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The state and use of municipal tree inventories in Swedish municipalities – results from a national survey

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Abstract
Urban trees are an essential component of urban ecosystems, and management of this resource constitutes an essential element of urban open space management. However, municipal tree inventories in Sweden and elsewhere have received limited attention. It is unknown how common municipal tree inventories are in Sweden, factors governing whether a municipality has an inventory and what the inventories are used for. This study therefore sought to: Create an overview of the state of Swedish municipal tree inventories and determine how municipality size, green space budget and management organisation affect the presence and scope of municipal tree inventories. The research questions examined were: What is the current state of Swedish municipal tree inventories? and what affects the status of these municipal tree inventories? A survey with questions related to strategic and operational perspectives of municipal tree inventories, e.g. how they are conducted and used, together with questions relating to budget and potential use of consultants, was sent to all 290 Swedish municipalities. The response rate was 55.5%. The main findings were that municipality size affects whether a municipality has an urban tree inventory and that the municipal organisation form affects how inventories are used. The existence of an inventory also increased the probability of the municipality having a tree management plan. Based on these results we recommend further research related to strategic management perspectives of tree inventories.

Keywords Survey · Municipality · Street trees · Park trees · Management · Ecosystem services · Ecosystem disservices

Introduction

Research has clearly shown the importance of urban trees for sustainable urban development through their capacity for delivering numerous important ecosystem services, which include: Provisioning services (e.g. fuel and food), regulating services (e.g. stormwater management, urban heat island mitigation, air pollution regulation), cultural services (e.g. recreation, physical and mental health benefits) and supporting services (e.g. wildlife habitats) (Grahn and Stigsdotter 2003; Tyrväinen et al. 2005; Gill et al. 2007; Jones 2008; Morgenroth et al. 2016; Dobbs et al. 2017).

Another concept gaining attention is *ecosystem disservices*, defined as "*functions or properties of ecosystems that are perceived as negative for human well-being*" (Lyytimäki 2014, p. 311), and how management can affect the extent of ecosystem disservices caused by urban trees (Östberg et al. 2012; Delshammar et al. 2015; Dobbs et al. 2017; Lyytimäki 2017).

Management of urban trees is key to sustaining and increasing important ecosystem services (Dobbs et al. 2017) and reducing the amount of ecosystem disservices (Lyytimäki 2017), and municipal tree inventories are the foundation on which management of urban trees is based (Kielbaso 2008; Miller et al. 2015; Morgenroth et al. 2016). In recent decades there has therefore been increasing interest in municipal tree inventories, resulting from e.g. growing problems with pest and disease attack on the urban tree stock (Raupp et al. 2006) and growing awareness among decision-makers of the multiple ecosystem services trees provide in the cityscape (Roy et al. 2011; Hubacek and Kronenberg 2013; Nielsen et al. 2014). Municipalities, especially in North America and Europe, have therefore increasingly started to perform municipal tree inventories (e.g. Nowak et al. 2001; Keller and Konijnendijk 2012; Sjöman et al. 2012). Municipal tree inventories in North America have largely involved the use of i-Tree to perform

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economic valuations of urban trees (Kielbaso 2008; i-Tree 2017; Morgenroth and Östberg 2017; Rogers et al. 2017), whereas Northern Europe has focused more on management issues, e.g. tree health and management related to monitoring the dynamics of the tree stands (Keller and Konijnendijk 2012; Morgenroth and Östberg 2017).

Municipal tree inventories in Sweden have only recently received attention among researchers. One of the first studies to compare municipal tree inventories presented data for 10 Nordic cities (Sjöman et al. 2012). Since then, a related practical national standard focusing on what to include and how to perform an urban tree inventory in Swedish municipalities has been published (Östberg et al. 2013). However, there is no overview of the current state of municipal tree inventories and thus there is a lack of understanding of how municipality size, green space budget and management organisation affect the presence and state of municipal tree inventories. The relationship between tree inventory and green space budget may be a prerequisite for good tree management, while organisational aspects might also be important since there is an obvious need for an inventory if tree maintenance is outsourced (Lindholst 2009; Randrup and Persson 2009). Hauer and Peterson (2016) suggest that the execution of municipal tree inventories can be connected to factors such as size of the municipality, green space budget, or perceived need for the municipality to maintain a high number of urban trees and related records of tree removal and planting.

Therefore, the **objective** of the present study was to gain further insights into Swedish practice concerning tree inventories, driven by the following **research questions**: *What is the current state of Swedish municipal tree inventories?* and *What affects the status of the municipal tree inventories*? In order to analyse these research questions, five sub-questions were formulated:

a. What is the extent of municipal tree inventories in Sweden?
b. What areas are included in the inventories?
c. Who conducted the inventories?
d. What kind of data has been collected?
e. What are the inventories used for?

Materials and methods

The survey

Based on recent surveys in the United States of America, Canada and the United Kingdom (Neal et al. 2014; Hauer and Peterson 2016; Bardekjian et al. 2016), a survey was developed for the Swedish context. The survey was divided into five parts, each consisting of 5–11 questions:

- Budget/Financing included questions relating to the municipality's economic situation and specifically which economic resources are available for management of green spaces and trees. Questions relating to historical developments and how municipal managers viewed future resource allocations were also included.
- Maintenance of green spaces and trees included questions relating to the daily maintenance, e.g. personnel, type of contractors being used (public/private), total amount of green spaces/trees, and how these have developed over time and how they are expected to be developed in the future.
- Policy, plans and strategies included questions about the strategic documents used in order to steer and develop green spaces/trees.
- Quality included questions relating to municipal managers' perceptions on the quality of their green spaces and urban trees.
- Tree inventories included questions specifically relating to urban trees, e.g. about management systems such as tree inventories and use of digital data systems.

This paper primarily deals with the questions specifically relating to trees and tree inventories. The survey was first tested in a pilot study involving 15 municipalities representing different sizes and locations around Sweden. Based on the comments collected from the pilot study, the survey questions were revised.

All 290 Swedish municipal websites were visited in December 2015 in order to obtain correct contact names and addresses and personal contact was made with some municipal arborists known to the authors. Municipal personnel with the greatest responsibility for green spaces and trees were selected as contact persons. If more than one person was identified, all were included as recipients of the survey. The actual distribution of the survey and issue of reminders were performed via e-mail, with reminders being sent to all non-respondents at 2, 3, 4 and 8 weeks after the initial distribution.

Written responses received via ordinary mail ($n = 17$) were entered manually into Netigate (Netigate AB, Sweden) and then all responses was downloaded to Microsoft Excel 2010 (Microsoft Corporation, USA). All responses were evaluated manually for obvious errors, and in this process eight duplicate answers were deleted. In cases where a municipality had submitted two responses, the most recent and most comprehensive was kept. Responses that were less than 10% complete were also deleted. In total, 161 surveys (55.5% response rate for all Swedish municipalities) were included in the dataset and formed the basis for further analysis.

Statistical analysis

All statistical tests were performed at a significance level of 0.05. To test the representativeness of the survey concerning spatial distribution and municipal types, a Chi-square test was performed on the observed distribution of responses between municipal groups as defined by the Swedish Association of Local Authorities and Regions (SKL 2011) compared with the actual distribution for Sweden. This test was non-significant ($\chi^2 = 8.086$, df = 9, $n = 161$, $p = 0.525$). To test whether the responding municipalities differed in population size and area from Swedish municipalities in general, one-sample Z-tests based on national statistics were performed. Neither of these tests gave a significant result ($Z = 0.97$; $p = 0.331$ and $Z = -1.30$; $p = 0.194$, respectively). Accounting for eventual skewed distribution by using one-sample sign test did not produce any significant results. As such, the responses to the survey can be seen as a fair representation of Sweden as a whole.

The statistical tests performed for the research questions and the five sub-questions are described below.

What is the extent of municipal tree inventories in Sweden?

In order to study the factors affecting the presence of an urban tree inventory, we modelled this in several steps. First, due to the strong evidence in the literature (Miller 1997) that having a tree management plan is dependent on having a tree inventory, we explored this relationship with 2×2 cross tables and Fisher's exact test (R Core Team 2016) and found that it was significant ($p < 0.0001$). Based on this, in a second step we only used inventory as response variable and excluded management plan due to their collinearity. To explore the reasons for having a tree inventory, we employed generalised linear modelling in SAS 9.4, using the genmod procedure with a binomial distribution and logit link function (i.e. binary logistic regression). The p-scale option was used to avoid problems of over-dispersion in the models. Having a tree inventory was modelled as the binomial response. As explanatory variables, the following variables were included: population (Koeser et al. 2016), greenspace budget per capita (Randrup and Persson 2009), percentage of contractors used in tree management (Hauer and Peterson 2016), number of trees planted per capita (Bardekjian et al. 2016) and record of trees being removed or planted (Kuhns et al. 2005).

Using the Bayesian information criteria (BIC) and Type 3 significance test of the variables, the most theoretically sound and parsimonious model was selected based on adding the variables to the models individually in the order above that reflected our hypothesis on their importance, with significance level for inclusion in the model set to $p < 0.05$.

To test the hypothesis that 'number of municipalities with a digitalised tree inventory increases with population size', the same generalized linear modelling approach as above was used. The response was derived from the subset of the data having an inventory and then split into having the inventory digitalised or not. The same approach was used to analyse the reasons for updating the inventory or not.

To test the relationship between population size and number of municipal trees, Spearman correlation and associated test was calculated between population size and number of municipal trees as well as municipal trees per capita (R Core Team 2016).

To gain an insight into factors that might influence changes in the number of trees in the urban municipal tree population, we calculated the net gain of trees by subtracting the number of trees removed from the number of reported planted trees. This value was then modelled as the response in a general linear model using proc. mixed (SAS 9.4) and population, budget per capita, contractors and presence of a management plan as explanatory variables.

Analysis of multiple choice questions

For the multiple choice questions 'Who conducted the inventory?', 'What kind of data have been collected?', 'What are the inventories used for?' and 'What areas are included in the inventories?' we used the approach presented below for each individual question, using the binary matrix of variables for the specific question as analytical unit. To give an overview of the relations and eventual grouping between the variables concerning each question, we used clustering with additional graphical tools. This was performed by average agglomerative clustering using the unweighted pair group method with arithmetic mean (UPGMA) (Maechler et al. 2014) with binary distances from the dist function in R (R Core Team 2016). We verified that UPGMA had the highest cophenetic correlation coefficient compared with single-linkage agglomerative clustering, complete-average agglomerative clustering and Ward's minimum variance clustering. We used Mantel statics to decide on number of clusters to display in the dendrogram. We then applied the vegemite and heatmap function in R package vegan (Oksanen et al. 2013) to produce a graphical overview of the data matrix in relation to the clustering. To get an approximation of the differences between the different response rates for each area, multiple Chi-square tests with Holm's correction for multiple testing were performed (Holm 1979; R Core Team 2016). These approximations were added to the graphs using the convention whereby variables sharing the same letter do not differ significantly from each other.

To explore the relationship with population size, budget per capita and percentage of contractors, we used these as explanatory variables in a multivariate regression tree (Therneau et al. 2013; Ouellette and Legendre 2013) of the response matrix with a chord transformation (to linearise the data).

Discriminate variables for the different branches of the regression tree and significant coding for them were added. The results of the regression tree were verified by comparing the results with a global non-metric multidimensional scaling with a Gower distance and post-hoc testing of the explanatory variables with the Envfit function (Oksanen et al. 2013).

Results and discussion

The results are structured around the research questions and sub-questions and are addressed in the following order:

1. What is the extent of municipal tree inventories in Sweden?
2. What areas are included in the inventories?
3. Who conducted the inventories?
4. What kind of data has been collected?
5. What are the inventories used for?

What is the extent of municipal tree inventories in Sweden?

Of the 161 municipalities that responded to the survey, 85 (52.8%) had a municipal tree inventory. The number of municipalities that had an inventory increased with municipal population, from 34.4% for cities with populations ranging from 2500 to 9999 to 92.3% for the largest municipalities (100,000 to 500,000 inhabitants). A similar trend was seen for the number of inventories digitalised, which ranged from 27.3% to 83.3%. However, a large number of inventories were either 'under development' (54.1%) or 'outdated' (27.1%) (Table 1). There were no significant relationships between any of the parameters tested and whether the inventory was updated or not.

The probability of the inventory being digitalised increased significantly with population size of the municipality ($F_{1,80} = 6.68$, $p = 0.0116$). This influence of population was also confirmed by statistical analysis, which showed that population size of the municipality was the only variable significantly related to the presence of an inventory ($F_{1,148} = 23.51$, $p < 0.0001$) when comparing the factors: Population, greenspace budget per capita, percentage of contractors used in tree management, number of trees planted per capita and record of trees being removed or planted. There was also a significant positive correlation ($r_{Spearman} = 0.6721256$, $n = 83$, $p < 0.0001$) between population size and number of municipal trees.

The results suggested that, if a municipality has a tree inventory (54.5% of all), it is also likely to have a tree management plan (55.2% of those with an inventory). Only 2% of all municipalities had a tree management plan without the presence of a tree inventory. This difference was supported by the Fisher exact test, which gave a significant result ($p < 0.0001$), implying that for almost all municipalities a tree inventory forms the basis for their tree management plan. These results confirm findings in a number of studies and recommendations that stress the need to first conduct an tree inventory and then create a management plan (e.g. Kielbaso 2008; Miller et al. 2015; Morgenroth et al. 2016; Zürcher 2017).

The reason why population size influences the presence of municipal tree inventories is unknown. Since most national and international surveys have focused on existing inventories (e.g. Sjöman et al. 2012; McPherson et al. 2016), have conducted their own inventories (Britt and Johnston 2008) or have been limited to specific regions (Kuhns et al. 2005; Schroeder et al. 2003), it is difficult to compare the Swedish situation with that internationally. However, the effect of population size might be due to several different factors. (1) Municipalities with larger population size will, in most cases, have relatively larger tree populations and therefore it is more difficult to get an overview of the whole tree population without a municipal tree inventory. This is supported by the trend that larger municipalities had more trees per capita ($r_{Spearman} = 0.3323806$, $n = 83$, $p < 0.0021$), and is in line with previous findings by Kuhns et al. (2005). Larger municipalities might thereby not only have more trees, but also more trees per capita,

Table 1 Number of responding municipalities that had an urban tree inventory and the status of those inventories

Population size of the municipality	n	Have an inventory (n and %)[a]	Digitalised inventories of all inventories (n and %)	Updated inventories of all inventories (n and %)	Inventories that are under development of all inventories (n and %)	Inventories that are outdated of all inventories (n and %)
2500 to 9999	32	11 (34.4%)	3 (27.3%)	2 (18.2%)	6 (54.5%)	4 (36.4%)
10,000 to 24,999	61	24 (39.3%)	10 (41.7%)	6 (25.0%)	11 (45.8%)	6 (25.0%)
25,000 to 49,999	33	21 (63.6%)	15 (71.4%)	4 (19.0%)	13 (61.9%)	4 (19.0%)
50,000 to 99,999	22	17 (77.3%)	14 (82.4%)	2 (11.8%)	10 (58.8%)	5 (29.4%)
100,000 to 500,000	13	12 (92.3%)	10 (83.3%)	2 (16.7%)	6 (50.0%)	4 (33.3%)
Total	161	85 (52.8%)	52 (61.2%)	16 (18.8%)	46 (54.1%)	23 (27.1%)

[a] The municipalities were asked if the inventory was *digitalised* or not, and if the inventory was *updated*, *in-development* or *outdated*

which creates an even higher need for an urban tree inventory and a management plan. In comparison with North American cities (Hauer and Peterson 2016; Bardekjian et al. 2016), Swedish municipalities have fewer municipal tree inventories. (2) There could be an organisational aspect that differentiates large and small municipalities, where larger municipalities have a higher number of decision steps between the tree work and the highest level of administration. This is supported by findings by Hauer and Peterson (2016) that large communities have 6.7 description steps, while smaller communities have 2.6 steps. This difference might thereby create a need not only to collect data, but also to present it to politicians in a comprehensive way (Miller et al. 2015). This theory is supported by the fact that larger municipalities to a higher degree than smaller have created a management plan.

What areas are included in the inventories?

Most municipalities reported that they conduct inventories on *street trees* (93%) and *park trees* (79%), but inventories are also conducted on other municipal areas, although to a lesser extent: *Municipal urban woodlands*, i.e. woodlots (26%), *green corridors managed by the municipality,* i.e. greenbelts (20%), *other municipal buildings such as urban real estate/kindergarten/school/home for the elderly* (15%), and *private trees* (2%). There was no statistically significant difference between *street* and *park* trees and all other areas except for *private* trees, which differed significantly from all other groups (Fig. 1).

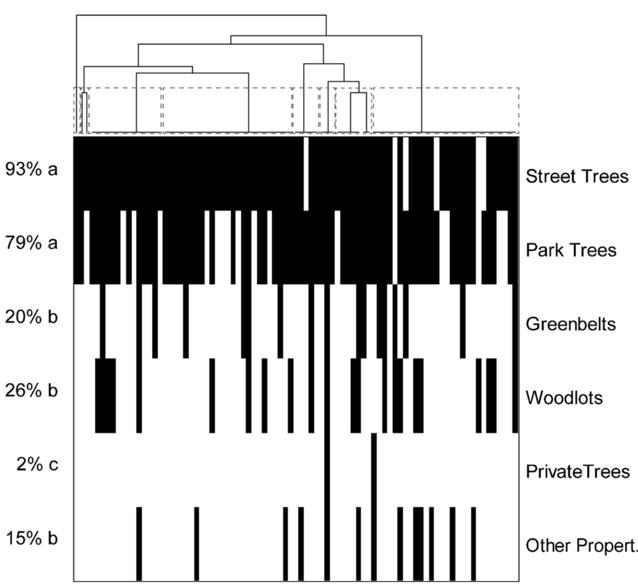

Fig. 1 Heatmap of the unweighted pair group method with arithmetic mean (UPGMA) clustering for "What areas have been inventoried?". Grouping and dendrogram at the top and variable names to the right. Approximation of significant difference in frequencies based on pairwise Chi-square tests with Holm correction to the left. Variables sharing the same letter do not differ significantly from each other

In the multivariate regression tree (MRT), there was a tendency for municipalities with large budgets (≥72.5 SEK/person (7.5 Euros/person)) to inventory woodlands and other properties to a greater extent than other municipalities, whereas municipalities with lower budgets had a tendency to focus on street trees (Appendix). Sjöman et al. (2012) found that many inventories begin with street trees and then later add other trees, which is in line with international recommendations that street trees should be prioritised due to risk (Long et al. 2008; Sreetheran et al. 2011), contribution to ecosystem services (McPherson et al. 2016) and higher costs than other trees (McPherson et al. 2016). This is supported by the findings of the present study, where 65% of responding municipalities included risk as a parameter. However, we also found that smaller municipalities included inventories of greenbelts and woodlands. The reason for this may lie in the fact that many Swedish municipalities with smaller populations are primarily rural, and thus almost integrated in highly forested areas where urban woodlands are a natural part of the urban fabric (Rydberg and Falck 2000). A traditional forestry operating approach (Mikkonen 2004; Andersson et al. 2013) is likely in these municipalities, thus including also green spaces, green corridors and urban woodlands in operations.

Due to weak legal protection, urban woodlands are frequently exploited as part of urban densification (Tallhagen 1999; Nielsen et al. 2017) and as such often fall within the remit of the municipal planning department instead of the management department. This discrepancy between single tree approaches and stand approaches to the urban forest as a whole might be one important aspect that hinders effective adoption of a total green infrastructure approach (Matthews et al. 2015).

Private trees emerged as the area that received least attention in all Swedish municipalities, although private trees have started to attract more attention from the scientific community (McPherson 1998; Jones 2008; Jones and Davis 2017). Private trees also constitute a large part of the total urban forest in the USA, with studies showing that they account for roughly 75% of all trees in cities (McPherson 1998). While most planting decisions are made by private landowners and developers (Berland and Elliot 2014), only two municipalities in our survey have conducted municipal tree inventories on private land. This is probably related to the many problems associated with conducting inventories on private land, e.g. access to the trees (McPherson 1998), but also to the fact that municipalities prioritise their focus to what is directly administrated by the city administration. Swedish municipal tree inventories are primarily conducted for management purposes and therefore the areas that are used most, i.e. streets and parks, are prioritised. In Denmark, many inventories are conducted due to risk (Keller and Konijnendijk 2012) and the same seems to apply in Sweden which also explains why private trees are not prioritised. If the focus instead were to create strategic plans for e.g. ecosystem services, private trees might be a higher priority, but Swedish tree inventories are primarily used for maintenance and not for planning (see section: What kind of data have been collected?).

Who conducts the municipal tree inventories?

Overall 64% of all municipalities used C*onsultants* for collecting tree inventory data, and 58% used *in-house staff. Seasonal employee/temporary employee* was used by only 12%, and no-one used *volunteers* (Fig. 2). However, as seen in Fig. 2 and confirmed by the multiple branching of the MRT (Appendix), the use of contractors is not an 'either/or' response, as many municipalities use both municipal staff and consultants, and sometimes even interns.

The use of both in-house staff and consultants is probably due to available resources, where municipalities sometimes lack sufficient in-house staff to conduct the inventory. This assumption is supported by a study in Norway, which also describes a situation where specific green space management tasks might be performed by consultants (Leiren et al. 2016). This could also be the case for municipal tree inventories, where e.g. risk assessments are performed by consultants (Terho and Hallaksela 2005).

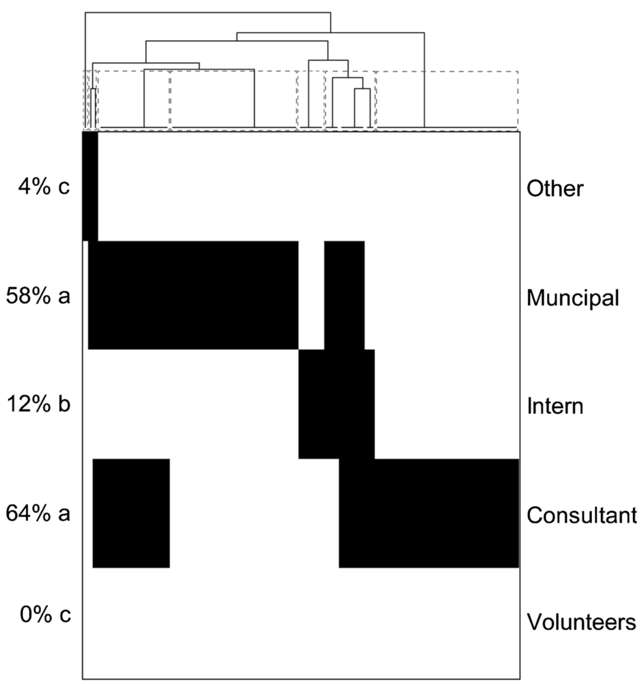

Fig. 2 Heatmap of the unweighted pair group method with arithmetic mean (UPGMA) clustering for "Who conducts the urban tree inventory?". Grouping and dendrogram at the top and variable names to the right. Approximation of significant difference in frequencies based on pairwise Chi-square tests with Holm correction to the left. Variables sharing the same letter do not differ significantly from each other

None of the municipal tree inventories in Sweden had used volunteers, which is in line with the results of Keller and Konijnendijk (2012, p. 28) who concluded that "*No volunteers were used in Scandinavia when carrying out the inventory, and no further community-engaging projects were started as a result of the inventory*". The results of the present study and that by Keller and Konijnendijk (2012) can be compared to the situation reported by Hauer and Peterson (2016), where 14% of the inventories were conducted by volunteers, or Roman et al. (2013) where 42% used volunteers. According to Keller and Konijnendijk (2012), the use of volunteers raises concerns over the validity of the inventory itself. However, Roman et al. (2016) found very little difference in the quality of data collection between volunteers and professionals. In Sweden, there might also be a cultural reason for the lack of volunteers used in urban tree inventorying. Swedes in general do not volunteer for issues that they regard as a government/municipal responsibility, whereas they spend rather much time volunteering for e.g. sport organisations (Grassman and Svedberg 1996). However, there may be some changes occurring concerning the willingness of Swedes to actively participate in the management of urban trees. A study conducted by Östberg and Kleinschmit (2016) showed how private citizens in Stockholm were highly involved in demonstrating against felling of a large oak. Similar situations have arisen all around Sweden, ranging from avenue trees in Gothenburg (GP 2013) to a large apple tree in Gävle (SR 2014).

What kind of data have been collected?

In tree inventories, Swedish municipalities primarily focus on *tree species* (89%) and information on *vitality* (74%), followed by *risk* (65%), the *need for removal* (64%) and diameter at breast height (*DBH)* (57%), whereas *locations for planting trees, economic value* and *woody debris* are not often included (Fig. 3). In the MRT, smaller municipalities (population lower than 7128, corresponding to the 15th percentile) focused more on *risk* and *removal* (operational aspects), than more analytical variables such as DBH, vitality, insects/pest and species (Appendix). Otherwise, as seen in Fig. 3, no major differences in data collection could be seen.

The urban tree inventory parameters measured have a direct impact on the potential use of the inventory (Miller 1997; Östberg et al. 2013; Miller et al. 2015) and it is therefore crucial to select appropriate tree inventory parameters (Östberg et al. 2013). Many of the Swedish municipalities are following the international trend of prioritising *species*, *DBH* and *vitality* (Roman et al. 2013; Östberg et al. 2013). However, Scandinavian municipalities seem to collect information on risk to a higher degree than other urban tree managers, as also observed by Keller and Konijnendijk (2012) for Danish municipalities. The origins of this risk focus are difficult to discern, but personal communications

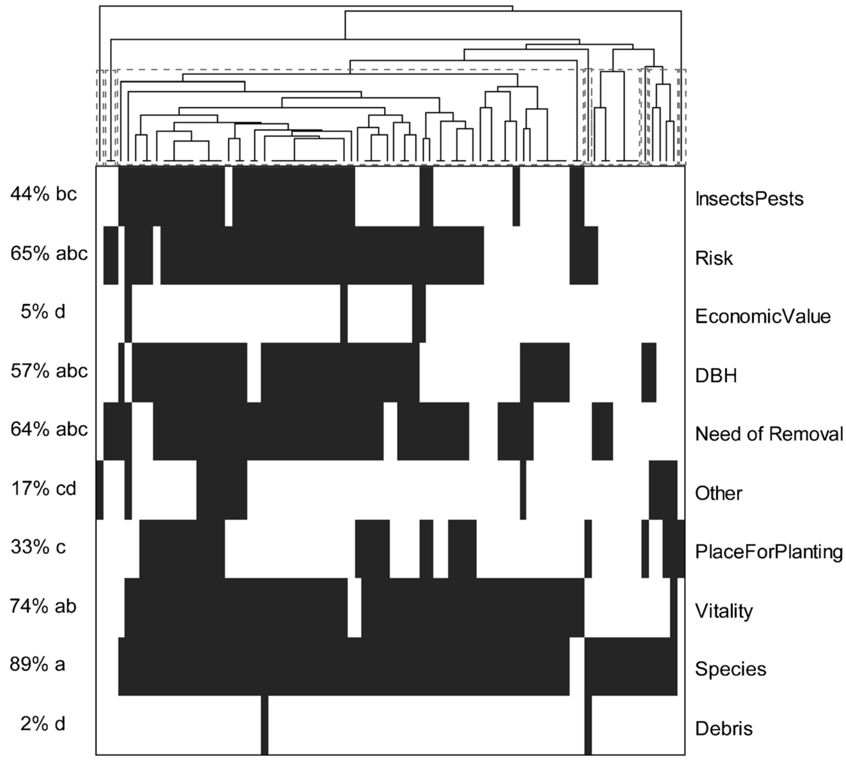

Fig. 3 Heatmap of the unweighted pair group method with arithmetic mean (UPGMA) clustering for "What kind of data have been collected?". Grouping and dendrogram at the top and variable names to the right. Approximation of significant difference in frequencies based on pairwise Chi-square tests with Holm correction to the left. Variables sharing the same letter do not differ significantly from each other

with Swedish municipalities suggest that *risk* is sometimes used as an excuse to conduct municipal tree inventories since politicians are more willing to pay for inventories that have a risk focus than e.g. an inventory of tree canopy cover. This reflects the claim by Matthews et al. (2015) that green infrastructure questions are often seen as either capital-based or risk-based.

The risk focus can also be associated with the cost of managing the damage that urban trees can cause, so-called ecosystem disservices (Lyytimäki 2014; Delshammar et al. 2015; Cariñanos et al. 2017), including risk-based removal of urban trees (Cariñanos et al. 2017), which suggests that Swedish municipalities have a lower tolerance to both risk and ecosystem disservices and the costs associated with these. This might in turn be due to the fact that economic valuation of ecosystem services is a very new field, and thereby Swedish municipalities have only seen the costs of urban trees, the ecosystem disservices (Lyytimäki 2014), and not the economic savings in the form of ecosystem services by which urban trees contribute to the overall municipal economy (Rogers et al. 2017).

The survey results indicated that smaller municipalities focus more on risk, contradicting findings in previous studies of no significant difference in frequency of tree risk assessments depending on municipality size (Koeser et al. 2016). It might be due to the fact that smaller municipalities focus more on operational tasks and may not collect information to create management plans (see section What is the extent of municipal tree inventories in Sweden?).

What are municipal tree inventories used for?

Tree inventories in Swedish municipalities are focused on the day-to-day maintenance of urban trees, where *tree removal* accounts for 71% of all use, *pruning* 55%, *tree care planning* 52%, dealing with *complaints* 45% and *height pruning* 31%. There is also a focus on planning, which includes *policy* (42%), *tree selection* (41%) and *place for planting* (40%). Only a few municipalities use their inventory for anything other than strategic purposes, e.g. *canopy cover* (5%) and *ecosystem services* (5%) (Fig. 4).

The MRT showed a clear difference between those municipalities with higher amounts of contractors (>35%), which focused more on policy development than those municipalities primarily using in-house staff for the collection of data (Appendix). The latter municipalities use their inventory more for operational management aspects and especially overall tree management planning.

There was no significant relationship between changes in urban tree population development (sum of trees planted minus trees removed) and any of the variables tested, including the presence of a management plan.

The limited use of tree inventories for strategic purposes is rather surprising, since Swedish municipalities have a government mandate to work with ecosystem services (Regeringen 2014). However, there might be a discrepancy between the long-term goals which ecosystem services often represent (Jones 2008; Dobbs et al. 2017) and the fact that most green space managers are

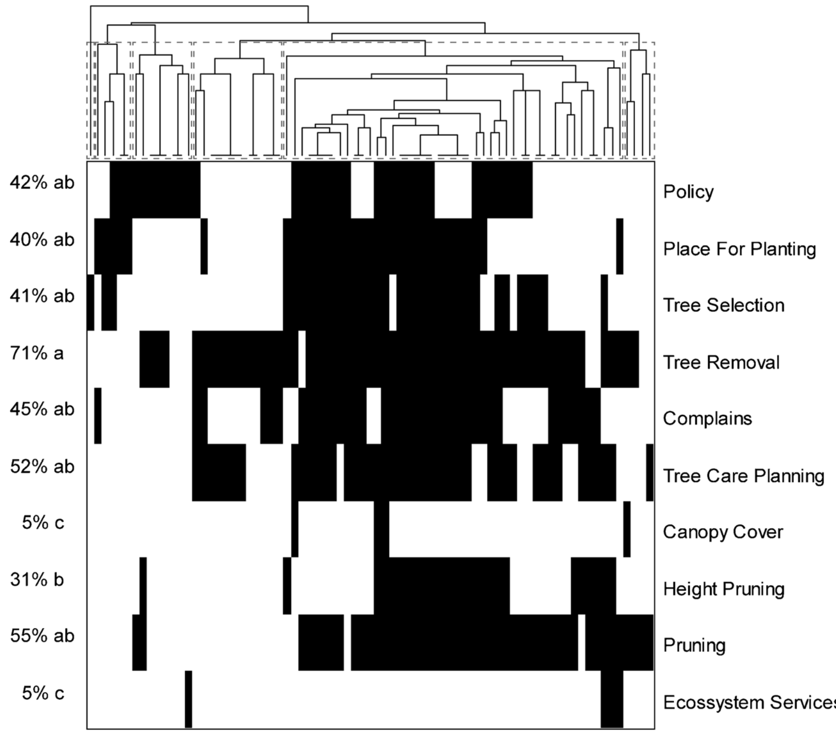

Fig. 4 Heatmap of the unweighted pair group method with arithmetic mean (UPGMA) clustering for "What are the inventories used for?". Grouping and dendrogram at the top and variable names to the right. Approximation of significant difference in frequencies based on pairwise Chi-square tests with Holm correction to the left. Variables sharing the same letter do not differ significantly from each other

operating on a day-to-day basis (Randrup and Persson 2009). In relation to this, the fact that municipalities which used contractors to a greater extent also more often used their tree inventory for policy development is worth noting. It reflects the fact that in previous studies, use for strategic purposes is a strong driver for the collection of data (Miller 1997; Östberg et al. 2013; Miller et al. 2015).

Use of the inventory was linked with the use of contractors, which might be due to the fact the closer the organisation is to the practical management level, the more focus needs to be aimed at operational questions, whereas municipalities that work with consultants probably need to focus more on policy documents in order to steer the organisation and its consultants. This is supported by findings of Randrup and Persson (2009) that the distribution of the budget between municipal authorities responsible for green space planning, including trees, other public organisations, and private companies is 53%, 21% and 26% respectively, in Sweden. The similar figures for Denmark are 29%, 63% and 8%, indicating that a focused green space authority (as in Sweden), also has a larger use of private contractors.

Conclusions

Most Swedish municipalities have conducted an urban tree inventory, but the size of the municipality strongly affects the presence of an inventory, with primarily larger municipalities being more likely to perform municipal tree inventories. This can be seen as an indication that the larger the municipal budget, the more likely the municipality is to conduct a tree inventory. These results are in line with international findings. We found large differences between Swedish municipalities in all aspects of urban tree inventorying, ranging from *Which municipalities conduct inventories*? to *What data are collected*? and *What are the data used for*?.

The inventories are conducted by both consultants and in-house staff and the parameters they collect data on are primarily *species*, *vitality*, *risk* and *DBH*. The inventory data are primarily used for operational tasks, which might indicate the difficulty in moving from operational to the much wider and strategic ecosystem services approach. At present there are no guidelines describing how municipalities should work with this topic, and therefore, we foresee a future potential, but also a challenge municipal tree inventories for Swedish municipalities when, by law, they are expected to go from an operational to a more strategic management level. We therefore recommend further research on how municipalities can move towards a more strategic perspective and how municipal tree inventories can be used as a resource in describing the services – and dis-services of urban trees, based on comprehensive municipal tree inventories.

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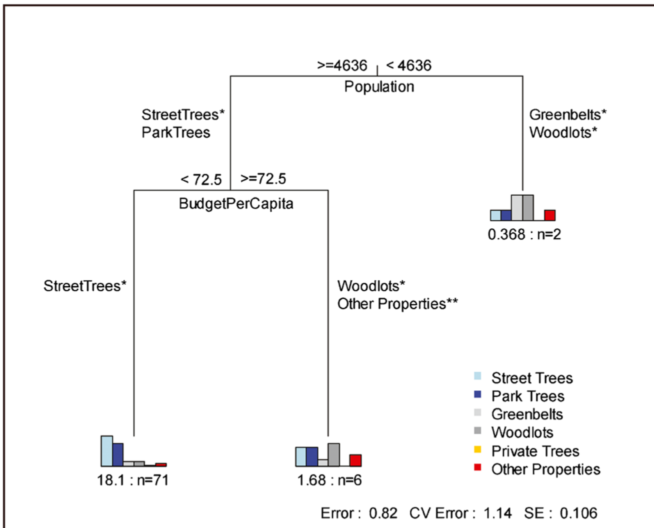
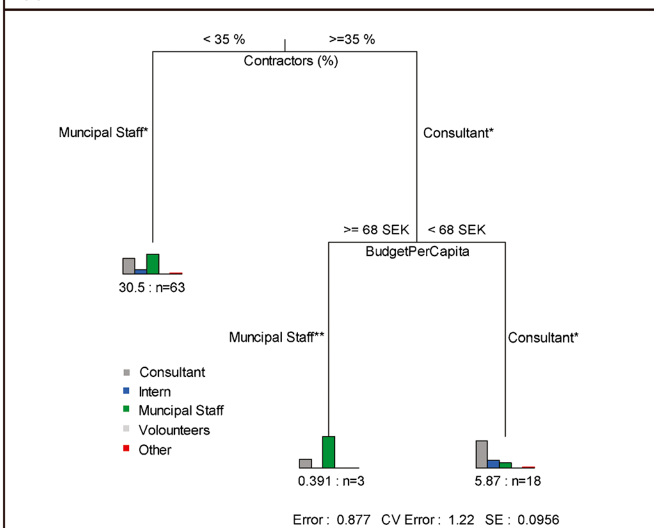
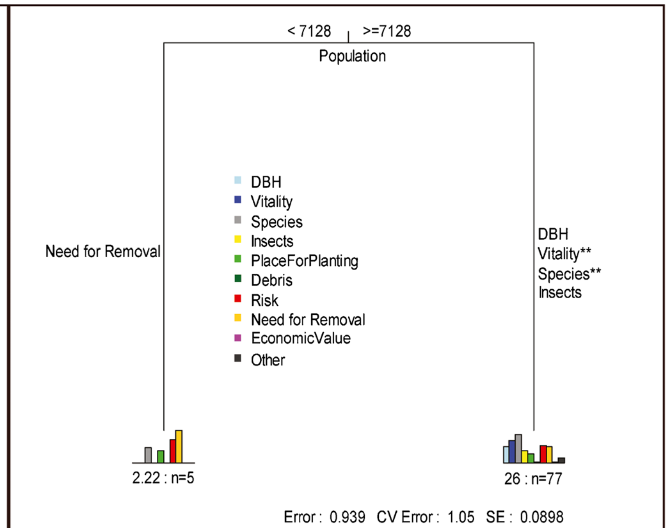
Appendix



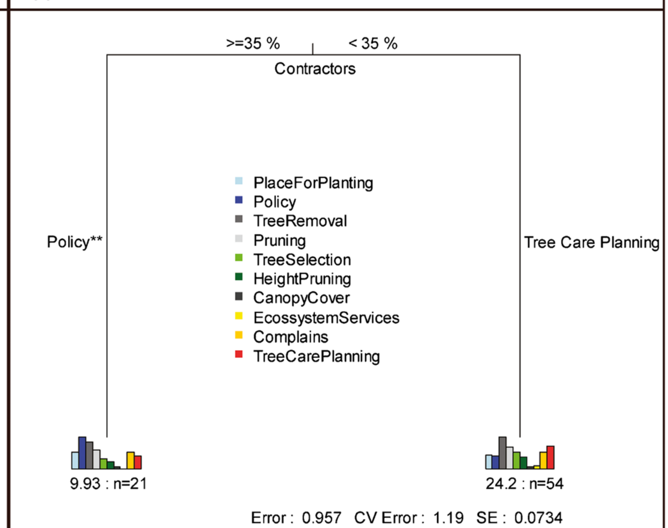
Appendix 1.1: MRT for "What areas have been inventoried?"



Appendix 1.2: MRT for "Who have conducted the inventory?"



Appendix 1.3: MRT for "What kind of data have been collected?"



Appendix 1.4: MRT for "What are the inventories used for?"

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