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Between tree lovers and tree haters. Drivers of public perception regarding street trees and its implications on the urban green infrastructure planning.

Abstract

Street trees can play an important role in the urban green infrastructure (UGI). However, changes in the urban fabric often have perverse effects on the structure, diversity, and performance of street trees, and, consequently, on their perception by the public.

This research explores public perception of the current street tree adequacy in a coastal neighborhood of Porto that went through a major densification in its urban fabric during the second half of the 20th century.

The research methodology included: i) a survey to evaluate public perception of tree services and disservices, and public perception of the adequacy of street trees in the study area; and ii) two Logit models relating public perception of tree services with the characteristics of respondents and streets.

96% of the respondents self-reported as tree lovers. However, more than 30% found the street trees of the study area inadequate to the present urban fabric and 5% have already made a complaint to the municipality. Characteristics of respondents and streets affect respondent's perceptions. Education plays a key role in the acknowledgment of tree services. Older respondents are more likely to perceive trees as dangerous. Respondents who live on streets dominated by Black Poplar are more likely to dislike trees.

Results implications on UGI planning and design advise an adjustment of tree dimensions to street dimensions, an increase in street tree diversity, and an improved street planting design. Results also suggest that an investment in education and information could lead to conflict mitigation.

Keywords: Logit models; Porto; Tree-lined streets design and management; Urban forest; Urban fabric change.

Introduction

Cities, people, and street trees

In recent years, a wide range of research studies demonstrates that the presence of trees in cities is mandatory to minimize the effects of the unprecedented urban densification that our planet is experiencing (Sanesi and Chiarello, 2006; Soares et al., 2011; Gerstenberg and Hofmann, 2016). Earth's current situation demands greener cities, where trees are key elements in the urban fabric and important instruments in urban planning. Street trees play a crucial role in this quest, as they increase the livability of the urban environment by reducing stormwater runoff, improving air quality, storing carbon, providing shade, and lessening the urban heat-island effect (Mullaney et al, 2015). Also, their linear arrangement allows the connection among green spaces, contributing to a more cohesive Urban Green Infrastructure (UGI) (Fernandes et al., 2015).

While in the past, street trees have been essentially perceived as decorative elements (Sanesi and Chiarello, 2006), nowadays their environmental, economic, social and aesthetical services have been increasingly acknowledged (Millennium Ecosystem Assessment, 2005; Seamans, 2013). However, the positive attributes of street trees are not the only ones perceived by people. In the streets, trees live alongside with people and buildings, which increases the opportunities for negative interactions (Dandy, 2010). The costs of maintenance, the potential damages to urban infrastructures, the produced green waste and the allergies caused by pollinating can lead people to complain and to feel that, somehow, trees are inappropriate (Rotherham, 2010; Escobedo et al., 2011).

Over the years, several studies about public perception, attitudes and opinions regarding street trees were conducted to understand what drives people to either "love" or "hate" them (Hitchmough and Bonugli, 1997; Todorova et al., 2004; Flannigan, 2005; Schroeder et al., 2006; Zhang et al., 2007; Rae et al., 2010; Monteiro et al., 2013; Camacho-Cervantes et al., 2014; Gerstenberg and Hofmann, 2016; Zhao et al., 2017). These studies were mainly accomplished through questionnaires or visual simulations. According to a broad literature review conducted by Mullaney et al. (2015), residents consistently express a positive view of street trees, and most residents believe that the benefits provided by street trees clearly outweigh any detriments. The same study mentions that most residents cite aesthetics, shade provision, and the calming effect as the most important reasons for wanting street trees in their neighborhood.

Furthermore, research has found that social, economic and psychological factors (such as age, gender, education level, social and economic status, ethnic-racial origin, or emotional bond) might influence opinions and attitudes towards street trees (Lo et al., 2017). Schroeder et al. (2006) argue that different cultures and climatic zones can also affect public perception. These authors have found that the shade provided by trees is more appreciated in warmer locations (Midwestern United States) than in cooler locations (northern United

Kingdom), suggesting that the specific needs of these communities play an important role in people’s perceptions.

Studies also reveal strong ambivalent attitudes towards street trees. Even though the negative aspects of street trees are usually outweighed by the positive aspects, people who dislike (living near) trees tend to complain to the local authority, while people who have more positive opinions are more likely to remain silent (Schroeder et al., 2006). References to the NIMBY syndrome “I like trees but… Not-In-My-Back-Yard” are also currently found in the literature (Schroeder et al., 2006; Nassauer et al., 2009). Thompson and Barton (1994) distinguished the attitudes toward nature (trees) in three categories: ecocentric, anthropocentric and apathic. Ecocentric individuals appreciate nature for its own sake; anthropocentric individuals understand that the environment should be protected because it is important for human well-being and quality of life; apathic individuals express a clear indifference regarding environmental issues.

The health condition and the planting design of trees can also trigger negative responses from the population. Street trees are not always planted under optimal circumstances and do not always receive the necessary care and attention during their lifetime. The lack of proper maintenance by qualified professionals usually leads to a decrease in the provision of services and aesthetic quality of trees, which tends to negatively affect people’s opinion (Rotherham, 2010).

Planning, design and management of street trees

Trees in the urban environment, especially street trees, are constantly under a wide range of stress factors, such as pollution, high temperatures, soil compaction, lack of space to grow, vandalism, etc. (Yang and McBride, 2003). These harsh conditions force an unceasing replacement of the trees and prevent the development of stable and mature tree alignments. This constitutes a problem because trees’ benefits are proportional to trees’ dimension, i.e. large and mature trees provide more services than smaller trees (McPherson, 2005). Moreover, smaller trees are more susceptible to the hostility of the urban environment (Trees and Design Action Group, 2010).

In the design process of tree-lined streets some key aspects can be anticipated to reduce future problems, maximize the benefits of trees, and allow a cost-effective tree management system: i) select appropriate tree species, ii) ensure that trees are planted in a proper location and, very important, iii) implement a preventive maintenance program that will monitor trees’ development (Bloniarz and Ryan, 1993; Bell et al., 2005).

Tolerance, resistance, adaptability to the environmental site conditions, and costs of production, establishment, and maintenance are some of the characteristics that should determine the selection of a tree species (Sæbø et al., 2005; Gerstenberg and Hofmann, 2016). Aesthetic quality must also be carefully considered. Some studies have shown that people usually prefer trees with a dense canopy (Asgarzadeh et al., 2014; Gerstenberg and Hofmann, 2016; Zhao et al., 2017) and monospecific compositions of small species with colored flowers (Todorova et al., 2004). Despite the visual preference for regular monospecific alignments, species diversity is instrumental for overall urban forest resilience and resistance to diseases (Gerstenberg and Hofmann, 2016).

Public perception studies regarding street trees are useful tools to identify people's opinions and preferences and to instruct a more suitable planning, design, and management of the UGI (Monteiro et al., 2013). However, it should be noted that most research on the perception of street trees has been undertaken in the United States of America (Mullaney et al, 2015) and focused on specific cities (Schroeder et al., 2006), what advises caution in generalization or extrapolation of findings.

Objectives and Research questions

In recent years, research has been conducted on the Porto UGI focusing mainly on the urban biodiversity (Farinha-Marques et al., 2015). However, apart from parks and gardens, the individual contribution of other types of green space to the UGI, namely of tree-lined streets, has not yet been properly addressed in this city. This research examines tree-lined street users' perception of trees and street trees and its implications in UGI planning, by exploring the following research questions:

i. How tree-lined street users perceive trees' services and disservices?
ii. How tree-lined street users perceive street trees' adequacy to streets?
iii. Do characteristics of tree-lined street users affect their perception of trees and street trees, and how?
iv. Do characteristics of tree-lined streets affect the perception of their users, and how?

Material and Methods

Study Area

The study area encompasses 13 tree-lined streets (S1 to S13), belonging to the associated parishes of Foz do Douro, Nevogilde, and Aldoar, in the Porto seafront (Fig. 1). The climate of the study area is influenced by the close proximity to the Atlantic Ocean, being characterized by warm winters and mild summers, and frequent north winds.

Insert Fig. 1

Porto seafront is one of Porto areas with a higher number of tree-lined streets and one of the most difficult to manage due to the high number of resident complaints about street trees (Fernandes et al, 2015). Street tree planting in the area began in the first decades of the 20th century when the urban fabric was dominated by single-family houses surrounded by gardens. In the second half of the 20th century with the increasing demand for housing, multi-story buildings, with 3 to 5 floors, gradually substituted for single-family detached houses. These buildings, in addition to its higher volume, are closer to the street as they have also occupied the space of front gardens (Fernandes et al., 2015). These changes are quite evident in Fig. 2, especially in Gondarém street (S11 in Fig. 1; second street from the seafront in Fig. 2). This densification of the urban fabric marked the beginning of the conflict among street trees, buildings and residents in this neighborhood, which has been increasing with the growth and aging of trees.

Insert Fig. 2

The Data

The data includes respondents' perception of trees and street trees (Y variables), observable characteristics of the respondents (R variables), observable characteristics of the streets (Z variables), and a set of street dummy variables that allow the capture of unobservable characteristics of respondents and streets (S variables). See Tables A1, in the Appendix, for a description of the variables and a summary of the data.

Respondents' Data (R and Y variables)

Data regarding respondents' observable profile (R variables) and respondents' perception of trees and street trees (Y variables) was collected in street interviews, conducted between 2016 and 2017, to the users (residents and non-residents) of 13 tree-lined streets located in the study area (Fig. 1), and comprises 281 observations.

The interview was pre-coded and subdivided into 3 sections. Section 1 gathered information on the respondent profile: i) street user status (resident, frequent user, occasional user); ii) gender; iii) age-class; and iv) education. Section 2 required the respondents to rate a list of services and disservices of trees in general. Section 3 inquired respondents about the adequacy of street trees in the street where the interview occurred. Respondents that found the street trees inadequate were asked to justify their opinion and provide suggestions to improve tree-line design of the street. Finally, respondents were asked if they have presented a complaint about the street trees and why? Answers in section 3 were pre-coded but provided the option "other" to capture non-coded information.

Environmental Data (Z variables)

Data regarding streets observable profile (Z variables) was collected in a previous research by Fernandes et al. (2015). Streets were characterized according to the following parameters: i) street length and width; ii) street tree dominant species; iii) average street tree diameter at breast height (DBH) and crown diameter (CD); iv) existence of conflicts with facades; v) dominant type of street tree plantation (single row, double row) and dominant place of street tree plantation (with or without tree pit); vi) dominant urban fabric typology (single family or multi-story); vii) traffic intensity and way; and viii) tree health diagnosis, according to the Visual Tree Assessment method (Mattheck and Breloer, 1994) supported by a Vertex III V1.5, Transporter T3 and a resistograph. A full description of all variables (R, Y, Z, and S) can be found in Table A1 of Appendix.

The Logit models

Two Logit models were used to relate respondents' perception of street trees with respondent and street observable and unobservable profiles:

- Model 1 relates respondents' perception of street trees (Y variables) with respondents' observable characteristics (R variables) and with unobservable characteristics of respondents and trees (S variables). In this model, the Z variables are not specified. They are treated as unobservable characteristics of the streets, being their effects captured by the S variables. The model yields consistent estimators.

- Model 2 relates respondents' perception of street trees (Y variables) with respondents' observable characteristics (R variables) and streets' observable characteristics (Z variables). In this model, the S variables are not specified. Part of the effects captured by the S variables in Model 1 is captured by the Z variables in this model. Model 2 yields consistent estimators unless there are unobservable characteristics of respondents and streets (captured by the S variables in Model 1) correlated with the observable characteristics considered in the model (R and Z variables).

Due to multicollinearity between S and Z variables, we did not consider the simultaneous inclusion of these variables in the regressions. However, the adoption of two regression models helped us to identify the characteristics of streets that affect respondents' perceptions of street trees.
Concerning the Y variables, respondents were asked if they agreed or disagreed or were indifferent to with $j = 1, \ldots, 13$ statements regarding street trees.
We have run 13 multiple logistic regressions for each model, 1 per statement *j*, in a total of 26 regressions. Each regression *j* has a binary outcome: $Y_j = 1$, the respondent agrees with statement *j*; $Y_j = 0$, the respondent disagrees or is indifferent to statement *j*. Therefore, each multiple logistic regression yields the likelihood of agreement with a given statement *j* ($Y_j = 1$) in relation to the independent *X* variables, the latter assembling the R and the S or the Z variables, depending on the Logit model being considered:

$$\hat{p}_j = E(Y_j = 1 \backslash X) = \frac{exp^{X\beta + u_j}}{1+exp^{X\beta + u_j}} \text{ , } j = 1, \ldots, 13 \text{ statements} \quad (1)$$

By using the natural log of the likelihood of $Y_j = 1$ as the dependent variable, the relationship in (1) can be linearized and treated much like multiple linear regression:

$$ln\left(\frac{\hat{p}_j}{1-\hat{p}_j}\right) = X\beta + u_j \quad (2)$$

$\hat{L}_j = ln\left(\frac{\hat{p}_j}{1-\hat{p}_j}\right)$ is called the logit.

In (1) and in (2), u_j is the residual term associated with the likelihood of $Y_j = 1$. As $\hat{p}_j$ goes from 0 to 1, the logit goes from $-\infty$ to $+\infty$. The logit is linear in the X variables while the probabilities are not. Regression results can be presented showing the coefficients or equivalently the related 'Odds Ratios'. The logistic regression used in this research yields the 'Odds Ratios'. An 'Odds Ratio' greater (less) than 1 indicates that the regressor increases (decreases) the likelihood of $Y_j = 1$, that is, the likelihood of respondents agreeing with the statement.

Results and Discussion

Users' observable profiles by street

Fig. 3a shows the distribution of respondents per street. Longer and busier streets, with more street trees, like S11 and S10, have more interviews. Regarding street user status, results show a similar percentage of residents (38%) and frequent users (39%), totaling almost 80% of the respondents. This fact can provide us with more assertive perception results, as the perception of street trees adequacy can be influenced by the time people spend in the street and how they experience it (van der Linden, 2014). This dominance is observable in all but one of the surveyed streets (Fig. 3b).

The majority (58%) of respondents are female. This female dominance occurs in all surveyed streets, with the exception of S9, with 62% of male respondents, and S3 and S2, with a balanced percentage of male and female respondents (Fig. 3c). Respondents are distributed among all the age groups. However, it is noticeable a greater representation of older age classes: 1/4 of all the respondents have more than 65 years and most of them (59%) have more than 45 years (Fig3d). Almost half of the respondents (48%) have higher education (bachelor degree or above), but respondents' education is quite variable in the study area (Fig.3e).

Insert Fig. 3

Streets' observable profiles

Data regarding streets' observable profiles is presented in Table 1.

Insert Table 1

Streets in the study area are mainly one-way streets and have a high variability in traffic intensity. 'Single-family' is the dominant house type, but in most streets, this typology coexists with the typology 'multi-story'.

Tree density varies widely in the study area. S7 and S13 are, respectively, the streets with the lowest and the highest tree density. The dominant type of street tree plantation is 'double row' (trees on both sides of the street), occurring in ten streets; and 'with tree pit', occurring in eight streets.

There are four dominant street tree species in the study area. *Platanus x acerifolia* (London Plane), the largest species, is the dominant in seven streets (S2, S4, S5, S7, S10, S11, and S13); *Celtis australis* (Mediterranean Hackberry) is dominant four streets (S3, S6, S8, and S12); *Acer negundo* (Box Elder) is dominant just in S1 and *Populus nigra* (Black Poplar) is dominant just in S9.

The relation between the Crown Diameter (CD) and the Diameter at Breast Height (DBH) is an indicator of the stability and naturalness of the trees. High values indicate trees with a normal shape and size. Low values indicate trees with an under normal shape and size, which can be the result of severe pruning (Sumida et al., 2013). S5 and S12 are, respectively, the tree-lined streets with the highest and lowest CD/DBH relation. All the streets in the study area have street trees in conflict with facades. S11 is the street with more trees in conflict with facades (63%). S7 and S8 also stand out with almost half of the trees in conflict. S2 has the less percentage of trees in conflict (10%).

Fig. 4 displays the most common observable profiles of the streets of the study area.

In the Appendix, Table A1 presents the mean values of the R variables (tree-lined streets users' observable characteristics) and Z variables (tree-lined streets observable characteristics) per street.

Insert Fig. 4

Logit models' results

Logit models were used to relate respondents' perception of street trees with respondent and street observable and unobservable profiles, specifically addressing the following research questions: Do characteristics of tree-lined street users affect their perception of trees and street trees, and how? Do characteristics of tree-lined streets affect the perception of their users, and how?

Table 2 and table 3 below yield the 'Odd Ratios' respectively of Model 1 and Model 2. Only the significant 'Odds Ratios' are stated. The STATA complete output is available upon request. The explanatory power of both models is similar. Except for statement Y10-'Trees damage houses', the significance and magnitude of coefficients on the R variables are similar in both models. In what respects to statement Y10, the coefficients on R2 (occasional visitor) become significant in Model 2. Altogether, Model 2 does not seem to have a problem of omitted variables. As Model 1, it seems to be generating consistent estimators.

Insert Table 2

Insert Table 3

Regarding respondents' perception towards trees in general, it was found that to be a respondent of S9 or streets having Black Poplar as the dominant species (Z3) (which is the single case of S9), decreases the likelihood of agreement with the statement Y1-'I like trees'. These results suggest a dislike for Black Poplar as a street tree, which stems from the "cotton" produced by this tree in the seeds spreading season. According to Camacho-Cervantes (2014), people say that the Black Poplar produces "garbage" and wrongly relate it to health problems, namely allergies. Although this urban myth has already been clarified by researchers as Çelik et al. (2005) and Dursun et al. (2008), it still remains rooted in people's mind. Beliefs regarding trees influence people attitudes (Heberlein, 2012). To believe that trees provide benefits can induce positive attitudes towards trees, but the opposite is also true: to believe that trees can bring problems can induce negative attitudes and justify the above result (Moskell and Allred 2013).

To be a respondent of S2 decreases the likelihood of agreement with statement Y2-'I like the shadow of trees'. This result may be related to the narrowness of this street combined with the dominant species being the London Plane, which makes S2 one of the streets of the study area with greater shadow. According to Asgarzadeh et al. (2014), "*a dense tree canopy could make the street dark, increasing perceptions of oppressiveness and danger, especially if trees are really close*". Some studies claim that shade provision is an important reason for wanting street trees (Mullaney et al., 2015) especially in locations with hot summers (Schroeder et al., 2006). As stated before, in Porto, and specifically in the seafront (the study area), summers are mild with frequent north winds and that can also explain this result.

Respondents being residents increases the likelihood of agreement with the statement Y3-'I like the seasonal variations of trees (flowers, leaves, etc.)' since residents are closer witnesses of these variations.

Respondents of S3, S9, and S10 streets are less likely to agree with the statement Y4-'Trees favor the physical and mental well-being of populations. In all these streets, Black Poplar, perceived as a source of health problems, is either the dominant tree (S9) or has a substantial occurrence (S3 and S10). The likelihood of agreeing with the statement Y5-'Trees are important for life in a city (oxygen production, temperature regulation, etc.)' decreases for respondents from S4. The lower education of this street respondents' might be at the basis of this result since the importance of education as a driver for increasing the acceptability of urban trees has already been suggested (Kirkpatrick et al., 2012).

Regarding respondents' perception of disservices of trees in general, it was found that respondents of S2, S9 and S10 are more likely to agree with the statement Y6-'Trees are ugly'. In all these streets, Black Poplar is either the dominant tree (S9) or has a substantial occurrence (S2 and S10). In S2, to the "Black Poplar effect" adds the overshadow effect. As opposed, respondents from streets with trees planted in tree pit (Z8) are less likely to agree with this statement, which might reveal a preference for well-ordered and designed tree-lined streets.

Occasional visitors (R2) (less aware of tree dimension) and more educated respondents (R5) (more likely informed about the proportionally greater services performed by big trees) (Stagoll et al., 2012; Kirkpatrick et al., 2012) are less likely to agree with the statement Y7-'Trees are too big'. On the contrary, respondents from S5, S8, and S10 are more likely to agree with the statement. The dominant tree being London Plane in S5 and S10; and the high percentage of trees in conflict with facades (50%), combined with the 'single-family' dominant housing type, in S8, might also justify this result. This can also explain respondents of S5 being more likely to agree with the statement Y8-'Trees occupy too much space'. The relation between street trees appropriateness and attractiveness and house size was mentioned by Hitchmough and Bonugli (1997): small trees were perceived to be most attractive when adjacent to small houses. Head and Muir (2005) also found that the major stated motivation for removal of trees was the potential danger afforded by tree size.

Older respondents are more likely to agree with statement Y9-'Trees are dangerous', as the (increasing) age of respondents has a negative impact on opinions towards trees (Williams, 2002; Schroeder et al. 2006). On the contrary, more educated respondents (R5) are very significantly less likely to agree with this statement, as they can better evaluate and balance the advantages and risks of trees (Kirkpatrick et al. 2012). The same occurs, although with less significance, with occasional users (R2), a fact that can be justified by the absence of the NIMBY syndrome in this group (Thompson and Barton, 1994).

The likelihood of agreeing with Y10-‘Trees damage houses’, increases with older respondents, which can be justified by their higher perception of risk, as previously mentioned. It also increases for respondents from S1, S2, S5, S9, and S10. With few exceptions, these streets have in common London Plane as the dominant species (except for S1- Box elder and S9 – Black Poplar), planted in ‘double row’ (except for S1), and ‘single-family’ as the dominant housing type (except for S10, though a substantial occurrence of ‘single-family’ can be noted in this street). So, it is likely that the combination of these Z variables is contributing for this result (very significant for S10) as people perceive that trees are bigger than their houses and, therefore, can damage them (Kirkpatrick et al., 2012). As happened with statements Y7 (“Trees are too big”) and Y9 (“Trees occupy to much space”), more educated respondents are very significantly less likely to agree with statement Y10 (“Trees damage houses”). Although less significant, residents (R1), occasional users (R2) and respondents from streets dominated by Mediterranean Hackberry (Z2) (S3, S6, S8, S12) are also less likely to agree with the statement. These results can arise from the low tree density in the streets dominated by the Mediterranean Hackberry; from the absence of the NIMBY syndrome, in occasional users; and from the higher education of residents (48% with a bachelor degree or above).

The likelihood of agreeing with statement Y11-‘Trees should be planted only in parks and gardens’ increases in older respondents (R4), a result consistent with the previous ones for this age group. It also increases for respondents from S2, S3, and S8; and for two-way streets (Z11). S2 and S3 are both two-way streets (Z11), so driving space and visibility issues could explain this outcome (Gorman, 2004). S8 is a one-way street, but it has a high tree density and a quite high percentage of trees in conflict with facades. Respondents that are occasional visitors (R2) and/or more educated (R5) are less likely to agree that ‘Trees should be planted only in parks and gardens’ for the reasons already pointed out in the analysis of results of statement Y9- ‘Trees are dangerous’.

Section 3 of the interview includes two questions addressing the adequacy of street trees in the street where the interview occurs. In what concerns statement Y12-‘The trees in this street are well planted’, respondents from S3, S8, and S10 and from streets with trees planted in tree-pits (the case of all the previous ones) are more likely to agree with the statement, suggesting that people prefer street trees planted in tree-pits. Respondents that are resident (R1) are less likely to agree with the statement because their daily contact with the trees makes them more demanding about the adequacy of street trees on their street of residence.

Finally, respondents are asked if they already ‘have presented a complaint to the municipality about the street trees’ - Y13. Female (R3) respondents are less likely to have presented a claim. Older respondents (R4), more educated respondents (R5), and respondents from S1, S7, S8, S9, and S12 are more likely to have presented a claim. These results are consistent with previous findings. Older people are more likely to present a claim as they often perceive trees as dangerous. More educated people are more likely to present a complaint, as they tend to be more proactive. Complains by street can be related with the following: S1 and S12 respondents being mainly residents or frequent users (over 80%), with more than 55 years (over 60%), and with a bachelor degree or more (near 60%); S7 having a high percentage of trees in conflict (40%); S8 respondents being mainly residents or frequent users (80%), with more than 55 years (over 60%), and S8 having half of the trees in conflict with facades; and Black Poplar being the dominant species in S9.

Conclusions

Tree-lined streets are an important component of the Porto urban forest, performing an instrumental role in the UGI anatomy and connectivity. Complains about street trees are abnormally high in the seafront neighborhoods, demanding a great effort to properly manage and maintain them. To inform the future planning, design, and management of the Porto urban forest, a research was conducted to assess how the characteristics of streets, street trees, and street users affect attitudes towards street trees.

Seafront street users are mainly residents or frequent users, female, over 45 years old, and with a bachelor degree or above. Streets and street trees observable profiles are quite variable. Single-family is the dominant housing type but 'single family' and 'multi-story' housing typologies often coexist in the streets of the study area. London Plane is the dominant species in most streets, but Black Poplar has a substantial occurrence. Most of the trees are planted in a double row and in tree pits.

Specific research questions were addressed:

How tree-lined street users perceive trees' services and disservices?

More educated people recognize the importance of (large) trees, valuing more the services than the disservices of trees. As opposed, less educated people tend to take no notice of the services provided by trees in the city. Older people have a greater perception of trees and street trees disservices, as they are more afraid of the dangers afforded by trees and believe that big trees can damage their houses. While the shadow of trees is often perceived as a service, in this study it is perceived as a disservice in narrow overshadowed streets. Residents perceive the seasonal variation of trees as a service.

This research shows that people living in close proximity with Black Poplar tend to undervalue the benefits of trees for human health. This probably arises from the perception of Black Poplar as a provider of disservices (respiratory allergies). According to Moskell and Allred (2013), to believe that trees are problem causers can induce negative attitudes towards them. Accordingly, results show that most people reject Black Poplar as a street tree and that people who do not like Black Poplar, do not like trees.

How tree-lined street users perceive street trees' adequacy to streets?

More than 1/3 of tree-lined street users found street trees inadequate and 5% have already made a complaint. Some of the respondents suggested a ‘change in the pruning regime’ and others ‘replacing the current trees for more suitable ones’. Recommendations like ‘tree pits should be included or replaced by new ones’, and ‘planting conditions should be gradually improved and tree species should be suited to the existing space’ were also made. The Black Poplar is perceived as an inadequate street tree, probably due to its association with respiratory health problems. The London Plane is perceived as an inadequate street tree, probably due to its large dimensions.

Do characteristics of tree-lined street users affect their perception of trees/street trees, and how?

The characteristics of tree-lined street users affect their perception of trees and street trees. Older respondents tend to dislike larger trees; more educated respondents tend to value more the services than the disservices of trees; and occasional users reveal some indifference regarding the services of street trees. According to these findings, more educated respondents reveal eco/anthropocentric characteristics and occasional users apathic characteristics (Thompson and Barton, 1994).

Do characteristics of tree-lined streets affect the perception of their users, and how?

Characteristics of tree-lined streets affect the perception of their users, namely the perception of residents and frequent users. Residents of streets dominated by single-family houses like less the plane trees, probably due to their large dimensions.

Contribute of this research to the design of tree-lined streets and UGI planning in the city of Porto.

Research main findings advise the following guidelines for tree-lined street design and UGI planning in Porto:
- in narrow streets, gradually replace large trees by medium or small trees guiding their growth from the juvenile stages,
- avoid planting trees directly on the pavement, and insert tree pits in streets where trees are planted directly on the road or sidewalk pavement,
- avoid using Black Poplar as a street tree, allocating its planting to parks and gardens, but invest in environmental awareness and education about this species,
- diversify street tree species by introducing some species with greater seasonal variation,
- take into account preexisting street trees when planning changes in the urban fabric regulated by the City Master Plan.

To understand what drives public perception of street trees, to engage the population in the street tree design process, and to raise awareness by providing targeted education about trees' benefits are fundamental steps to generate more public acceptance, satisfaction, responsibility, and care over the shared space.

Future research is needed to better inform the planning and design of Porto's UGI. This will require other study areas in a more extensive research. Expansion of this research would also allow the use of a more explanatory regression model and the overcome of some of the limitations of the binary model adopted, namely the need to collapse indifference and disagreement responses, and the inability to use the explanatory power of mediator variables.

Appendix

Insert Table A1

References

Asgarzadeh, M., Koga, T., Hirate, K., Farvid, M., Lusk, A., 2014. Investigating oppressiveness and spaciousness in relation to building, trees, sky and ground surface: A study in Tokyo. Landscape and Urban Planning 131, 36-41. http://doi.org/10.1016/j.landurbplan.2014.07.011.

Bell, S., Blom, D., Rautamäki, M., Castel-Branco, C., Simson, A., Olsen, I.A., 2005. Design of Urban Forests. In: Konijnendijk, C.C., Nilsson, K., Randrup, T.B., Schipperijn, J. (Eds.), Urban Forests and Trees, Springer, Berlin, pp. 149-186.

Bloniarz, D.V., Ryan, H.D., 1993. Designing Alternatives to Avoid Street Tree Conflicts. Journal of Arboriculture 19(3), 152-156.

Camacho-Cervantes, M., Schondube, J.E., Castillo, A., MacGregor-Fors, I., 2014. How do people perceive urban trees? Assessing likes and dislikes in relation to the trees of a city. Urban Ecosyst 17, 761-773. https://doi.org/10.1007/s11252-014-0343-6.

Çelik, G., Mungan, D., Pinar, M., Misirligil, Z., 2005. Poplar pollen-related allergy in Ankara, Turkey: how important for patients living in a city with high pollen load? Allergy and Asthma Proceedings 26(2), 113-119.

Dandy, N., 2010. The social and cultural values, and governance, of street trees. Forest Research, UK. Retrieved July 21st, 2017 from http://www.forestresearch.gov.uk/fr/INFD-8D4FJ8.

Dursun, A.B., Çelik, G.E., Alan, S., Pınar, N.M., Mungan, D., Mısırlıgil, Z., 2008. Regional pollen load: Effect on sensitisation and clinical presentation of seasonal allergic rhinitis in patients living in Ankara, Turkey. Allergol et Immunopathol 36(6), 371-8.

Escobedo, F.J., Kroeger, T., Wagner, J.E., 2011. Urban forests and pollution mitigation: analyzing ecosystem services and disservices. Environ. Pollut. 159(8–9), 2078-2087, http://doi.org/10.1016/j.envpol.2011.01.010.

Farinha-Marques, P., Fernandes, C., Guilherme, F., Lameiras, J.M., Alves, P. & Bunce, R., 2015. Morphology and Biodiversity in the Urban Green Spaces of the City of Porto. Book II – Habitat Mapping and Characterization. Porto. CIBIO ISBN 978-989-987-32-4-7.

Fernandes, C., Mota, M., Lufinha, I., Silva, I., Marques, P.F., 2015. Ok, cities grow, but the trees too! Now what? In Niin, G., Mishra, H.S. (Eds.), Proceedings of the ECLAS Conference "Landscapes in Flux", Sep 20-23, Tartu, Estonia, pp. 289-298.

Flannigan, J., 2005. An Evaluation of Residents' Attitudes to Street Trees in Southwest England. Arboricultural Journal 28, 219-241. http://doi.org/10.1080/03071375.2005.9747428.

Gerstenberg, T., Hofmann, M., 2016. Perception and preference of trees: A psychological contribution to tree species selection in urban areas. Urban Forestry & Urban Greening 15, 103-111. https://doi.org/10.1016/j.ufug.2015.12.004.

Gorman, J., 2004. Residents' Opinions on the Value of Street Trees Depending on Tree Location. Journal of Arboriculture 30(1), 36-44.

Head, L., Muir, P., 2005. Living with trees - Perspectives from the suburbs. In Calver, M., Bigler-Cole, H., Bolton, G., Dargavel, J., Gaynor, A., Horwitz, P., Mills, J., Wardell-Johnson, G. (Eds.), Proceedings of the 6th national conference of the Australian Forest History Society, Rotterdam: Millpress, pp. 84-95.

Heberlein, T.A., 2012. Navigating environmental attitudes. New York: Oxford University Press.

Hitchmough, J.D., Bonugli, A.M., 1997. Attitudes of residents of a medium sized town in South West Scotland to street trees. Landscape Research 22(3), 327-337. http://doi.org/10.1080/01426399708706518.

Kirkpatrick, J.B., Davison, A., Daniels, G.D., 2012. Resident attitudes towards trees influence the planting and removal of different types of trees in eastern Australian cities. Landscape and Urban Planning 107, 147-158. thttp://doi.org/10.1016/j.landurbplan.2012.05.015.

Lo, A.Y., Byrne, J.A., Jim, C.Y., 2017. How climate change perception is reshaping attitudes towards the functional benefits of urban trees and green space: Lessons from Hong Kong. Urban Forestry & Urban Greening 23, 74-83. http://doi.org/10.1016/j.ufug.2017.03.007.

Mattheck, C., Breloer, H., 1994. The Body Language of Trees – A handbook for failure analysis. Londres: HMSO.

McPherson, E.G., 2005. Trees with benefits. American Nurseryman 201(7), 34-40.

Millennium Ecosystem Assessment, 2005. Ecosystems and Human Well-being. A Framework for Assessment. Island Press, Washington, DC.

Monteiro, M.M., Tetto, A.F., Biondi, D., Silva, R.R., 2013. The Users' Perception of Street Afforestation on Cândido De Abreu Avenue, Curitiba City, Paraná State, Brazil. REVSBAU 8(2), 28-40.

Moskell, C., Broussard Allred, S., 2013. Residents' beliefs about responsibility for the stewardship of park trees and street trees in New York City. Landscape and Urban Planning 120, 85-95. http://doi.org/10.1016/j.landurbplan.2013.08.002.

Mullaney, J., Lucke, T., Trueman, S.J., 2015. A review of benefits and challenges in growing street trees in paved urban environments. Landscape and Urban Planning 134, 157-166. http://doi.org/10.1016/j.landurbplan.2014.10.013.

Nassauer, J.I., Wang, Z., Dayrell, E., 2009. What will the neighbors think? Cultural norms and ecological design. Landscape and Urban Planning 92, 282-292. http://doi.org/10.1016/j.landurbplan.2009.05.010.

Rae, R.A., Simon, G., Braden, J., 2010. Public Reactions to New Street Tree Planting. Cities and the Environment 3(1), 1-21.

Rotherham, I.D., 2010. Thoughts on the Politics and Economics of Urban Street Trees. Arboricultural Journal 33(2), 69-75. http://doi.org/10.1080/03071375.2010.9747596.

Sæbø, A., Borzan, Ž., Ducatillion, C., Hatzistathis, A., Lagerström, T., Supuka, J., García-Valdecantos, J.L., Rego, F., van Slycken, J., 2005. The selection of plant materials for street trees park trees and urban woodland. In: Konijnendijk, C.C., Nilsson, K., Randrup, T.B., Schipperijn, J. (Eds.), Urban Forests and Trees, Springer, Berlin, pp. 257-280.

Sanesi, G., Chiarello, F., 2006. Residents and urban green spaces: The case of Bari. Urban Forestry & Urban Greening 4, 125-134. https://doi.org/10.1016/j.ufug.2005.12.001.

Schroeder, H., Flannigan, J., Coles, R., 2006. Residents' Attitudes Toward Street Trees in the UK and U.S. Communities. Arboriculture & Urban Forestry 32(5), 236-246.

Seamans, G. S. 2013. Mainstreaming the environmental benefits of street trees. Urban Forestry & Urban Greening, 12(1), 2-11. https://doi.org/10.1016/j.ufug.2012.08.004

Soares, A.L., Rego, F.C., McPherson, E.G., Simpson, J.R., Peper, P.J., Xiao, Q., 2011. Benefits and costs of street trees in Lisbon, Portugal. Urban Forestry & Urban Greening 10, 69-78. https://doi.org/10.1016/j.ufug.2010.12.001.

Stagoll, K., Lindenmayer, D.B., Knight, E., Fischer, J., Manning, A.D., 2012. Large trees are keystone structures in urban parks. Conservation Letters 5, 115-122.

Sumida, A., Miyaura, T., Torii, H., 2013. Relationships of tree height and diameter at breast height revisited: analyses of stem growth using 20-year data of an even-aged Chamaecyparis obtusa stand. Tree Physiology 33, 106-118. https://doi.org/10.1093/treephys/tps127

Thompson, S.G.C., Barton, M.A., 1994. Ecocentric and anthropocentric attitude toward the environment. Journal of Environmental Psychology 14, 149-157.

Todorova, A., Asakawa, S., Aikoh, T., 2004. Preferences for and attitudes towards street flowers and trees in Sapporo, Japan. Landscape and Urban Planning 69, 403-416. https://doi.org/10.1016/j.landurbplan.2003.11.001.

Trees and Design Action Group, 2010. No trees, no future. CABE and English Heritage.

van der Linden, S., 2014. On the relationship between personal experience, affect and risk perception: The case of climate change. European Journal of Social Psychology 44, 430-440. http://doi.org/10.1002/ejsp.2008.

Williams, K., 2002. Exploring resident preferences for street trees in Melbourne, Australia. Journal of Arboriculture 28, 161-170.

Yang, J., McBride, J., 2003. A Unique Technique for Street Tree Planting in Beijing. Arboricultural Journal 27(1), 1-10. http://doi.org/10.1080/03071375.2003.9747358.

Zhang, Y., Hussain, A., Deng, D., Letson, N., 2007. Public Attitudes Toward Urban Trees and Supporting Urban Tree Programs. Environment and Behavior 39(6), 797-814. https://doi.org/10.1177/0013916506292326.

Zhao, J., Xu, W., Li, R., 2017. Visual preference of trees: The effects of tree attributes and seasons. Urban Forestry and Urban Greening 25, 19-25. https://doi.org/10.1016/j.ufug.2017.04.015.

Fig. 1. Location of the study area. Street (S): (1) *Cândida da Sá Albergaria*; (2) *Crasto*; (3) *Diu*; (4) *Doutor Jacinto Nunes*; (5) *Doutor Sousa Rosa*; (6) *Farol*; (7) *Índia*; (8) *José de Carvalho*; (9) *Molhe*; (10) *Marechal Saldanha*; (11) *Gondarém*; (12) *Teatro*; (13) Faial.

Fig. 2. (a) Postcard of the beach Foz do Douro, Porto (1939) (source: http://www.origens.pt/files/content/01/89/2045.jpg); (b) 3D Satellite Image of the beach Foz do Douro, Porto (2017) (source: Google Maps).

Fig. 3. *R* variables descriptive statistics by street.

Fig. 4. Street's observable profiles types.

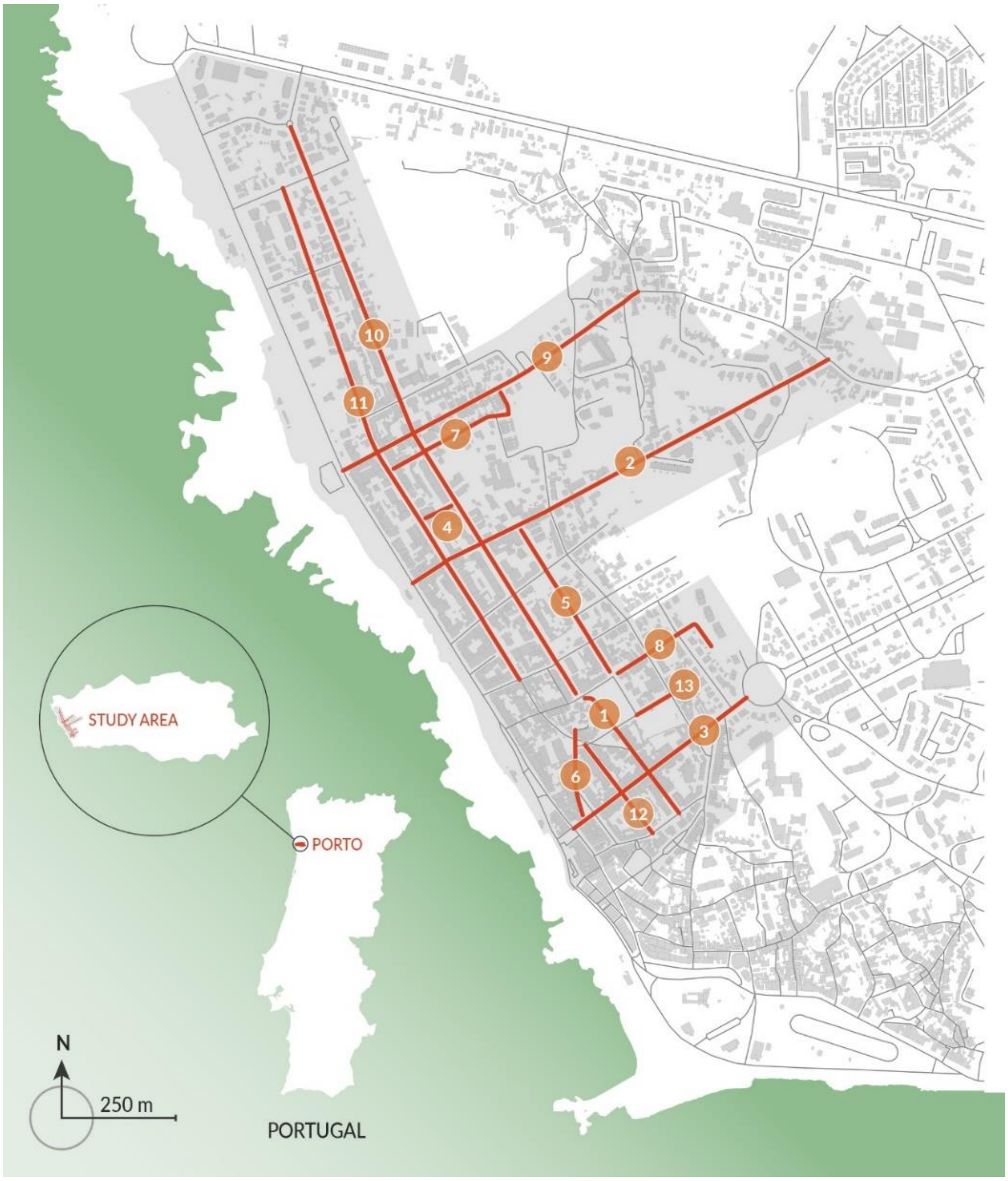

Fig. 1. Location of the study area. Street (S): (1) *Cândida da Sá Albergaria*; (2) *Crasto*; (3) *Diu*; (4) *Doutor Jacinto Nunes*; (5) *Doutor Sousa Rosa*; (6) *Farol*; (7) *Índia*; (8) *José de Carvalho*; (9) *Molhe*; (10) *Marechal Saldanha*; (11) *Gondarém*; (12) *Teatro*; (13) Faial.

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Fig. 3. R variables descriptive statistics by street

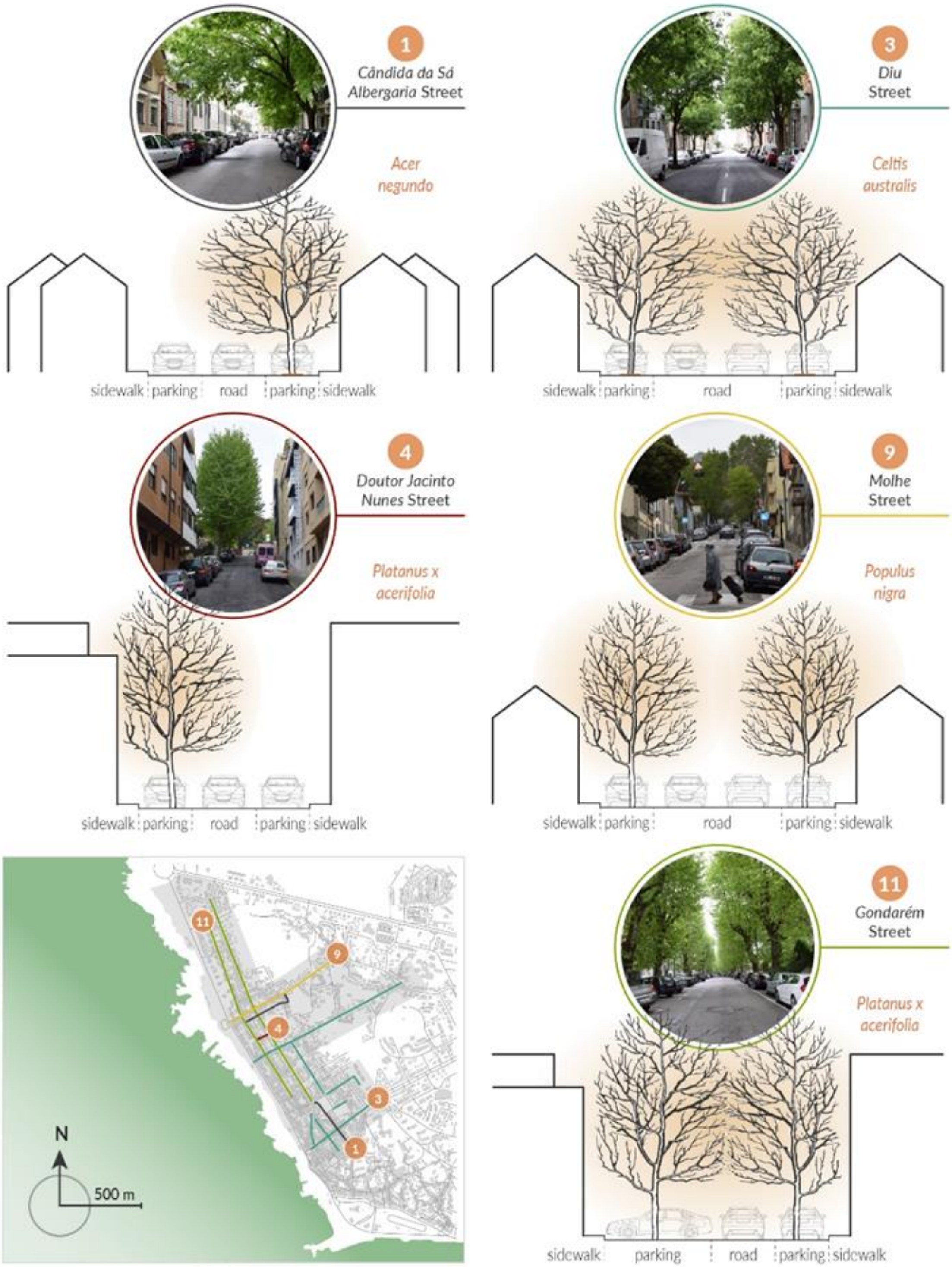

Fig. 4. Street's observable profiles types

Table 1. Streets' observable environmental profiles.

Table 2. Model 1 results (*R* and *S* variables).

Table 3. Model 2 results (*R* and *Z* variables).

Table A1. Description and summary of the variables.

Street code	Street name	Tree density (trees/100 m^2)	Dominant species				Biomechanics index	% of trees in conflict with facades	Type of plantation				Dominant house type		Traffic intensity			Traffic direction	
			Platanus x acerifolia	*Celtis australis*	*Populus nigra*	*Acer negundo*			Single row	Double row	With tree pit	Without tree pit	Single family house	Multi-story building	High	Moderate	Low	One-way	Two-way
S1	Cândida Sá Albergaria	0,8				x	0,22	0,14	x		x		x			x		x	
S2	Crasto	1	x				0,17	0,10		x		x	x			x			x
S3	Diu	0,9		x			0,21	0,34		x	x		x		x				x
S4	Dr. Jacinto Nunes	0,7	x				0,17	0,40	x					x			x	x	
S5	Dr. Sousa Rosa	1,1	x				0,16	0,26		x		x	x			x		x	
S6	Farol	0,9		x			0,23	0,48		x	x		x			x		x	
S7	Índia	0,4	x				0,19	0,40	x		x		x				x	x	
S8	José de Carvalho	0,8		x			0,21	0,50		x	x		x				x	x	
S9	Molhe	0,7			x		0,17	0,19		x		x	x		x				x
S10	Marechal Saldanha	0,8	x				0,23	0,15		x	x			x	x			x	
S11	Gondarém	0,5	x				0,18	0,63		x		x		x	x			x	
S12	Teatro	1		x			0,25	0,44		x	x		x			x		x	
S13	Faial	2,1	x				0,22	0,25		x	x		x			x		x	

Table 1. Streets' observable environmental profiles.

Odds ratio (level of significance 1%***, 5%**, 10%*)													
	Y1	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**	**Y9**	**Y10**	**Y11**	**Y12**	**Y13**
R1			3,245 **							0,474 *		0,497 **	
R2			4,649 **				0,368 **		0,244 **		0,177 **		
R3													0,278 **
R4									1,303 **	1,344 **	1,420 *		1,479 *
R5							0,616 **		0,545 ***	0,562 **	0,607 *		2,041 ***
S1										8,944 **			11,897 *
S2		0,169 **				26,722 ***				5,386 **	12,297 ***		
S3				0,082 **							6,281 *	4,970 ***	
S4					0,086 *								
S5							4,581*	5,233**		8,119 **			
S6													
S7													17,23 *
S8							5,624**				6,426 *	4,97 *	13,965 *
S9	0,081 **			0,085 *		32,247 ***				5,227 **			11,324 *
S10				0,127 *		8,253 *	3,370**			7,784 ***		3,87 ***	
S12													23,371 **
S13												6,761 **	
Log likelihood	-20,651	-39,525	-75,243	-40,849	-33,392	-31,269	-117,059	-89,91	-106,551	-88,78	-58,992	-161,187	-45,183
Number of obs	281	281	281	281	281	281	281	281	281	281	281	281	281
LR chi2(8)	8,9	13,8	13,5	11,15	8,86	23,82	29,04	11,09	37,41	37,57	26,26	30,05	20,91
Prob > chi2	0,26	0,244	0,197	0,346	0,45	0,002	0,016	0,522	0,002	0,001	0,024	0,026	0,075
Pseudo R2	0,177	0,149	0,082	0,12	0,111	0,276	0,110	0,058	0,149	0,175	0,182	0,085	0,188

Table 2. Model 1 results (*R* and *S* variables).

Odds ratio (level of significance 1%***, 5%**, 10%*)													
	Y1	**Y2**	**Y3**	**Y4**	**Y5**	**Y6**	**Y7**	**Y8**	**Y9**	**Y10**	**Y11**	**Y12**	**Y13**
R1			3,007 **							0,466*		0,402 **	
R2			4,888 **				0,409 *		0,239 **	0,357*	0,174 **		
R3													0,244 **
R4									1,302 **	1,351 **	1,441 *		1,424 *
R5							0,656 **		0,553 ***	0,59 *			1,934 **
Z1													
Z2										0,333 *			
Z3	0,048 *												
Z4													
Z5													
Z6													
Z7													
Z8						0,148 *						5,926 **	
Z9													
Z10													0,264 **
Z11											9,143 *		
Z12													
Log likelihood	-18,962	-41,417	-73,266	-41,664	-35,056	-34,458	-117,967	-89,698	-107,262	-93,67	-59,944	-161,328	-47,099
Number of obs	281	281	281	281	281	281	281	281	281	281	281	281	281
LR chi2(8)	12,27	10,02	17,45	9,53	9,54	17,44	27,22	11,51	35,99	27,78	24,36	29,76	17,07
Prob > chi2	0,139	0,124	0,18	0,483	0,573	0,026	0,027	0,568	0,003	0,004	0,041	0,013	0,106
Pseudo R2	0,245	0,108	0,106	0,103	0,12	0,202	0,103	0,06	0,144	0,129	0,169	0,085	0,153

Table 3. Model 2 results (*R* and *Z* variables).

Variable	Description	Type	Mean	Std. Dev.	Min	Max
Observable characteristics of respondents (R variables)						
R1	Resident	Dummy	0.38	0.49	0	1
	Frequent visitors					
R2	Occasional visitors	Dummy	0.23	0.42	0	1
R3	Feminine gender	Binary	0.58	0.49	0	1
	Masculine gender					
R4	Age	Scale	3.87	1.74	1	6
R5	Education	Scale	2.43	1.04	1	5
Observable characteristics of streets (Z variables)						
Z1	Density of trees per 100 m^2	Continuous	0.86	0.35	0.4	2.1
	Platanus x acerifolia is the dominant species					
Z2	*Celtis australis* is the dominant species	Dummy	0.28	0.45	0	1
Z3	*Populus nigra* is the dominant species	Dummy	0.07	0.26	0	1
Z4	*Acer negundo* is the dominant species	Dummy	0.04	0.19	0	1
Z5	Biomechanics index	Continuous	0.20	0.03	0.16	0.25
Z6	Percentage of trees in conflict with facades	Continuous	0.33	0.19	0.10	0.63
Z7	Single row plantation	Dummy	0.09	0.29	0	1
	Double row plantation					
Z8	Plantation with tree pit	Dummy	0.57	0.50	0	1
	Plantation without tree pit					
	Single family house					
Z9	Multi-story building	Dummy	0.37	0.48	0	1
Z10	Traffic intensity	Scale	2.46	0.66	1	3
	One-way traffic					
Z11	Two-way traffic	Dummy	0.31	0.46	0	1
Street dummies that capture unobservable characteristics of respondents and streets (S variables)						
S1	Cândida da Sá Albergaria street	Dummy	0.04	0.19	0	1
S2	Crasto street	Dummy	0.11	0.31	0	1
S3	Diu street	Dummy	0.13	0.33	0	1
S4	Doutor Jacinto Nunes street	Dummy	0.02	0.13	0	1
S5	Doutor Sousa Rosa street	Dummy	0.05	0.22	0	1
S6	Farol street	Dummy	0.05	0.22	0	1
S7	Índia street	Dummy	0.03	0.18	0	1
S8	José de Carvalho street	Dummy	0.04	0.20	0	1
S9	Molhe street	Dummy	0.07	0.26	0	1
S10	Marechal Saldanha street	Dummy	0.16	0.37	0	1
	Gondarém street					
S12	Teatro street	Dummy	0.06	0.23	0	1
S13	Faial street	Dummy	0.05	0.23	0	1
Perception of trees and street trees by respondents (Y variables)						
Y1	I like trees	Binary	0.98	0.13	0	1
Y2	I like the shadow of trees	Binary	0.96	0.19	0	1
Y3	I like the seasonal variations of trees (flowers, leaves, etc.)	Binary	0.91	0.28	0	1
Y4	Trees favor the physical and mental wellbeing of populations	Binary	0.96	0.19	0	1
Y5	Trees are important for life in a city (oxygen production, temperature regulation, etc.)	Binary	0.97	0.18	0	1

Y6	Trees are ugly	Binary	0.04	0.19	0	1
Y7	Trees are too big	Binary	0.18	0.38	0	1
Y8	Trees occupy too much space (parking places, sidewalks, etc.)	Binary	0.11	0.31	0	1
Y9	Trees are dangerous (fallen branches, leaves, and fruits)	Binary	0.16	0.37	0	1
Y10	Trees damage houses	Binary	0.13	0.33	0	1
Y11	Trees should be planted only in parks and gardens	Binary	0.07	0.26	0	1
Y12	The trees in this street are well planted	Binary	0.68	0.47	0	1
Y13	Respondent already presented a claim to the municipality regarding the trees of the street	Binary	0.05	0.22	0	1

Table A1. Description and summary of the variables.