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Street trees as cultural elements in the city: Understanding how perception affects ecosystem services management in Porto, Portugal

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ABSTRACT

Processes shaping urban ecosystems reflect and influence the cultural context in which they emerge, bearing implications for ecosystem services (ES) planning and management. Investigating the perception of benefits and losses / costs delivered by a specific service providing unit (SPU) can generate objective orientations suitable for urban planning and management deeply embedded in the social-ecological systems where they occur, because the realization of ES into benefits and losses / costs is mediated by specific beneficiaries and reflects their characteristics, information and use of ecosystems. Street trees are a particularly relevant SPU in many densely built Southern-European cities due to the difficulty in implementing new sizeable green areas. In this study, a questionnaire was developed and applied in Porto to investigate how benefits (cultural, regulating and economic) and losses / costs caused by street trees are perceived by citizens and influenced by a set of socio-economic variables (N = 819 people aged 18 years or older), and parametric statistical tests were used to analyze the effect of gender, age and school level. Results evidenced that people in Porto valued more environmental benefits (particularly air quality improvement) than cultural ones. School level was the variable accounting for more differences, underlining a tendency in people with lower level of academic education to value less the benefits provided by street trees in Porto and attribute more importance to losses and damages, compared to people who attended university or had higher academic degree. Age also held considerable differences in mean responses, with older people showing more concern towards losses and costs, while gender influenced perception of cultural benefits, which were more important for women than for men. The findings of the research are discussed concerning implications for environmental justice, planning and management of urban ecosystems.

1. Introduction

Mainstreamed by the Millennium Ecosystem Assessment as the benefits human populations obtain from ecosystems (MEA, 2005), ecosystem services (ES) emerged as a metaphor to highlight public awareness on our dependence of nature, in order to foster biodiversity conservation (Gómez-Baggethun et al., 2010). However, the concept has been on the verge of stripping the human-nature relationship of the highly complex social-cultural drivers that define it (Chan et al., 2012). Ecosystems are not only shaped by humans according to diverse sets of cultural values, they also reflect and influence cultural systems in a bidirectional relational process. Hence, humans are not passive receptors of benefits and values generated by ecosystems, but rather active players in the interactive process that generates ES. It follows that processes shaping ecosystems cannot be properly understood without considering the cultural context in which they emerge, bearing implications for ES planning and management.

Cultural ecosystem services (CES) probably reflect more than any other type of ES the beliefs and practices behind landscape change, because they are imbued of the individual and collective experience upon which our relationship with nature is set. According to Fish et al. (2016), CES are the "ecosystems' contribution to the non-material benefits (capabilities and experiences) that arise from human-ecosystem relationships". CES generate many physical, emotional and

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mental benefits (Fish et al., 2016; Russell et al., 2013), and their importance has been found to increase globally in developed countries, as dependence on provisioning and regulating ES decreases (Guo et al., 2010); in addition, they have a low potential for replacement, once degraded in the ecosystem (Plieninger et al., 2013).

Nevertheless, most CES are rarely accounted in an explicit manner in assessments and decision-making processes that shape the landscape (Chan et al., 2012; Plieninger et al., 2013), especially in urban settings, despite being considered by and large particularly important for the wellbeing of city dwellers, compared to other types of ES (Andersson et al., 2015b; La Rosa et al., 2016). Many challenges make it difficult to assess and value CES, although they have been increasingly considered a top priority for ES research to assist in tailoring urban planning and management of social-ecological systems (Kremer et al., 2016).

In light of the growing proportion of worldwide urban population, estimated to surpass 66% by 2050 (United Nations, 2014), urban ecosystems are becoming increasingly important for human wellbeing. They provide the interface through which most citizens primarily experience nature regularly, and potentially engage in a meaningful relationship that supports their welfare and happiness. In addition, previous research has shown the importance of informal stewardship in generating ecosystem services (Andersson et al., 2007), which is deeply influenced by local culture and knowledge systems. Therefore, understanding how citizens perceive and value urban ecosystems can generate insights about the cultural practices shaping them. Such knowledge might help to derive planning and management practices of urban ecosystems grounded in specific cultural contexts, which can potentially generate stronger values towards nature. This is particularly important, because a difference exists between potential and actual delivery of CES, the latter depending on the existence of beneficiaries recognizing value in ecosystems (Bagstad et al., 2014), which is not necessarily the case for a given urban setting (Kronenberg, 2015; Rae et al., 2016).

Fish et al. (2016) proposed a novel approach to understand CES as non-linear, relational *processes and entities* resulting from human-ecosystem interactions. According to these autors, CES are not unidirectional contributions of nature used or consumed by humans; instead, they are co-produced within culture-nature relationships, and are composed of two parts: the environmental places, or the geographical contexts of interaction between nature and people, and the cultural practices taking place in them. This idea is also conveyed by the Common International Classification of Ecosystem Services (CICES), in which "cultural services are primarily regarded as the physical settings, locations or situations that give rise to changes in the physical or mental states of people", thereby proposing a distinction between "settings that support interactions that are used for physical activities such as hiking and angling, and intellectual or mental interactions involving analytical, symbolic and representational activities" (Haines-Young and Potschin, 2013). By disentangling services from benefits, and identifying explicitly the components of CES, this conceptualization helps to bring down to earth the intangible elements in the social-cultural dimension of ES.

It is also crucial to establish direct relationships between specific cultural benefits and components of urban ecosystem that affect ES supply. According to Andersson et al. (2015a), the concept of Service Providing Units (SPU) can help to better understand the links between ES and the spatial structure and dynamics that sustain them, through the identification of "the smallest distinct physical unit that generates a particular ES and is addressable by planning and management". We suggest that investigating cultural benefits and losses/costs delivered by a specific urban SPU can provide objective orientations suitable for urban planning and management deeply embedded in the social-ecological systems where they occur, because the realization of ES into benefits and losses/costs is mediated by specific beneficiaries, and reflects their characteristics, perception, information and use of ecosystems (Fig. 1).

Street trees are a particularly relevant SPU in Southern-European cities because the usually dense urban matrix prevents the creation of new sizeable green areas. Street trees therefore constitute the most abundant and conspicuous public green element in these cities, and the most accessible form of nature to a significant share of the population. Moreover, urban trees provide many local ES (Roy et al., 2012) although scientific evidence identifying the specific environmental processes mediating street trees contribution to health outcomes is still scarce (Salmond et al., 2016). Nevertheless, many studies have related street trees with positive impacts in microclimate regulation (Gillner et al., 2015; Shashua-Bar et al., 2010; Vailshery et al., 2013), air quality regulation (Pugh et al., 2012; Vailshery et al., 2013) and stormwater regulation (Armson et al., 2013; Stovin et al., 2008). Research has also established links between urban street tree density and antidepressant rates (Taylor et al., 2015) and lower asthma prevalence in children (Lovasi et al., 2008), although some studies suggest that specific social processes, such as social cohesion, mediate the path between streetscape greenery and health outcomes (De Vries et al., 2013). Street trees therefore have the potential to enhance urban resilience and positively influence the quality of life in cities. However, the notion of benefit is highly subjective and should also be considered when developing strategies to support urban wellbeing: what is considered desirable by a particular social group can simultaneously be regarded as nuisance by another group, and some benefits stemming from ecological processes might not be perceived at all by local communities without proper formulation by responsible stakeholders, via participatory processes (Tadaki et al., 2015). Likewise, certain benefits generated by urban trees might be more demanded in contexts of environmental inequity

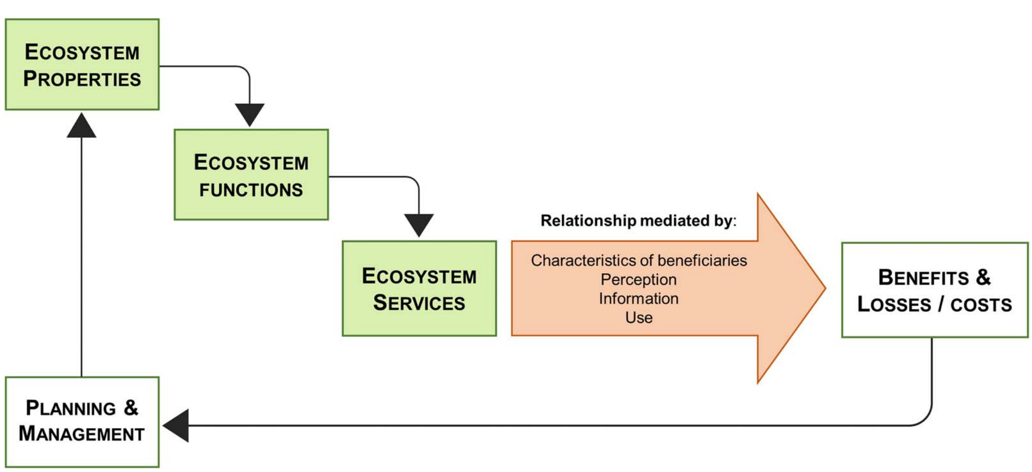

Fig. 1. Planning and management of social-ecological systems considering the role of beneficiaries in mediating the realization of benefits and losses/costs from ecosystem services.

(Landry and Chakraborty, 2009). For example, cooling and thermal comfort might be especially important for deprived social groups in urban areas prone to extreme heat events, who lack economic resources to mitigate exposure to heat stress (Jenerette et al., 2011; Pham et al., 2012). Socioeconomic factors and local environmental factors also influence attitudes and preferences of city dwellers towards urban trees (Avolio et al., 2015). Heynen et al. (2006) concluded that residents in poorer areas of Milwaukee were less fond of urban trees, and more aware of their disservices, implying that planting more trees in these communities would potentially augment their feeling of disempowerment. Schroeder et al. (2006) also observed that variables such as climate and proximity of trees to houses can affect attitudes of residents regarding street trees, and Fraser and Kenney (2000) found that cultural differences affected perception of the urban forest by four communities living in Canada. These findings suggest the need to customize locally decision-making frameworks based in ES, and bring together the cultural and scientific understanding in order to take into account both who are the beneficiaries of urban greening initiatives, and how they are actually benefited, to effectively generate positive outcomes for wellbeing.

Following this reasoning, an exploratory case study was developed in Porto, Portugal, to investigate the hypothesis that benefits and losses caused by street trees are perceived differently by citizens according to a set of socioeconomic variables: age, gender and school level. Results are discussed in light of existing scientific knowledge about ES supply by urban trees in Porto, and considering the implications for planning and management of urban ecosystems.

2. Methods

2.1. Study area

The research was developed in Porto (Fig. 2), the center of the second largest metropolitan area in Portugal. The city covers 41.4 km^2 and has a population of 237 591 residents (INE, 2011), but polarizes the daily commuting of the 17 municipalities of Porto Metropolitan Area (PMA), where 1 759 524 inhabitants live. Porto was the municipality of PMA with the greater negative variation in resident population between 2001 and 2011 (−6%; Faria et al., 2014), suffering from a double aging process due to the simultaneous increase of inhabitants over 65 years old (+27% of total population in 2015) and decrease of population ranging 0–14 years old (−12,3%; FFMS, 2017).

Porto has Mediterranean climate (Csb climate, according to Köppen-Geiger classification), with temperatures usually ranging between 5.0–16.8 °C in winter and 13.8–25.0 °C in summer (however they can reach 36 °C or higher) and precipitation averaging 1254 mm annually (IM, 2011). The city is fringed by the Atlantic Ocean in the west, and Douro River establishes the southern limit.

Abundant green areas and an immense rural belt surrounded the small urban core by the end of the 19th century. The interior of many blocks was green, there was a considerable number of public gardens and green areas totalized about 75% of the city, which decreased to a meager 30% by 2000 due to intense urbanization (Madureira et al., 2011). Nevertheless, Porto still holds outstanding value and the historic center was recognized as UNESCO World Heritage in 1996, attracting many tourists.

Nowadays, street trees are the green feature most accessible to the population in many parts of the densely built-up city. Furthermore, in a study comparing delivery of several regulating ES in Porto by eight types of green space, street trees were included in the second most proficient green type per unit area (Graça et al., 2018) hence constituting a major provider of local benefits.

Many studies also indicate Porto as an urban area particularly susceptible to the impacts of climate change and increased heat-wave risk (Lau et al., 2015; Monteiro et al., 2013; Rafael et al., 2016).

2.2. Survey design and implementation

A questionnaire was developed to assess how citizens perceive benefits and losses/costs caused by street trees in Porto, and what characteristics of the beneficiaries influence more strongly their opinion. Drawing from a literature review, potential cultural and economic benefits provided by street trees were listed, and possible losses/costs were likewise enumerated. Benfits related to provision services such as food or fiber supply were not included in this list, due to their residual importance in Porto.

To explore how information about urban ecosystems can affect perception regarding street trees, regulating ES were explicitly accounted for in our inventory. As regulating ES can provide multiple benefits simultaneously, one single benefit particularly relevant for urban planning and management was selected to represent each of six classes: i) air quality, ii) global climate regulation, iii) microclimate

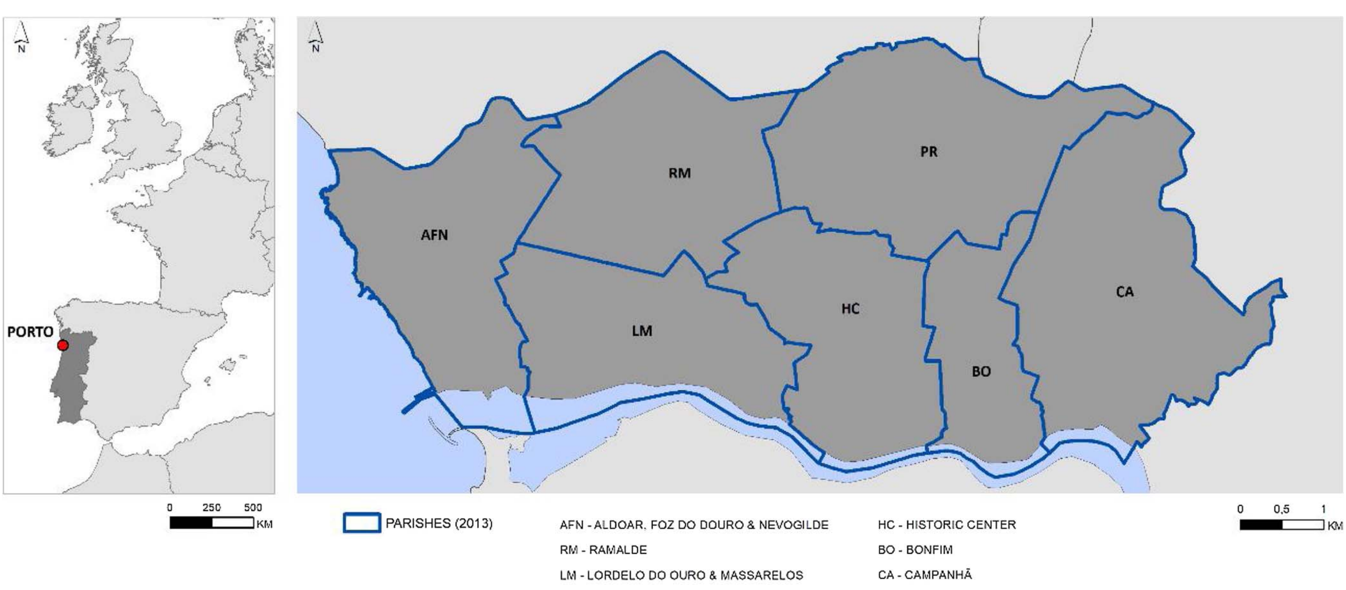

Fig. 2. Localization of the city of Porto, in Portugal (left), with the delimitation of the seven administrative parishes established since 2013 (right).

Table 1
Classes of potential benefits, losses/costs and ecosystem services generated by street trees.

Classes	Definition
Cultural benefits	
Inspiration	Stimulating new ideas, thoughts and/or creative expressions
Aesthetic pleasure	Beautifying streets, views and/or the city
Social cohesion	Promoting meetings with friends and neighbors
Leisure activities	Promoting recreation and tourism by providing pleasant places for walking, running, cycling, …
Sense of place	Fostering a sense of attachment to a place and/or to the city
Spiritual enrichment	Representing spiritual, religious, or personal special meanings
Education	Raising curiosity and knowledge about nature's cycles and biodiversity
Cultural heritage	Supporting local historical/cultural values and identity
Economic benefits	
Real-estate valorization	Increasing the monetary value of real-estate
Prosperous commerce/tourism	Fostering commercial/touristic activities which provide monetary revenues
Energy conservation	Increasing energetic efficiency of buildings, by reducing consumption of energy for cooling/heating
Losses & costs	
Goods and property damage	Damaging goods and structures such as cars, sidewalks, walls, …
Allergy risk	Increasing allergic reactions due to pollen release
Sunlight blocking	Providing unwanted shade, blocking sunlight
Visibility decrease	Reducing visibility to streets (from home)
Risk to individual integrity	Increasing risks for people's security due to tree or branch fall
Litter	Undesired accumulation of residues due to leaf and fruit fall
Insecurity feelings	Increasing fear of potential criminal activity in streets due to reduced visibility caused by trees
Unpleasant view	Unattractive views due to neglected maintenance or bad condition of trees
Maintenance costs	Public funds needed to support tree plantation and maintenance
Regulation & maintenance of ecosystems	Associated benefits
Air quality regulation	Improving air quality through removal of atmospheric pollutants
Climate regulation	Supporting global climate regulation through carbon sequestration/reduction of greenhouse gas concentrations
Microclimate regulation	Improving microclimatic comfort through regulation of local temperature and wind
Stormwater regulation	Preventing or mitigating floods by slowing down and intercepting rainwater before falling to the ground
Noise mediation	Buffering the noise of cars or specific activities
Habitat maintenance	Supporting lifecycle conditions for biodiversity in cities

These variables were selected and defined adapting lists from Bolund and Hunhammar (1999); Dobbs et al. (2011); Escobedo et al. (2011); Jim and Chen (2006); MEA (2005); Nowak and Dwyer (2007); Plieninger et al. (2013). Following the service cascade model proposed by Haines-Young and Potschin (2010), regulation and maintenance items were considered ecosystem services, to which benefits are associated; the list here presented for these services was built upon the Common International Ecosystem Service Classification (CICES).

regulation, iv) stormwater regulation; v) noise mediation and vi) habitat maintenance. Additionally, we followed the approach of CICES regarding supporting services (as defined by the Millennium Ecosystem Assessment), and considered that these are not final services or outputs directly consumed or used by beneficiaries (Haines-Young and Potschin, 2013), thereby not accounting them in this study. The resulting list (Table 1) was used to outline one single statement translating each variable into an easily comprehensible concept for the general population. A set of three additional statements was created to assess the general opinion of people about street trees in Porto, expressing their perceived trade-off between benefits and losses/costs.

The final set of 29 statements was organized in a questionnaire in Portuguese (Appendix A) consisting of three groups of questions. The first block consisted of seventeen questions in which interviewees were asked to rate the level of importance they attributed to a set of cultural, regulating and economic benefits provided by street trees according to a Likert-type scale with five possible responses (0 – not important, 1 – not very important, 2 – important, 3 – very important, 4 – no opinion). An open question was also included, to allow responses not included in the list of benefits developed by the research team. The second block included nine statements about potential losses/costs that interviewees should classify according to a five-class agreement scale (1 – strongly disagree, 2 – disagree, 3 – agree, 4 – strongly agree, 5 – no opinion). The same agreement scale was used in the last group of questions, in which the respondents were asked to evaluate the following three statements: "Trees bring more benefits than damages", "Bigger trees bring more benefits than smaller trees", and "The city of Porto needs more trees". The questionnaire also included fields to register the socioeconomic variables: age, gender and school level.

A test questionnaire was applied to a sample of ten convenience people of different ages, gender and school levels, unaware of the purposes and methods of this case study, to assess the duration of the interview (estimated around five minutes) and the clearness and meaning of the statements.

The final revised questionnaire was applied between February and May of 2017 in the streets of the city to a sample of 819 people aged 18 years or above, characterized in Table 2. The sample was representative of Porto's population regarding gender and age, although the age class 18–24 years old was overrepresented (15.6% in the sample versus 9% of the adult population in Porto) and people older than 64 years were underrepresented (19.8% versus 27.2% of the adult population). The proportion of people holding the 9th grade or below was smaller in the sample than in the real population (35.3% versus 51.6%), and consequently all other school levels were overrepresented.

The interviews were conducted mostly by students of the 11th and 12th grades of four secondary schools in Porto, and also by research staff. To recruit students, eighteen schools (public and private) with secondary school classes in Porto were invited directly or on behalf of the research team to participate in this project. Four schools accepted to take part in the project, and were subsequently contacted to schedule informative/training sessions for all participating classes in each school before carrying out the interviews. The purpose of the sessions was to familiarize students with the objectives of the study and the procedures to follow during the fieldwork. The distribution of teams was organized in order to target, as best as possible, the different zones of the city.

2.3. Statistical analysis

To study how citizens perceive benefits and losses/costs caused by street trees in Porto, the differences in mean response for each question

Table 2
Socioeconomic characterization of a sample of 819 people interviewed between February and May of 2017 in the streets of Porto (Portugal), to explore perception of benefits and losses/costs caused by street trees.

Socioeconomic variables	Classes	Percentage in sample	Percentage in Porto (INE, 2011)[a]
Gender	Men	46.2	45.5
	Women	53.8	54.5
School level	9th Grade or below	35.3	51.6
	High school (≤12th grade)	25.8	16.5
	University	28.2	24.7
	Master or higher degree	10.8	7.2
Age class (years old)	<18	–	14.8
	18–24	15.6	7.7
	25–44	31.6	25.6
	45–64	33.1	28.7
	+64	19.8	23.2
Municipality	Porto	73.0	–
	Other	27.0	–

[a] Percentages for school level in Porto refer only to the population aged 18 years or above.

(Appendix A), were assessed according to socioeconomic variables using one-way analysis of variance (ANOVA) for age and school level, and Student tests (*t*-test) for gender (variable with only two levels: men and women). Additionally, a single average response was calculated for each of the four dimensions of questions included in the questionnaire (cultural and economic benefits; regulation & maintenance ES; losses/costs caused by street trees; Table 1), by summing up the mean response for each individual question in a dimension, and then dividing the result for the total number of questions in that dimension. The objective was to assess if any of these dimensions held considerably more importance for respondents.

The main assumptions of normality and homogeneity of variance for the population samples were checked using respectively the Kolmogorov–Smirnov and Levene tests, which confirmed the non-normality of some variables. Nevertheless, parametric tests have been shown to yield robust results when analyzing data obtained with Likert-type scales, even though these are conceptually ordinal and may violate homogeneity of variance and normality assumptions (for a thorough discussion about the use of parametric tests to analyze data from Likert scales see Norman, 2010). In addition, we used a very large independent sample to insure that the distribution of response means approached a normal distribution, as established by the Central Limit Theorem of probability theory.

Results of ANOVA were expressed as F-ratio values (Fischer test) and the W-ratio value (Welch test) was used for cases without homogeneity of variance. Whenever differences resulted significant, individual means were compared using planned orthogonal contrasts ($p < 0.05$). Orthogonal contrasts are an essential aid in reducing the number of possible pairwise comparisons to the maximum number of independent hypotheses, and hence in ensuring the testability by comparing each level or class of each variable against the remaining, subsequently grouping together levels/classes that share similarities. All statistical analysis were run in IBM SPSS version 24.

3. Results

3.1. Aggregated dimensions of benefits and losses

Average responses according to the four dimensions of the questionnaire (cultural and economic benefits; regulation and maintenance ES; losses/costs caused by street trees) are presented in Table 3, and indicate that the people interviewed valued mostly the regulation & maintenance ES provided by street trees (mean: 2.40). Cultural benefits were also considered important (mean: 2.16), while economic benefits were the less appraised ones (mean: 1.89). The dimension concerning losses/costs was the one yielding the highest mean (2.60) among the four considered in our analysis, because a different numeric scale was associated with the possible responses to express agreement instead of degree of importance for each statement.

Results showed statistically significant differences of response according to gender only for the cultural benefits dimension, which was more important for women (mean: 2.22) than for men (mean: 2.08). Age also affected significantly responses, with older people (+64 years) consistently valuing more losses caused by street trees than other age classes, and the contrast analysis highlighted a dichotomy between people aged 18–44 years old and those above 44 years (Table 3). This suggests that differences of opinion are more pronounced when this threshold is crossed. The variable associated with the highest impact in mean responses was school level, which revealed significant differences for all the four dimensions considered in the questionnaire. People holding higher education level (university attendance or above) valued cultural benefits and regulation & maintenance ES considerably more than people holding lower school level, also showcasing a threshold between the first two classes and the two last. The contrast analysis showed that only people in the high school class had a significantly lower mean response concerning the economic benefits dimension, compared to all other classes. This might be due to the high variability in responses in this dimension (confirmed by the higher standard error of means), probably reflecting more individual differences than socioeconomic patterns. The losses/costs caused by street trees were significantly considered more important by people holding lower academic level than by people who attended or completed an university degree.

3.2. Individual benefits

Considering the sample as a whole, responses for individual items reflected the findings concerning the dimensions of benefits most and least valued (Table 4). All the regulation & maintenance ES ranked in the top positions of importance, with the exception of noise mediation (mean: 2.01). Nevertheless, two cultural benefits were also very highly accounted by respondents: aesthetic pleasure (mean: 2.46), and leisure activities (2.44). The benefit considered in average the least important of all was spiritual enrichment generated by street trees (mean: 1.50). Among economic benefits, the contribution of street trees to energy conservation in buildings was the most highly regarded (mean: 2.06). Promoting local commerce and tourism or increasing the monetary value of real-estate were considered among the least important benefits provided by street trees (mean: 1.71 and 1.90, respectively).

Gender played an important role in how benefits were perceived,

Table 3
Average perception of four dimensions of variables – cultural benefits, economic benefits, regulation & maintenance ecosystem services (ES), and losses/costs – generated by street trees in Porto (Portugal), according to socioeconomic variables. Results for 819 interviews.

Socioeconomic variables	Cultural benefits	Economic benefits	Regulation & maintenance ES	Losses & costs
Gender				
Men	2.08 (0.02)	1.89 (0.04)	2.36 (0.02)	2.58 (0.03)
Women	2.22 (0.02)	1.89 (0.04)	2.44 (0.02)	2.61 (0.03)
Student's t-test (Sig.)[1]	0.000	0.976	0.013	0.456
Age class (yrs)				
18–24	2.09 (0.04)	1.83 (0.06)	2.36 (0.04)	2.45 (0.04)[a]
25–44	2.20 (0.03)	1.91 (0.05)	2.46 (0.03)	2.52 (0.04)[a]
45–64	2.16 (0.03)	1.987 (0.04)	2.39 (0.03)	2.66 (0.03)[b]
+64	2.13 (0.04)	1.95 (0.06)	2.36 (0.04)	2.75 (0.04)[b]
ANOVA (Sig.)[2]	0.139	0.478	0.120	0.000
School level				
≤9th Grade	2.10 (0.03)[a]	1.94 (0.04)[a]	2.32 (0.03)[a]	2.76 (0.03)[a]
High school	2.10 (0.03)[a]	1.73 (0.05)[b]	2.33 (0.03)[a]	2.59 (0.03)[b]
University	2.22 (0.03)[b]	1.92 (0.05)[a]	2.53 (0.03)[b]	2.45 (0.03)[c]
≥Master degree	2.26 (0.05)[b]	2.02 (0.08)[a]	2.51 (0.05)[b]	2.42 (0.06)[c]
ANOVA (Sig.)[2]	0.001	0.003	0.000	0.000
Total sample	2.16 (0.02)	1.89 (0.03)	2.40 (0.02)	2.60 (0.02)

Response results are expressed as Mean (Standard Error) of response in a Likert-type importance scale for benefits and ES (0 – not important; 1 – not very important, 2 – important, 3 – very important), and an agreement scale for losses/costs (1 – strongly disagree, 2 – disagree, 3 – agree, 4 – strongly agree).
The superscript letters highlight differences between levels of one socioeconomic variable concerning mean responses; levels with similar responses for one dimension do not differ significantly according to orthogonal contrast analysis ($p < 0.05$).

[1] Significance of Student's *t* -test.

[2] Statistical significance of the F test (Fischer) or Welch test (for cases with unequal variances).

Table 4
Comparative analysis of potential benefits, ecosystem services (ES) and losses/costs generated by street trees in Porto (Portugal), for total sample and according to gender. Results for 819 interviews.

Benefits, ES and losses/costs		Gender		Student's *t*-test (Sig.)[1]
	Sample	Men	Women	
Cultural benefits				
Inspiration	2.07 (0.03)	1.96 (0.04)	2.15 (0.03)	0.000
Aesthetic pleasure	2.46 (0.02)	2.40 (0.03)	2.52 (0.03)	0.005
Social cohesion	2.22 (0.03)	2.17 (0.04)	2.26 (0.03)	0.063
Leisure activities	2.44 (0.02)	2.41 (0.03)	2.47 (0.03)	0.144
Sense of place	2.18 (0.03)	2.13 (0.04)	2.23 (0.03)	0.054
Spiritual enrichment	1.50 (0.04)	1.37 (0.05)	1.62 (0.05)	0.001
Education	2.21 (0.03)	2.11 (0.04)	2.29 (0.03)	0.000
Cultural heritage	2.10 (0.03)	2.03 (0.04)	2.16 (0.04)	0.016
Economic benefits				
Real-estate valorization	1.71 (0.04)	1.71 (0.05)	1.70 (0.05)	0.825
Prosperous commerce and/or tourism	1.90 (0.03)	1.88 (0.05)	1.91 (0.04)	0.659
Energy conservation	2.06 (0.03)	2.03 (0.05)	2.08 (0.05)	0.460
Regulation & maintenance ES				
Air quality regulation	2.71 (0.02)	2.69 (0.03)	2.73 (0.03)	0.268
Climate regulation	2.48 (0.02)	2.42 (0.04)	2.53 (0.03)	0.017
Microclimate regulation	2.45 (0.02)	2.40 (0.04)	2.49 (0.03)	0.059
Stormwater regulation	2.37 (0.03)	2.32 (0.04)	2.41 (0.04)	0.097
Noise mediation	2.01 (0.03)	1.95 (0.05)	2.06 (0.04)	0.092
Habitat maintenance	2.41 (0.02)	2.36 (0.04)	2.45 (0.03)	0.060
Losses & costs				
Goods and property damage	2.65 (0.03)	2.60 (0.04)	2.68 (0.04)	0.184
Allergy risk	2.95 (0.03)	2.89 (0.04)	3.00 (0.04)	0.071
Sunlight blocking	2.40 (0.03)	2.35 (0.05)	2.44 (0.04)	0.166
Visibility decrease	2.44 (0.03)	2.41 (0.04)	2.45 (0.04)	0.545
Risk to individual integrity	2.67 (0.03)	2.64 (0.04)	2.68 (0.04)	0.510
Litter	2.67 (0.03)	2.67 (0.04)	2.67 (0.04)	0.982
Insecurity feelings	2.35 (0.03)	2.34 (0.05)	2.36 (0.04)	0.764
Unpleasant view	2.65 (0.03)	2.65 (0.05)	2.65 (0.04)	0.921
Maintenance costs	2.54 (0.03)	2.56 (0.05)	2.52 (0.04)	0.535

Response results are expressed as Mean (Standard Error) of response in a Likert-type importance scale for benefits and ES (0 – not important; 1 – not very important, 2 – important, 3 – very important), and an agreement scale for losses/costs (1 – strongly disagree, 2 – disagree, 3 – agree, 4 – strongly agree).

[1] Statistical significance of Student's *t*-test.

Table 5
Comparative analysis of potential benefits, ecosystem services (ES) and losses/costs generated by street trees in Porto (Portugal) according to age classes. Results for 819 interviews.

Benefits, ES and losses/costs	Age classes (years old)				ANOVA (Sig.)[1]
	18–24	25–44	45–64	+64	
Cultural benefits					
Inspiration	1.94 (0.07)	2.13 (0.05)	2.07 (0.05)	2.07 (0.07)	0.133
Aesthetic pleasure	2.43 (0.06)	2.53 (0.04)	2.47 (0.04)	2.37 (0.06)	0.097
Social cohesion	2.13 (0.07)	2.29 (0.04)	2.23 (0.04)	2.15 (0.06)	0.141
Leisure activities	2.50 (0.06)	2.51 (0.04)	2.39 (0.04)	2.38 (0.05)	0.052
Sense of place	2.11 (0.06)	2.21 (0.05)	2.21 (0.04)	2.17 (0.05)	0.583
Spiritual enrichment	1.28 (0.08)[a]	1.53 (0.07)[b]	1.49 (0.06)[b]	1.65 (0.08)[b]	0.018
Education	2.18 (0.06)	2.25 (0.05)	2.20 (0.04)	2.19 (0.06)	0.795
Cultural heritage	2.00 (0.07)	2.12 (0.05)	2.15 (0.04)	2.05 (0.07)	0.249
Economic benefits					
Real-estate valorization	1.59 (0.09)	1.72 (0.06)	1.71 (0.06)	1.79 (0.08)	0.428
Prosperous commerce and/or tourism	1.88 (0.08)	1.86 (0.06)	1.88 (0.05)	2.01 (0.07)	0.391
Energy conservation	2.03 (0.08)	2.12 (0.06)	2.03 (0.06)	2.04 (0.08)	0.710
Regulation & maintenance ES					
Air quality regulation	2.66 (0.05)	2.76 (0.03)	2.71 (0.03)	2.65 (0.05)	0.146
Climate regulation	2.43 (0.06)[ac]	2.58 (0.04)[b]	2.42 (0.05)[ac]	2.45 (0.05)[bc]	0.027
Microclimate regulation	2.39 (0.06)	2.53 (0.04)	2.41 (0.04)	2.43 (0.05)	0.122
Stormwater regulation	2.38 (0.06)	2.43 (0.05)	2.34 (0.05)	2.29 (0.07)	0.333
Noise mediation	1.78 (0.09)[a]	2.03 (0.06)[b]	2.03 (0.06)[b]	2.12 (0.08)[b]	0.021
Habitat maintenance	2.42 (0.05)	2.45 (0.05)	2.42 (0.04)	2.30 (0.06)	0.149
Losses & costs					
Goods and property damage	2.63 (0.07)	2.57 (0.05)	2.73 (0.05)	2.66 (0.07)	0.132
Allergy risk	2.90 (0.07)	2.96 (0.05)	2.99 (0.05)	2.94 (0.07)	0.785
Sunlight blocking	2.25 (0.07)[a]	2.32 (0.05)[ab]	2.45 (0.05)[bc]	2.59 (0.07)[c]	0.001
Visibility decrease	2.26 (0.07)[a]	2.36 (0.05)[ab]	2.49 (0.05)[bc]	2.60 (0.07)[c]	0.002
Risk to individual integrity	2.43 (0.07)[a]	2.61 (0.05)[b]	2.67 (0.05)[b]	2.94 (0.06)[c]	0.000
Litter	2.56 (0.06)[a]	2.57 (0.05)[a]	2.76 (0.05)[b]	2.77 (0.07)[b]	0.003
Insecurity feelings	2.12 (0.06)[a]	2.24 (0.06)[a]	2.41 (0.05)[b]	2.64 (0.07)[c]	0.000
Unpleasant view	2.31 (0.08)[a]	2.51 (0.05)[b]	2.77 (0.05)[c]	2.97 (0.07)[d]	0.000
Maintenance costs	2.49 (0.07)	2.46 (0.05)	2.57 (0.05)	2.69 (0.08)	0.062

Response results are expressed as Mean (Standard Error) of response in a Likert-type importance scale for benefits and ES (0 – not important; 1 – not very important, 2 – important, 3 – very important), and an agreement scale for losses/costs (1 – strongly disagree, 2 – disagree, 3 – agree, 4 – strongly agree).
The superscript letters highlight differences between levels of one socioeconomic variable concerning mean responses; levels with similar responses for one dimension do not differ significantly according to orthogonal contrast analysis ($p < 0.05$).
[1] Statistical significance of the F test (Fischer) or Welch test (for the cases with unequal variances).

with significant differences being found in responses for five out of eight cultural benefits (inspiration, aesthetic pleasure, spiritual enrichment, education and cultural heritage), all of which were more important for women than for men. Women also considered the benefits associated with climate regulation as being more important than men did.

Age was the independent variable accounting for fewer differences in responses concerning benefits provided by street trees (Table 5). People aged 18–24 years valued significantly less spiritual enrichment and noise mediation than older people, and climate regulation was more highly regarded by those between 25 and 44 years old.

The academic education of respondents accounted for significant differences in twelve out of seventeen individual benefits, usually revealing that those who attended or completed a university degree valued more the benefits generated by street trees than those with lower school level (Table 6). Access to university emerged as a threshold affecting mean responses in all regulation & maintenance ES, and in three of the four cultural benefits showing significant differences (aesthetic pleasure, leisure activities and sense of place). The influence of street trees in promoting a prosperous commerce/tourism was also perceived differently among school level classes, and the contrast analysis revealed that people in the high school class rated this benefit as being less important than other classes.

3.3. Individual losses & costs

Allergy risk due to street trees was the issue more highly rated by respondents of the sample taken as a whole (mean: 2.95), as shown in Table 4. Insecurity feelings were the least important nuisance (mean: 2.35), although many people agreed that it was still a relevant problem (particularly people older than 64 years).

Age was behind a number of significant differences in average responses relative to damages caused by street trees. Older people consistently attributted higher importance to issues associated with personal safety (risk to individual integrity, insecurity feelings), accumulation of leaves and other residues (litter), deficient maintenance (unpleasant view), sunlight blocking and visibility decrease (Table 5).

Again, school level accounted for differences in all items except allergy risk, and also goods and property damage (Table 6), suggesting that people with higher academic education consider losses caused by street trees to be of less importance than those having lower schooling (especially people holding the 9th grade or below). One additional relevant finding is that people holding the 9th grade or below considered more negatively than all other school level classes the maintenance costs of street trees.

Considering gender, no significant differences were found regarding responses about losses and costs generated by street trees.

Table 6
Comparative analysis of potential benefits, ecosystem services (ES) and losses/costs generated by street trees in Porto (Portugal), according to school level classes. Results for 819 interviews.

Benefits, ES and losses/costs	School level classes				ANOVA (Sig.)[1]
	≤9th Grade	High school	University	≥Master degree	
Cultural benefits					
Inspiration	1.99 (0.05)	2.07 (0.05)	2.09 (0.05)	2.22 (0.09)	0.087
Aesthetic pleasure	2.30 (0.04)[a]	2.44 (0.04)[b]	2.59 (0.04)[c]	2.70 (0.05)[c]	0.000
Social cohesion	2.21 (0.04)	2.15 (0.05)	2.26 (0.05)	2.31 (0.07)	0.218
Leisure activities	2.34 (0.04)[a]	2.39 (0.05)[a]	2.57 (0.04)[b]	2.58 (0.06)[b]	0.000
Sense of place	2.11 (0.04)[a]	2.14 (0.05)[ab]	2.27 (0.05)[b]	2.29 (0.08)[b]	0.023
Spiritual enrichment	1.59 (0.06)[a]	1.34 (0.07)[b]	1.55 (0.07)[a]	1.41 (0.11)[ab]	0.046
Education	2.15 (0.04)	2.17 (0.05)	2.29 (0.05)	2.22 (0.07)	0.125
Cultural heritage	2.09 (0.05)	2.06 (0.06)	2.05 (0.05)	2.28 (0.08)	0.110
Economic benefits					
Real-estate valorization	1.74 (0.06)	1.60 (0.07)	1.66 (0.06)	1.88 (0.10)	0.126
Prosperous commerce and/or tourism	2.01 (0.05)[a]	1.70 (0.07)[b]	1.89 (0.06)[a]	2.00 (0.10)[a]	0.002
Energy conservation	2.06 (0.06)[a]	1.88 (007)[b]	2.20 (0.06)[a]	2.14 (0.10)[a]	0.005
Regulation & maintenance ES					
Air quality regulation	2.67 (0.03)[a]	2.66 (0.04)[a]	2.77 (0.03)[b]	2.78 (0.05)[ab]	0.035
Climate regulation	2.35 (0.05)[a]	2.42 (0.05)[a]	2.62 (0.04)[b]	2.62 (0.06)[b]	0.000
Microclimate regulation	2.30 (0.04)[a]	2.40 (0.04)[ac]	2.62 (0.04)[b]	2.56 (0.07)[bc]	0.000
Stormwater regulation	2.29 (0.05)[a]	2.34 (0.06) [ab]	2.46 (0.05)[b]	2.50 (0.07)[b]	0.026
Noise mediation	2.00 (0.06)[ab]	1.85 (0.07)[a]	2.10 (0.06)[b]	2.18 (0.09)[b]	0.012
Habitat maintenance	2.33 (0.04)[a]	2.31 (0.05)[a]	2.57 (0.04)[b]	2.47 (0.07)[ab]	0.000
Losses & costs					
Goods and property damage	2.68 (0.05)	2.68 (0.05)	2.60 (0.05)	2.49 (0.08)	0.169
Allergy risk	3.03 (0.05)	2.92 (0.05)	2.93 (0.05)	2.84 (0.09)	0.206
Sunlight blocking	2.61 (0.05)[a]	2.35 (0.06)[b]	2.26 (0.05)[b]	2.19 (0.09)[b]	0.000
Visibility decrease	2.65 (0.05)[a]	2.39 (0.06)[b]	2.29 (0.05)[b]	2.19 (0.09)[b]	0.000
Risk to individual integrity	2.85 (0.05)[a]	2.66 (0.05)[b]	2.49 (0.05)[c]	2.46 (0.09)[bc]	0.000
Litter	2.86 (0.05)[a]	2.59 (0.05)[b]	2.52 (0.05)[b]	2.56 (0.09)[b]	0.000
Insecurity feelings	2.58 (0.06)[a]	2.38 (0.06)[b]	2.10 (0.05)[c]	2.17 (0.10)[bc]	0.000
Unpleasant view	2.82 (0.05)[a]	2.75 (0.05)[a]	2.41 (0.06)[b]	2.44 (0.10)[b]	0.001
Maintenance costs	2.71 (0.06)[a]	2.52 (0.06)[b]	2.36 (0.06)[b]	2.41 (0.09)[b]	0.000

Response results are expressed as Mean (Standard Error) of response in a Likert-type importance scale for benefits and ES (0 – not important; 1 – not very important, 2 – important, 3 – very important), and an agreement scale for losses/costs (1 – strongly disagree, 2 – disagree, 3 – agree, 4 – strongly agree).
The superscript letters highlight differences between levels of one socioeconomic variable concerning mean responses; levels with similar responses for one dimension do not differ significantly according to orthogonal contrast analysis ($p < 0.05$).
[1] Statistical significance of the F test (Fischer) or Welch test (for the cases with unequal variances).

3.4. Trade-offs among benefits and losses & costs

The first statement of the final set in the questionnaire referred to trade-offs among benefits and losses/costs caused by street trees, by asking respondents to evaluate the statement "Trees bring more benefits than damages". In average, people agreed or agreed a lot that trees bring more benefits than damages (mean = 3.50), as presented in Table 7. School level accounted for significant differences of opinion between people who attended university versus those who did not, showing a pattern where the former agree more than the latter with the statement. Still, about 4% (n = 33) of all respondents disagreed or strongly disagreed that trees bring more benefits than damages, of which only 4 people attended university or had a higher school level (data not shown). No significant differences were found for this statement considering age classes or gender (Table 7).

Most interviewed people also agreed that the city of Porto needs more trees (mean: 3.32), and the agreement intensity increased according to education level: those with higher education agreed significantly more with this statement (Table 7). Age also accounted for differences in mean response, with people between 25 and 44 years old agreeing more that Porto needs more trees than all the remaining age groups (mean: 3.41). Gender did not show statistically significant differences in responses (Table 7). Another important finding was that around 8% (n = 73) of the interviewees disagreed or strongly disagreed that Porto needs more trees, most of which completed the 9th grade or less (n = 39), or the 12th grade or less (n = 20) (data not shown).

The statement bearing less consensus in opinions was "Bigger trees bring more benefits than smaller trees" which accounted for about 35% (n = 217) of "disagree" or "strongly disagree" responses (data not shown). Surprisingly, younger interviewees (18–24 years old) and older people (above 64 years old) disagreed significantly more with the statement (mean: 2.58 and 2.71, respectively) than intermediate age classes (Table 7). No significant differences were found in response means according to school level or gender.

4. Discussion

This study revealed that people in Porto valued more environmental benefits (particularly air quality improvement) than cultural ones, not supporting the findings of Madureira et al. (2015). These authors analyzed, in four French and Portuguese urban areas including Porto, beliefs of residents concerning green space benefits, and found that cultural/social benefits were more valued than environmental ones in all cities, although "diminution of urban air pollution" was the second highest ranked individual benefit for Porto; however, "air temperature reduction" was in one of the lowest ranking positions for all cities. The disparities regarding our results might be due to a different formulation of individual benefits or to the fact that urban green spaces in general

Table 7
Agreement level for three statements relative to street trees in Porto (Portugal), according to socioeconomic variables. Results for 819 interviews.

Socioeconomic variables	Trees bring more benefits than damages	Bigger trees bring more benefits than smaller trees	The city of Porto needs more trees
Gender			
Men	3.50 (0.03)	2.85 (0.05)	3.29 (0.04)
Women	3.51 (0.03)	2.80 (0.04)	3.33 (0.03)
Student's t-test (Sig.)[1]	0.801	0.493	0.428
Age class (yrs)			
18–24	3.49 (0.05)	2.58 (0.07)[a]	3.22 (0.06)[ac]
25–44	3.55 (0.04)	2.89 (0.06)[bc]	3.41 (0.04)[b]
45–64	3.52 (0.04)	2.95 (0.05)c	3.31 (0.04)[bc]
+64	3.40 (0.06)	2.71 (0.08)[ab]	3.24 (0.07)[ac]
ANOVA (Sig.)[2]	0.177	0.000	0.038
School level			
≤ 9th Grade	3.34 (0.04)[a]	2.85 (0.06)	3.21 (0.05)[a]
High school	3.43 (0.04)[a]	2.79 (0.06)	3.28 (0.05)[ab]
University	3.67 (0.03)[b]	2.86 (0.06)	3.39 (0.04)[b]
≥Master degree	3.72 (0.05)[b]	2.79 (0.10)	3.57 (0.06)[c]
ANOVA (Sig.)[2]	0.000	0.833	0.000
Sample	3.50 (0.02)	2.82 (0.03)	3.32 (0.03)

Response results are expressed as Mean (Standard Error) of response in a Likert-type agreement scale (1 – strongly disagree, 2 – disagree, 3 – agree, 4 – strongly agree). The superscript letters highlight differences between levels of one socioeconomic variable concerning mean responses; levels with similar responses for one dimension do not differ significantly according to orthogonal contrast analysis ($p < 0.05$).

[1] Significance of Student's *t*-test.

[2] Statistical significance of the F test (Fischer) or Welch test (for the cases with unequal variances).

were considered in the study (while we restricted our analysis to street trees), but more probably to the composition of the sample used, which consisted mostly of respondents holding university degree or higher – about three quarters of the sample, far from the reality in Porto. Nevertheless, a study developed by Bertram and Rehdanz (2015) found that park visitors in four European cities considered the delivery of regulating ES in parks to be more important than the supply of cultural ES (with the exception of recreation), suggesting a potentially wider acknowledgment by city dwellers of the environmental impact of green spaces. Yet, other studies presented contrasting results (e.g. Casado-Arzuaga et al., 2013), indicating that more research is needed to better understand the role of the cultural context in perceiving and valuing different types of ES.

The results for Porto confirmed our initial hypothesis that benefits and losses/costs caused by street trees are perceived differently by citizens according to a set of socioeconomic variables. In our analysis, school level was the variable accounting for more differences in perception of benefits and losses/costs regarding street trees. We identified a tendency, in people with lower level of academic education, to value less the benefits provided by street trees in Porto and attribute more importance to losses and costs, compared to people who attended or completed a university degree. These results are in line with the findings from Avolio et al. (2015), who also found, in a survey of people living in five counties of southern California (in and surrounding the Los Angeles Metropolitan Area) that people with higher level of education attributed more importance to trees than people with less education. This is a noteworthy finding, given that the most deprived area of Porto (Campanhã), which represents about 14% of Porto's population, has a considerably larger proportion of residents holding the 9th grade or below (71% of residents aged 18 years or more; INE, 2011) and a much smaller share of people holding a college degree than all other parishes of Porto, as illustrated in Fig. 3. Furthermore, Graça et al. (2018) found that Porto displayed a considerable difference in terms of supply of regulating ES provided by the urban vegetation (climate and air quality regulation) across the city, and demonstrated environmental inequity towards access to the benefits provided by nature. These authors concluded that the eastern parish (Campanhã) was the greenest of the five city zones analyzed, but revealed the lowest proficiency of regulating ES supply in the whole municipality while the western area of Porto (parishes of Aldoar, Foz do Douro & Nevogilde, and Lordelo & Massarelos) revealed the best performance in ES delivery, reflecting a socioeconomic asymmetry between the deprived eastern side of the city and the wealthy parishes at west.

Of the socioeconomic indicators analyzed by Graça et al. (2017), the most striking was the much lower access to college education by those living in Campanhã, compared to the rest of the inhabitants of Porto (Fig. 3).

Although these findings suggest that the priority area in Porto to enhance environmental equity and ES supply by urban vegetation should be Campanhã, our results suggest that caution should be taken to insure that establishing more green areas and trees in the parish effectively promotes wellbeing in the community. This might be a concern because top-down institutional initiatives to improve tree

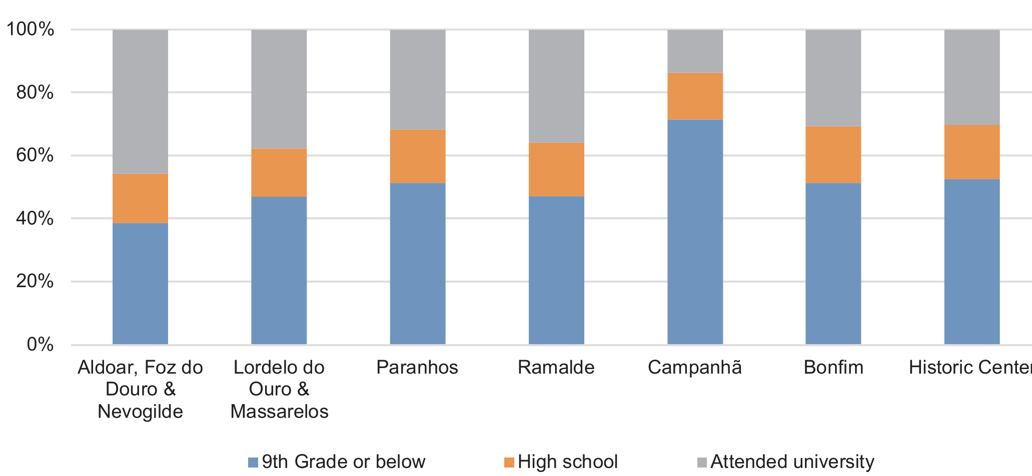

Fig. 3. School level of residents aged 18 years old or above, living in Porto in 2011, per parish of residence according to the administrative reorganization of parishes established in 2013 (INE, 2011).

density and condition in the parish risk to be considered as promoting more nuisances than wellbeing (Heynen et al., 2006).

Age was also an important variable explaining different perceptions regarding street trees, with older people showing more concern towards losses and costs. In a case study in southwest England, Flannigan (2005) noted, likewise, that increased age negatively influenced opinions about street trees. People aged 65 years or above constitute about 23% of Porto's population (20% in our sample), hence acknowledging and addressing negative aspects of street trees in urban planning and management is of crucial importance.

The differences accounted for gender can be explained by a stronger environmental attitude and behavior in women than men (Zelezny et al., 2000).

Information access can likewise influence intensely how benefits and losses/costs caused by trees are perceived, especially reflected in our results regarding the statement "Bigger trees bring more benefits than smaller trees", with which more than one third of the interviewed people disagreed or strongly disagreed. Research has shown that the size of trees impacts delivery of regulating ES (Nowak and Dwyer, 2007; Pretzsch et al., 2015), and the benefits associated with these services were in general considered the most important ones for respondents in our case study. Therefore, it was expected that people with higher education level would be more aware of the impact of tree size in generating benefits for wellbeing. Surprisingly, no significant differences were found for mean response across school level classes. These results suggest that there is a considerable margin to raise awareness among Porto's citizens about the increased value of bigger trees. If people become more aware of the advantages of larger specimens, they may change their attitude and behavior concerning nature and consider more positively trade-offs between benefits and losses/costs caused by trees, increasing public support for their protection (Jones et al., 2013).

Some authors suggest that environmental factors can also have an important role in shaping attitudes and preferences regarding trees. For example, Avolio et al. (2015) found that local climatic and environmental factors affected preferences for tree attributes as much as socioeconomic variables, and Schroeder et al. (2006) suggested that a cooler climate, together with the closer proximity of street trees to houses, might explain the preference for smaller trees in two communities of the United Kingdom, compared to one community located in the United States. Given the climate in Porto, shade could probably be regarded as an important asset for residents. However, the proximity of street trees to houses in Porto can probably explain the high level of general agreement with losses/costs and why so many interviewed people disagreed that bigger trees provide more benefits than smaller trees. Porto is a city with a dense urban fabric, where street trees are planted frequently very close to building facades, potentially creating many direct nuisances to residents.

Allergy risk was the most highlighted negative aspect of street trees, which is consistent with the association established by Ribeiro and Abreu (2014) between monthly hospital admissions and tree pollen in Porto, particularly of the genera *Acer, Platanus, Populus* and *Quercus*, which are very common in streets. Although more studies are needed to establish thresholds of allergenic pollen concentrations with impact in human health, caution should be taken regarding the choice of tree species when designing green spaces in urban settings (Cariñanos and Casares-Porcel, 2011).

Our results also underline climate and microclimate regulation as two of the most valued ES provided by street trees in Porto, and a general support for more trees in the city. Given the role that planting street tree species with high cooling potential in densely built areas might have in mitigating heat-wave risk (Gillner et al., 2015), this could be a positive strategy to enhance Porto's resilience to climate change. Nevertheless, street trees might also increase exposure to air pollution by trapping pollutants in narrow street canyons (Vos et al., 2013), although some studies suggest that vegetation type and design can have a significant impact in how air quality is affected (Gromke and Ruck, 2007; Janhäll, 2015).

The results do not allow to understand how the low importance attributed by respondents to direct economic benefits of street trees affects real-estate value in Porto, which has been found to increase with their presence in other geographical settings (Pandit et al., 2013). It is possible that local cultural and urbanistic characteristics affect real-estate valuation by street trees, but more research should be developed to answer these questions.

It has been demonstrated that opinions of urban residents about green spaces can vary across geographical contexts, although some consensual values emerge (Madureira et al., 2015). However, more studies are needed to confirm this consensus and to better understand the role of socioeconomic and cultural variables. Moreover, it is possible that specific types of green space are valued differently (e.g. urban parks might be more relevant for recreation and leisure than street trees, and private gardens might hold particular importance for provision of food).

Based in our findings, we strongly recommend implementing participatory approaches (see Lynam et al., 2007 for a comprehensive overview of methods) to provide more information to citizens about the benefits generated by urban trees, and work with the community to foster inclusive and democratic solutions. Co-management of the urban tree-resource can also lead to more legitimacy of measures, compliance from the community, justice, equity and empowerment (Berkes, 2009).

5. Conclusions

This exploratory study provided evidence that perception of benefits and losses/costs generated by a specific SPU is strongly influenced by the socioeconomic characteristics of urban societies, which might be a source of conflicts if not properly acknowledged in planning and management initiatives. Our results also underline that actions targeting environmental equity might have adverse effects, if the specific values and views of the community are overlooked. Furthermore, people may not be aware of the impact of specific factors, such as tree size, in ecological outcomes crucial for urban wellbeing. Therefore, appropriate communication strategies can be decisive to influence positively tree acknowledgement and support by urban citizens.

Our results encourage planning and management of street trees within a multicriteria decision-making framework, in which the specific location of trees, species type, future development and management must be considered in light of local problems and needs, in order to obtain the best compromise towards a desirable outcome for both stakeholders and beneficiaries. Consequently, integrating scientific knowledge and community opinions could provide a strong evidence-based strategy for implementing a successful urban green infrastructure.

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Appendix A. Questionnaire applied between February and May of 2017 to a sample of 819 people aged 18 years old or above, in the streets of Porto (Portugal)

Note: translated to English from the original Portuguese version used to collect the data.

Please indicate your degree of importance for each of the following benefits provided by street trees:	**Not important**	**Slightly important**	**Important**	**Very important**	**No opinion**
Stimulating new ideas, thoughts and/or creative expressions					
Beautifying streets, views and/or the city					
Promoting meetings with friends and neighbors					
Promoting recreation and tourism by providing pleasant places for walking, running, cycling, …					
Fostering a sense of attachment to a place and/or to the city					
Representing spiritual, religious, or personal special meanings					
Raising curiosity and knowledge about nature's cycles and biodiversity					
Supporting local historical and cultural values and identity					
Improving air quality through removal of atmospheric pollutants					
Supporting global climate regulation through carbon sequestration / reduction of greenhouse gas concentrations					
Improving microclimatic comfort through regulation of local temperature and wind					
Preventing or mitigating floods by slowing down and intercepting rainwater before falling to the ground					
Buffering the noise of cars or specific activities					
Supporting lifecycle conditions for biodiversity in cities					
Increasing the monetary value of real-estate					
Fostering commercial / touristic activities which provide monetary revenues					
Increasing energetic efficiency of buildings, by reducing consumption of energy for cooling / heating					

Other important benefits: ______________________________

Please indicate your level of agreement concerning the following damages caused by street trees:	**Strongly disagree**	**Disagree**	**Agree**	**Strongly agree**	**No opinion**
Damaging goods and structures such as cars, sidewalks, walls, …					
Increasing allergic reactions due to pollen release					
Providing unwanted shade, blocking sunlight					
Reducing visibility to streets (from home)					
Increasing risks for people's security due to tree or branch fall					
Undesired accumulation of residues due to leaf and fruit fall					
Increasing fear of potential criminal activity in streets due to reduced visibility caused by trees					
Unattractive views due to neglected maintenance or bad condition of trees					
Public funds needed to support tree plantation and maintenance					

Other important damages: ______________________________

Please indicate your level of agreement with the following statements:	**Strongly disagree**	**Disagree**	**Agree**	**Strongly agree**	**No opinion**
Trees bring more benefits than damages					
Bigger trees bring more benefits than smaller trees					
The city of Porto needs more trees					

Age: __________ Gender: ☐ Female ☐ Male

School level: ☐ 9th Grade or below ☐ High school (≤12th grade) ☐ Attended or completed university ☐ Master or higher degree

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