized.

This study suggests that in RPWS, different services may be prioritized differently in different spaces. Planners may incorporate such information to develop green infrastructure plans that consider these differences. For example, food provision and shade services by trees are more often recognized at the household scale than at the neighborhood scale, while air purification and aesthetic services are more often recognized at the neighborhood scales. Urban forestry practitioners could adjust tree management and species selection to local needs [49,116], provide information to residents for species selection and management needs [68], and the benefits or cost effectiveness of planting trees [68], local nurseries, and tree distribution programs could embrace providing tree species that provide

frequently mentioned services, such as fruit and low maintenance trees [58,117]. Urban forestry strategies can be developed to not only maximize ecosystem services of interest, but also to minimize potential disservices [58]. In the context of urban vegetation management, widely acknowledged disservices, such as damage to property (e.g., house, sidewalks, pipes), obstructing power lines, or maintenance hardships, could theoretically be addressed by adequate site and species selection and appropriate management [83,92]. The combined results of this and previous studies suggest that not all services and disservices may be equally important among residents, and the extent that these may be motivators for planting and removal should be considered when developing management strategies at the residential scale.

Positive attitudes toward street trees have been attributed to the perception of services they provide, often expressed by residents despite their awareness of their disservices [118], and the diminished recognition of tree disservices relative to services is consistent across spatial/geographic scales within this watershed. While it would appear that the majority of RPWS residents see trees as beneficial and not problematic and that disservices do not influence yard tree abundance, we argue that these relationships can be dynamic and need to be monitored. For example, residents seldom mentioned natural hazard moderation as a service and property damage due to natural hazards as a disservice. The surveys presented here, however, were performed before Puerto Rico suffered a devastating hurricane season in 2017, causing severe damage to urban green and grey infrastructure and a significant vegetation loss that has been estimated to be up to 31% in Puerto Rico and the U.S. Virgin Islands combined [119]. Experiences after the hurricanes, including the complexities of managing accumulated vegetation debris, the damage to power lines as a contributing factor to the complete collapse of the electric system, the damage of fallen trees and branches to private and public infrastructure, potentially influenced perceptions of tree disservices that could play a role in attitudes or management decisions [61]. One could hypothesize that the recognition of trees as problematic could increase due to negative experiences, and that perceptions of tree disservices (versus services) may have changed as a result. While ecosystem services frameworks may be useful in understanding urban green infrastructure dynamics, it is important to recognize that people's attitudes can be influenced by contextual changes and, as such, can be dynamic [120,121]. Since this study was conducted, the social–ecological system of the island of Puerto Rico has been subjected to important social (e.g., Puerto Rico's debt crisis) and ecological events (e.g., prolonged drought, catastrophic hurricane) that have been accompanied by profound demographic changes and may have, in turn, changed the worldviews and values of island residents.

5. Conclusions

Our explorations of the dynamics of urban tropical residential space within the Río Piedras Watershed continue to shed light on the complexities that characterize these systems. We emphasize the role of scale in understanding social–ecological interactions of dynamic urban residential infrastructure, the prevailing land use in urban landscapes. The awareness of services generated by trees is rich but important benefits for climate change adaptation are being overlooked. Understanding this feedback, addressing awareness gaps in ecosystem services where they manifest, mitigating disservices that trees may generate, and further research to identify the underlying values that residents hold toward trees could go a long way in facilitating current and future urban forestry strategies and green infrastructure planning.

Supplementary Materials: The following are available online at <http://www.mdpi.com/2071-1050/12/1/117/s1>, Table S1: Examples of verbatim responses coding to questions of tree benefits and problems; Table S2: Survey questions included in our study; Table S3: Frequencies of responses of ecosystem services and disservices.

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