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Original article

Residential urban trees – socio-ecological factors affecting tree and shrub abundance in the city of Malmö, Sweden

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A R T I C L E I N F O

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A B S T R A C T

Trees and large shrubs in urban environments provide a wide array of ecosystem services, enhancing the well-being of urban residents. Public trees in Sweden are managed by local governments, but private-owned urban trees, which represent a large proportion of the total urban tree population, are managed by residential property owners. Residential urban trees are generally not included in urban forest management plans at local government level. This study examined property-level characteristics that could lead to better management decisions by property owners on residential trees in Malmö, Sweden.

Using spatial sampling, 99 properties were inventoried to determine tree basal area (m^2/ha), as a measure of woody plant abundance. In parallel, residents were surveyed about their attitudes to trees, and information on background variables on their properties was collected using through publicly available spatial data. Statistical modelling was used to determine relationships between key socio-ecological variables and tree abundance as well as reasons for planting and removal of trees.

The results showed that positively perceived benefits of trees to property owners did not necessarily result in greater tree and shrub abundance on individual properties. Instead, house age and potential plantable space were the variables positively correlated with tree and shrub abundance. Years of residence had a negative correlation with probability of planting. The primary reason for tree removal was improper growing site, which indicates that providing practical information on appropriate site/species selection could reduce the risk of healthy urban tree removal.

1. Introduction

With the current rapid pace of urbanisation, increasing numbers of city dwellers are frequently being confronted by a wide array of challenges related to climate change, e.g. heat waves, urban flooding and air pollution (Nowak et al., 2006; Xiao and McPherson, 2002). Research clearly shows the value of trees and large shrubs in mitigating these challenges and making cities more liveable (Bowler et al., 2010; Gill et al., 2007; Grahn and Stigsdotter, 2003; Jones, 2008; Norton et al., 2015; Tyrväinen et al., 2007). The urban forest consists of a mosaic of different owners and management types, e.g. municipal arborists (Randrup and Persson, 2009; Östberg et al., 2018), institutions (Konijnendijk et al., 2005) and individual citizens (Buijs et al., 2016). In order to increase understanding of the urban forest, it is crucial to study how these different ownership groups regard urban green spaces, and the trees and shrubs grown on land under different ownership forms (EEA, 2015).

Residential landscapes make up over 40 % of urban landscapes (UN, 2014), so residential landowners play a key part in provision of ecosystem services at the global scale (Shakeel and Conway, 2014). The ecological outcomes of residential landscapes in the form of ecosystem services are a result of interactions between human drivers, legacy effects and management decisions by individuals (Cook et al., 2011). Decision-making by private individuals has been examined in several studies assessing the importance of urban residents' social values in environmental management (Ives and Kendal, 2014). Management decisions made by residential tree owners have been described as active, fragmented and spontaneous (Conway, 2016). Tree removal is often associated with poor risk assessment and can lead to removal of healthy trees (Kirkpatrick et al., 2013). Studies have shown that residents tend to exhibit risk-averse behaviour when it comes to trees and tree care, not fully recognising the positive benefits of owning trees (Kirkpatrick et al., 2013). This results in a trend for removal of healthy trees based on perceived risks to personal property and injuries. Recent trends in

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residential development often result in expansion of hardscapes, which has led to urban tree canopy loss (Lee et al., 2017), potentially exposing residential areas to environmental risks due to a decline in ecosystem services. On the other hand, tree retention is associated with high cost of removal and of non-compliance with government regulations and by-laws (Guo et al., 2019). Some urban residents clearly harbour negative perceptions of trees, leading to their removal, which could be explained by perceived or real ecosystem disservices associated with urban trees, e.g. fear of trees causing structural damage, unsuitable growing space and messiness (Delshammar et al., 2015).

Management of urban trees and green spaces in Sweden is predominantly the responsibility of local municipalities (Konijnendijk et al., 2006; Randrup and Persson, 2009), but their area of responsibility is limited to management of public spaces populated with park and street trees. Local municipalities have direct control over these spaces, but this control does not extend across private property boundaries. As a result, privately-owned trees are rarely included in urban tree inventories. A recent survey in Sweden found that only 2% of all local governments that conduct urban tree inventories include private trees (Wiström et al., 2016). Against this background, privately owned trees and large shrubs can be assumed to be a largely unknown and overlooked source of urban ecosystem services from a local government perspective, in Sweden and elsewhere (Wiström et al., 2016; Ordóñez-Barona et al., 2021).

Retention and survival of urban trees on privately owned land can be affected by direct or indirect incentives implemented by local governments. For example, tree ordinance and zoning regulations have been shown to have a positive impact on preserving the urban tree canopy (Hill et al., 2010). There are few ordinances in place to protect trees on private property in Sweden and the factors influencing woody species abundance in residential areas, including the extent of residential vegetation, are largely unknown (Östberg et al., 2018).

One of the approaches that local governments can adopt is to carry out educational activities highlighting the benefits of trees, but with a clear operational goal in mind (Ordóñez and Duinker, 2013). Among past attempts to establish trees in cities using tree planting initiatives aimed at residents, the most successful programmes have emphasised stewardship, species and site selection, and involvement of skilled volunteers (Roman et al., 2015). Some studies have identified different groups of residents based on their attitudes and approaches to tree management, suggesting that there is a wide range of opinions among residents. This needs to be addressed by practitioners (Kirkpatrick et al., 2012), as functional traits of urban tree communities have been shown to be dependent on residents' preferences and perceptions (Avolio et al., 2015). However, previous studies report mixed results regarding the role of residents' attitudes in decision-making on urban trees (Conway, 2016; Kirkpatrick et al., 2012; Larson et al., 2010). Based on the assumption that positive associations result in positive outcomes, social and pro-environment values are frequently incorporated in the framing of management activities for ecological systems, to minimise conflicts between stakeholders (Ives and Kendal, 2014). In a study by Guo et al. (2019), aesthetics were identified as the main driving force behind individual tree management actions, with increased tree retention linked to recognition of ecosystem services, while tree removal was linked to perceived disservices (Kirkpatrick et al., 2012). In a Swedish context, one study addressing why trees on public land are felled (Wiström et al., 2016) and one study on complaints about public trees to municipalities (Delshammar et al., 2015) have been published, but no previous study has focused on private residential land and the management decisions being made by these tree owners. Since few regulations influencing privately owned trees are in place in Sweden (Mebus, 2014), the relationship between resident preferences, perceptions and ecological outcomes is arguably the key factor in tree survivability and retention at individual property scale (Grove et al., 2006). In order to understand the management actions needed to promote sustainable urban forest management in Sweden, the connection between tree abundance and residential property owners' attitudes needs to be better explored.

In assessing tree abundance on private property, several parameters and their interactions need to be considered. Potential plantable space (PPS), i.e. the difference between total area of a private residential property and the building footprint, has been shown to be positively correlated with total tree canopy, as it reflects the capacity for potential urban canopy cover (Wu et al., 2008). When trees are introduced on new residential plots, they require time to mature and to reach peak production of ecosystem services. This in turn means that house age might be a factor that is positively correlated to tree abundance, while new developments and changes in ownership might have a negative impact on canopy cover. However, all of these aspects could also be affected by owners' individual decisions and views on trees.

The link between socio-ecological drivers and environmental outcomes of management decisions is a rapidly growing field of research, with recent publications (e.g.:Avolio et al., 2015; Engebretson et al., 2020; Padullés Cubino et al., 2020; Schmitt-Harsh and Mincey, 2020). However, the majority of these studies are within a North American or Australian context, within specific urban forestry management traditions and residential development legacies. Our study was specifically interested in the regional residential development context and in linking tree abundance to individual attitudes or preferences instead of vegetation diversity.

Based on this background, the aim of the present study was to develop a better understanding of factors related to existing tree and shrub abundance, and factors influencing tree plantings and removal on urban residential land in Sweden. Using examples from extensive research in socio-ecological dynamics in other regions, the following research question was addressed:

- How do physical properties, in the form of potential plantable space, house age and length of residence, together with residential property owners' perceptions of the ecosystem services supplied by trees, affect the abundance of trees on privately owned land? And which factors influence the tree owner's decision to remove or plant trees?

2. Methods

2.1. Study site and sampling method

The city of Malmö (55°36′21″N 13°02′09″E) is the third largest city in Sweden, with 338 230 inhabitants (SCB, 2020). It is located in the temperate vegetation zone, on the southern Swedish agricultural plains, a region with overall fertile soils and mean precipitation of 600 mm/year (SMHI, 2020). The city occupies an area of 8105 ha, of which 1133 ha are classified as *small housing units*, the term used in national statistics for detached or semi-detached single-household units (Statistics Sweden, 2019).

Using publicly available property information provided by Malmö city authority, small housing units in the city were identified for this study (Fig. 1). The sampling design used a fishnet grid with 290m × 290m cell dimensions. Within each cell grid, a random point was selected using ESRI ArcMap 10.8 (ESRI, 2020). From the total residential area, 137 points representing small housing units were selected (Fig. 2). None of the properties included in the survey were vacant or leased to tenants, providing a basis for establishing a direct relationship between the individual owners and their management actions regarding residential urban trees.

The 137 selected households were twice notified in advance, in order to gain their consent or record their refusal to participate in the study. The first communication introduced respondents to the study and gave an estimated date for a visit with a tree inventory and questionnaire-based survey. The second communication specified the date and time of the visit and gave additional details, including contact information for re-scheduling if necessary.

2.2. Tree inventory

In September and November 2018, the residential properties included in the study were visited. All trees and woody plants present on the property were recorded, trunk diameter at breast height (DBH) was measured with a tape measure and the plant species present were identified. The DBH threshold for the inventory was set at 5 cm. If a tree or shrub had multiple stems and the point of pith separation was above ground, DBH measurements were made on up to five branches per tree (i-Tree User's manual, 2020). The measured DBH values, along with date and point identification number, were recorded in a plot inventory paper form and later transcribed into an Excel spreadsheet (Microsoft Excel, 2016).

2.3. Property owner survey

During the visits, a survey was conducted of the residential property owners to identify the ecosystem services they associated with trees and their management decisions on their own trees. A total of 21 questions were included in the survey, covering: general information (years of residence, gender, age, education level and house age); management actions regarding trees (future and past planting or removal); likelihood of adding other features to the outdoor space; and tree-related interactions with the local government. Survey answers were recorded by the owner using a tablet computer, or via an online form (Google form) sent later to the owner. The field staff verbally confirmed that all the respondents were property owners (or co-owners).

In total, 99 surveys paired with full inventories of residential plots were completed, out of a total of 137 households invited to participate in the study, giving a response rate of 72.3 %.

2.3.1. Tree benefits

To assess the property owner's understanding of ecosystem services, we used the open-end survey question: *What benefits do you associate with trees?* Before this question was posed, respondents received no indication of the purpose of the survey and potential benefits of trees were not discussed. If respondents could not list any benefits (or simply did not want to answer the question), the answer field was left blank.

Based on the responses received to this question, we classified the participating residential property owners into four different groups:

1 Utilitarian (respondents who mentioned utilitarian benefits provided by trees).
2 Aesthetic (respondents who mentioned aesthetic benefits of trees).
3 Mixed (respondents who mentioned utilitarian and aesthetic benefits of trees).
4 None (respondents who gave no answer and possibly do not associate trees with any benefits).

2.3.2. Tree removal and tree planting

As a part of the survey, the following two questions on tree removal and tree planting were posed:

- Have you planted any trees in the past five years? (yes/no)
- Have you removed any trees in the past five years? (yes/no).

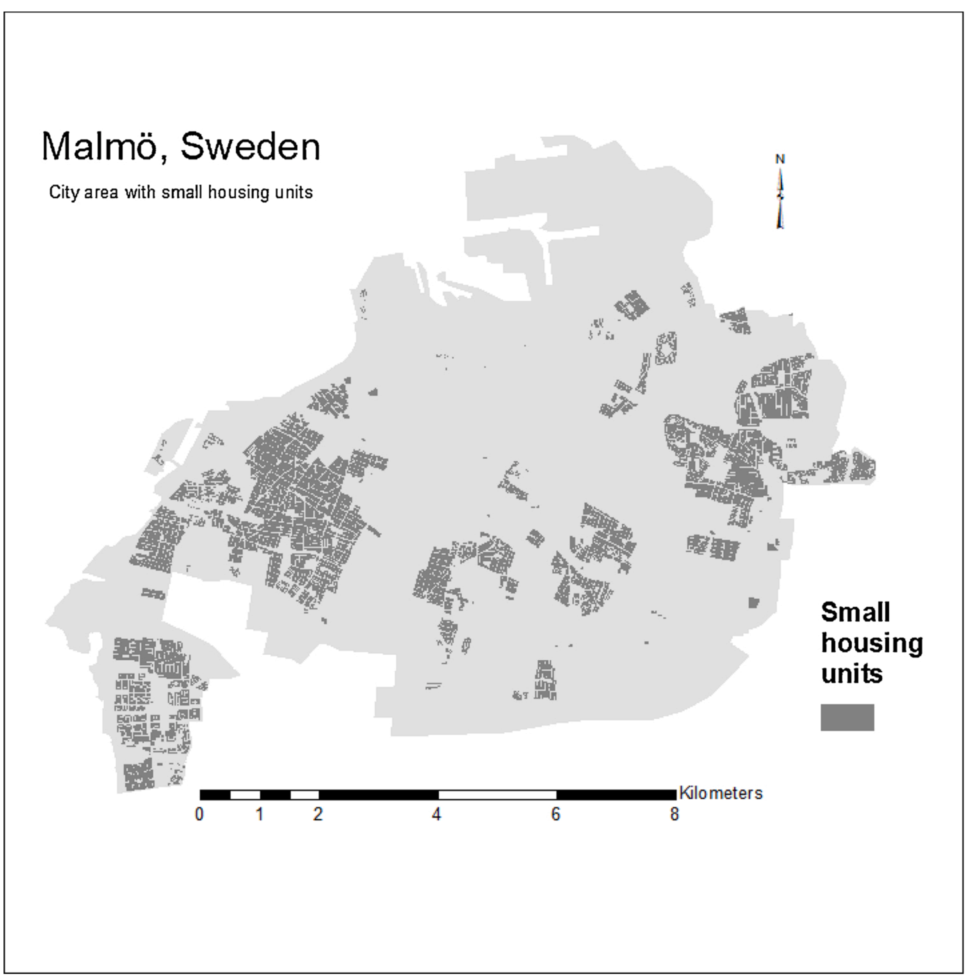

Fig. 1. Map of the study site, the city of Malmö, Sweden, showing total city area and the small housing units surveyed in this study.

Fig. 2. Example of a point in satellite imagery that coincided with a small housing unit within the borders of the city of Malmö.

If the answer to the latter question was yes, the respondent was asked to select the reason for removal from among pre-listed alternatives or state it in a free text field. The reason for providing pre-listed alternatives was to enable comparison of the results with those in previous studies by e.g. Wiström et al. (2016), (Hauer and Peterson, 2016) and Delshammar et al. (2015). The alternatives provided were:

- Tree mortality
- Lack of maintenance
- Neighbour complaint
- Poor vitality
- Improper growing site
- Risk
- Disease
- Infrastructure damage
- Traffic damage
- Shading
- Wind damage.
- Other (in free text format).*

*The authors reviewed the responses and all four answers could be classified as inappropriate growing site, since they included statements such as: "the tree was too large" and "the trees were planted too densely".

2.4. Analysis and modelling

All statistical analyses were performed in R (RStudio, 2020), using the packages "MASS", "dplyr", "car" and "tidyverse", with a significance level of $p < 0.05$. Missing values were treated by dropping observations in modelling. Descriptive statistics were calculated for the survey responses (basal area, PPS) using R and Excel. Statistical modelling was performed using the main measured parameters as response and explanatory variables.

2.4.1. Response variables in statistical modelling

The extent of regulating ecosystem services provided by trees (e.g. carbon storage, water uptake, air pollution removal) is positively related to tree size or, more accurately, leaf biomass per unit tree crown volume (Nowak et al., 2006, 2013). Studies have found a strong relationship between diameter at breast height (DBH) and crown volume (Troxel et al., 2013; Pretzsch et al., 2015). Indicators of tree abundance at areal unit are therefore better expressed as a function of DBH, rather than number of individual trees, since there is large variation between individual trees in their ability to produce ecosystem services. Basing tree abundance indicator on the number of trees would overestimate production of ecosystem services in residential plots with a large number of small trees. Urban forestry models based on allometric equations are available to predict growth of urban trees for management and maintenance and can estimate the provision of regulating ecosystem services (Nowak et al., 2001). These equations are widely used by local governments and individuals. In this study, basal area of the trees and shrubs was used as a proxy for the amount of ecosystem services provided. To map changes in the private tree population, survey responses to the questions of whether trees had been planted or removed during the past five years were used as binary response variables.

The basal area of trees (m^2/ha) in each residential plot was calculated as the sum of area occupied by tree stems per unit area of the property. Potential plantable space (PPS) was calculated as residential plot area minus building footprint.

2.4.2. Explanatory variables in statistical modelling

Information on the spatial geometry and building footprint of residential plots in Sweden is in the public domain and was obtained from the city department for property and streets. Although there were some constraints for individual properties, PPS was derived using publicly available information from the city of Malmö geodatabase, by deducting building footprint from individual residential plot area using ArcMap (ESRI, 2020). Tree age is strongly related to time since property construction (Lowry et al., 2011), and was determined from the questionnaire responses, as were house age and years of residence at the property. These three factors were later used as explanatory variables for tree abundance. Only three of the four groups of property owners classified in terms of perceived tree benefit types were included in the analysis (*Utilitarian*, *Mixed* and *None*), as the *Aesthetics* group was very small (n = 3) and was included in the *Mixed* group. Running the models without the Aesthetics groups did not affect final model selections and their goodness of fit.

2.4.3. Modelling approach

To find the best model describing the relationship between basal area, removal of trees, planting of trees and our explanatory variables of interest (including their two-way interactions), the following approach was used: First, we used stepwise variable selection with minimisation of Akaike information criterion with both forward and backward selection. Prior to model inclusion, explanatory variables were tested for inter-correlations, to avoid model inflation or strongly skewed groupings in relation to class variables. Since the automated stepwise procedure can in some cases create spurious results, manual model selection following a top-down strategy (Zuur et al., 2009) was used in parallel, starting with a full beyond-optimal model and then dropping non-significant explanatory variables. If the approaches gave different final models, these were compared using likelihood ratio tests. The final model was then tested against a null model using a likelihood ratio test and the assumptions in the model were verified by plotting the residuals from the model following the approach of Zuur et al. (2009). The final model was used to obtain estimated variables and related Type II ANOVA and deviance tables.

2.4.4. Modelling basal area

Basal area in m^2/ha was used as a numerical response variable in general linear modelling, using the *lm* function in R (RStudio, 2020). Explanatory variables were potential planting space (numerical), house age (numerical), years of residence (numerical) and perceived tree benefit type (class with three levels), including their two-way interactions.

2.4.5. Modelling tree planting and removal

Survey responses on tree planting and removal in the past five years were modelled as binary responses using a generalised linear model with logit as link function, using the function “glm”. Explanatory variables were potential planting space (numerical), house age (numerical), years of residence (numerical) and perceived tree benefit type (class with three levels), including their two-way interactions. In addition to plotting residuals to check assumptions, the final models were tested for over-dispersion.

3. Results

3.1. Descriptive summary of respondents

The mean age of the respondents was 58 years, which is similar to the average age of homeowners in Malmö (55 years) (SCB, 2020). In total, 70.8 % of the respondents had tertiary education (university degree). Mean duration of residence at the property was 19.8 years (range 0–73, SD = 16.2), while mean house age was 64.3 years (range 2–168, SD = 30.3) and mean PPS was 579.7 m^2 (range 101.2 to 1818.1 m^2, SD = 323.7).

3.1.1. Association of trees with ecosystem services

It was found that the majority of residents belonged to the *Utilitarian* group (43 %). A further 23 % were in the *Mixed* group and 34 % in the *None* group. Only 3% of property owners fell into the *Aesthetic* group. Table 1 shown all responses obtained translated from Swedish language.

3.2. Correlations to tree basal area

The final model for tree basal area included PPS, house age, respondent type (*Utilitarian*, *Mixed*, *None*) and the interaction between PPS and respondent attitude type. PPS and house age were found to be positively correlated with basal area, while respondent type as an individual variable did not show any significant correlations (Table 2). However, there was a significant interaction between PPS and respondent type. Re-running the analysis with only two groups, i.e. those associating benefits with trees (*Utilitarian* + *Mixed*) and the no answer group (*None*), or including the number of benefits mentioned per house owner as an explanatory variable in the model did not change the main results of the analysis. Thus, there was little evidence to suggest that property owners associating benefits with trees had more tree basal area on their property.

3.3. Correlations to tree planting and removal

Among the 99 respondents, 38 % reported having planted a tree in the past five years. The final model (Chisq = 6.9224, p = 0.009) explaining tree planting included years of residence and no other explanatory variable tested (e.g. PPS, perceived benefits group, house age). This gave the following final model, with SE in brackets: logit (Planting) = 0.2781(0.340) - 0.0369(0.015) x Years of residence. Since log odds are less intuitive than probabilities, the negative relationship between planting trees in the past five years and years of residence is visualised in Fig. 3 using predicted probabilities derived from the final model including 95 % confidence intervals. As an example, after 20 years of residence the predicted probability of planting was significantly below 0.5, while after 70 years of residence it was below 0.3 (Fig. 3).

Among the 99 respondents, 47 % reported that they had removed tree/s during the past five years. No significant model or explanatory variable was found to be associated with tree removal. When comparing the reasons for removal with those identified in three previous studies (Delshammar et al., 2015; Hauer and Peterson, 2016; Wiström et al., 2016), some similarities were found. For example, a tree showing poor vitality or dying was a common reason for removal in both the present survey of residential property owners (cited by 18.6 %), and in Swedish municipalities (Wiström et al., 2016) (26.7 %) and in the survey by Hauer & Peterson (2014) (46 %). The results were also similar for risk, disease and lack of maintenance as reasons for tree removal. However,

Table 1
Respondent types based on perceived ecosystem services associated with trees, categorised into four attitude types. Examples of responses and how they were classified together are shown, with the total number and percentages of each respondent type.

Respondent type	Response to the question: “What benefits do you associate with trees?”	Number and percentage of total respondents (n = 99)
Aesthetic	Colour richness, lush appearance, blossoming, beautification, enjoyment, aesthetically appealing, decorative purpose, natural appearance.	3 (3%)
Utilitarian	Oxygen production, carbon storage, water uptake, pollinator species, shading, fruit production, animal habitat, compost production, pollution removal, counteracting climate change, clean air, noise dampening, sight concealment, weather protection, wind protection, sheltering.	43 (43 %)
Mixed	Benefits from both the aesthetics and utilitarian categories.	20 (20 %)
None	No benefits listed or question left unanswered.	34 (34 %)
	Total	99 (100 %)

Table 2
Explanatory variables for basal area, where PPS is potential plantable space and residential property owners (n = 99) are grouped, based on perceived benefits of trees, as Mixed (M), None (N) and Utilitarian U).

	Coefficients		ANOVA table Type II test				
Variable	Estimate	StdError	SumSq	Df	F-value	Pr(>F)	
PPS	0.0015	0.0027	81.58	1	5.7023	0.0191	*
House age	0.0367	0.0130	113.96	1	7.9657	0.0059	**
Mixed group (M)			6.70	2	0.2343	0.7916	ns
No answer group (N)	3.0986	2.2564					
Utilitarian group (U)	1.5929	2.1553					
PPS x (M)			125.05	2	4.3705	0.0155	*
PPS x (N)	0.0063	0.0034					
PPS x (U)	0.0022	0.0034					
Residuals			1244.67	87			

there was a discrepancy for the parameter *Inappropriate growing site*, which 20.3 % of our respondents and 22 % of respondents in Wiström et al. (2016) cited as a reason for tree removal, but which was not mentioned in complaints to municipalities analysed by Delshammar et al. (2015). Receiving complaints was not cited as a reason for tree removal in the present study, compared with 6% in Wiström et al. (2016) (Table 3).

4. Discussion

As part of wider international efforts aligned with the United Nations Sustainable Development Goals (SDGs) in order to make urban areas more liveable (UN, 2014), the city of Malmö has a tree management plan with goals and objectives related to urban tree population specifically aimed at enhancement of regulating ecosystem services (2017). To achieve the desired goals and objectives, the actions taken by the city need to extend to the private tree population, as residential trees represent a significant proportion of the total urban tree population (Conway, 2016). Since ecosystem services materialise decades after tree planting (Maco and McPherson, 2003), understanding the small-scale dynamics in tree planting and removal in the private tree population is essential for creating a sustainable and liveable city. The results of the present study provide a better understanding of the link between tree and shrub abundance on private residential properties and the attitudes, actions and resources of the property owners. By assessing potential relationships between tree abundance and various property-level factors, we were able to identify areas where urban tree management efforts should be focused in order to achieve sustainability goals in tree management for the city of Malmö. We also examined some general factors behind residential tree management actions.

There were no statistically significant differences between the different groups of residential property owners identified based on their perceptions of trees. Tree abundance for the group that associated trees with utilitarian benefits did not improve with increasing PPS, showing that tree-positive views did not lead to higher tree abundance. Our results thereby differ from those of Ives and Kendal (2014), who found that that positive associations resulted in positive outcomes, and Guo et al. (2019), who identified aesthetics as the main driving force behind individual tree management actions. Additionally, the combination of selected social variables with biophysical variables did not result in better prediction of tree abundance in the studied case, in contrast to previous research (Luck et al., 2009). However, our results are in line

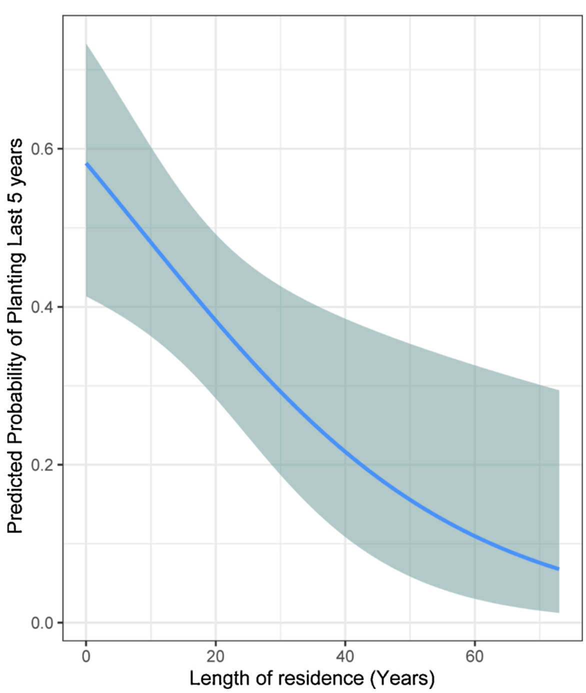

Fig. 3. Predicted probability, with 95 % confidence intervals, of tree planting by residential property owners in the past five years in relation to years of residence at the property Values shown are predicted from the logistic model of planting.

Table 3
Reasons cited for removal of residential urban trees in this study and in previous studies by Wiström et al. (2016) (based on a survey of Swedish local municipalities and answered by public servants), Delshammar et al. (2015) (compiled from complaints from residents received by various Swedish local governments regarding urban trees) and Hauer & Peterson (2014 (based on a survey of US communities and answered by public servants).

Reason for removal	This study	Wiström et al. (2016)[a]	Delshammar et al. (2015)	Hauer and Peterson (2016)
Complaint from resident	0	6%		
Lack of maintenance	1.0 %	1.2 %		
Poor vitality or dead	18.3 %	26.7 %		46.0 %
Inappropriate growing site	20.3 %[b]	0.0 %	22 %[c]	
Construction	4.1 %	5.0 %		8.6 %[d]
Risk	8.3 %	13.0 %	5%	12.3 %
Disease	7.1 %	11.8 %	10 %	11.9 %
Infrastructure damage	5.1 %	0.6 %	5%	5.0 %
Wind damage	5.1 %	11.2 %		9.1 %[e]
Damage to traffic	0.0 %	0.6 %		
Other	1.0 %	0.0 %		
Shading	3.1 %		3%	

[a] Listed as 'very common reasons for tree removal'.
[b] Too large, too close together etc.
[c] Obstructing roads and pavements, concealing traffic signs etc.
[d] Damage to sidewalk.
[e] Storm damage.

with findings by Kirkpatrick et al. (2012) that even people described as "tree-haters" do not live in a tree-averse way when comparing the amount of trees on their property. Similar findings have been made in a study in Scotland, where differences in attitudes were not reflected in degree of garden care or structural complexity of gardens (Hitchmough and Bonugli, 1997).

The strongest positive predictor of tree and shrub abundance was found to be house age, reflecting empirically the natural fact that trees need time to mature and reach peak production of ecosystem services (Lowry et al., 2011). Similarly to previous research (Boone et al., 2009), we found that current urban vegetation characteristics are partly reflected by past residents. What makes our findings interesting is that the changes over time occurred with little to no interference from local government, apart from urban planning decisions in the initial construction phase. By now, the trees present at these properties have matured and are more susceptible to pathogens and declining vitality. We suggest that future residential development plans for urban infill and re-development should place particular emphasis on retaining existing trees, as opposed to relying on replacement of trees by residents themselves. Local detailed plans already allow for special protection of trees within biotope protection measures, but we recommend that this be expanded to include a larger proportion of the older tree population.

The other significant factor for tree and shrub abundance was PPS, indicating the need for allowing space for residential property owners to plant trees. Previous studies using remote sensing technology to identify potential tree planting sites found that, unsurprisingly, the majority of suitable sites were in predominantly residential areas (Wu et al., 2008). With increased home size and other home extensions, individual households can severely limit the potential future tree canopy cover (Lee et al., 2017), replacing it with impermeable surfaces. Implementing tree protection ordinances and limiting the building footprint per plot through local planning legislation are possible measures to consider, especially since public support for such policies is reported to be high (Conway and Bang, 2014). However, these measures, although logical, are still somewhat problematic for the city of Malmö, which has strongly opted for densification instead of urban sprawl (2020). Densification may have some environmental advantages, but it limits the amount of trees that can be grown in a city, as clearly shown in this study.

Based on the finding that around 38 % of respondents had planted a tree in the past five years, the best-fitting explanatory model for predicted planting was years of residence, while none of the other explanatory variables (e.g. PPS, perceived benefits group, house age, age of residents) showed any significant correlation with tree planting (Table 2). The predicted probability of tree planting during the past five years decreased with years of residence at the property across all other aspects (Fig. 3). While this was surprising, some factors may influence why trees are primarily planted during the first years of an owner's residence in a house. For example, property owners might show a higher likelihood to invest in their newly acquired property in order to improve the appearance or the neighbourhood (Guo et al., 2019). With the passage of time, property owners might become less interested in committing to planting a new tree, which generally requires more care in the establishment phase (Roman et al., 2014). After this initial phase, we suspect that residents had fully utilised their planting space, according to individual perceptions, or felt that their preferences concerning tree abundance had been met.

Another factor that influenced tree abundance was tree mortality and removal. Monitoring studies on urban tree mortality suggest that trees die as a result of various interactive factors, but little is known of mortality rates for residential trees (Hilbert et al., 2019). A study using a field survey and image interpretation approach estimated that yearly mortality can reach 4% among shade trees (Ko et al., 2015). Other research generally suggests that predictions of residential tree survival tend to be optimistic (Roman et al., 2014). On analysing the rate of tree removal reported in this study, no significant model or significant explanatory variable was found, suggesting that removals happen indiscriminately across variables recorded in the study. The most common reason cited for tree removal was *Inappropriate growing site* (20.3 % of respondents). In contrast, other studies have found aesthetics and functionality of private space to be the main reasons for tree removal on private properties (Kirkpatrick et al., 2013). This discrepancy could be due to several reasons, the most obvious being that aesthetic reasons was not given as one of the pre-listed alternatives. However, none of the answers obtained in the open free text box listed aesthetics. Another reason might be that the residents included aesthetics in the *Inappropriate growing site* option. Even so, since *Inappropriate growing site* was the dominant reason for removing trees on private land in Malmö, good site and species selection can be expected to play a key role in the survival of residential trees (Roman et al., 2015), especially if such site and species selection also takes into account aesthetic reasons. In an analysis of complaints sent to local governments (Delshammar et al., 2015), site selection was identified as the number one issue causing conflicts in Swedish cities, explaining 22 % of total complaints reviewed (Table 3). There was good agreement between this general finding and the actions taken by private tree owners surveyed in the present study. Excluding implementation of additional regulatory measures, efforts to protect and prevent removal of healthy trees in the future should focus on promoting better site and species selection for residential areas today. As natural tree regeneration is rare in residential areas of Malmö, focusing on proper site and species selection would ensure long-term tree survivability and retention of mature trees, enabling them to reach peak production of regulatory ecosystem services. This recommendation, however, does not mean that all vegetation types should follow same set of site-selection criteria in order to reduce the total woody vegetation cover across residential areas.

5. Conclusions

This survey of private tree owners in the city of Malmö, Sweden, showed that positive associations of residential urban trees with benefits did not necessarily result in greater tree and shrub abundance on individual properties. Instead, house age and PPS were identified as being significantly related to shrub and tree abundance, which might indicate that contemporary dense building preferences are problematic when it comes to supporting privately owned trees for ecosystem services. The likelihood of planting a tree was found to decrease with years of residence at a property. The most common reason for removing trees was poor planting site selection, which indicates that providing practical information on appropriate site/species selection could reduce the risk of urban tree removal.

Individuals' attitudes are often assumed to be the core driver of their decision making, so our results may dispel some of the core beliefs about private urban tree retention and stewardship. Swedish authorities are limited in their ability to support local initiatives, so must rely primarily on dissemination of knowledge. Based on our results, knowledge dissemination should focus on more practical tree care in the form of selection of suitable tree species for different sites and performance of maintenance actions that might mitigate later problems. This type of knowledge could yield better results than merely educating urban residents about the various benefits of trees. It would also help residential property owners formulate their preferences with regard to practical care and improve their aptitude for planting, maintaining and retaining valuable urban trees and shrubs.

Author statement on the contributions to the paper

Blaz Klobucar: Conceptualization, methodology, data curation, writing-original draft preparation, vizualization, revising the manuscript, statistical analysis.

Märit Jansson: Conceptualization, writing-reviewing and editing.

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Declaration of Competing Interest

The authors declared no conflict of interest.

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Appendix A. Supplementary data

Supplementary material related to this article can be found, in the online version, at doi:https://doi.org/10.1016/j.ufug.2021.127118.

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