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Designing a long-term urban tree monitoring network – An Introductory Article

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Department of Landscape Architecture, Planning and Management
2020, Alnarp

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Place of publication: Alnarp
Year of publication: 2020
Online publication: https://pub.epsilon.slu.se

Keywords: urban forestry, urban trees, inventories, spatial sampling, governance

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Abstract

Tree inventories are recognized as an important tool for urban foresters and green space managers to perform sustainable management of urban trees. Urban trees are providers of several important ecosystem services, across ownerships and governance structures. There is a need to better understand how urban tree inventories tackle the need for holistic, complete and long term overviews, across administrative borders.

Therefore, this study examined literature on urban tree inventories with a primary focus on sampling design, identifying 62 relevant articles. First, we applied a governance arrangement approach to interpret which actors and aspects were involved, who took the initiatives to the inventories, and at which scale the inventories were carried out. Secondly, we studied the inventories themselves. The main results are that use of stratification in the sampling design was common, despite being problematic regarding its long-term usefulness. Only 7 % of the stratification sampling designs were regarded as having long-term stability. Studies frequently relied on new sampling designs, aimed at a particular issue as opposed to using an existing, longitudinal sampling network. Even though private trees can constitute over 50 % of the urban tree population, only 30 % of the studies included private trees.

The urban tree inventories mentioned in the academic literature are based on academic (scientific) initiatives and approaches, even if they primarily focus on tree data in local environmental perspectives. It is uncommon for these studies to include users or private tree owners, and very limited focus is on economic, cultural or social factors. This article stresses the need for long-term validation of sampling methods in urban areas and multi-lateral approach considerations.

Introduction

Urban areas are under transformation with climate change as one of the many contemporary challenges (UN, 2014). Adaptation to climate change begins and hinges on the measures taken in the urban areas where the majority of the world population resides (Revi *et al.*, 2014). Scientific research supports the notion that the urban population benefits in many ways from trees and green spaces (Norton *et al.*, 2015; Bowler *et al.*, 2010; Jones, 2008; Gill *et al.*, 2007; Tyrväinen *et al.*, 2007; Grahn & Stigsdotter, 2003). Remote sensing data from California has shown that residential developments can contribute to one percentage urban tree canopy loss per year due to construction of impermeable surfaces (Lee *et al.*, 2017), a concerning fact, since a decline in urban vegetation can have a direct impact on human health and quality of life (Jackson, 2003). Therefore, from a planning and management perspective, there is a need to monitor the development of urban vegetation and especially urban trees in order to develop and maintain this resource (Roman *et al.*, 2013).

Management of urban trees and green spaces is predominately driven by local governments (Randrup & Persson, 2009; Konijnendijk *et al.*, 2006), who are basically limited to management of publicly-owned areas. Many public managers struggle with the lack of resources to conduct or maintain an urban tree monitoring program (Nielsen *et al.*, 2014; Roman *et al.*, 2013), and utilize different approaches to overcome resource constraints. Most of these are derived from forest management and ecology (Nowak *et al.*, 2015), and applied to remote sensing data collection or field measurements. The sampling design of these methods offers a lot in terms of variability, but some of them are less suitable for long-term monitoring and representativeness in an urban setting.

An important stakeholder in urban tree management are the communities of private households (Shakeel & Conway, 2014) that can sometimes make up more than 50% of the urban tree cover (McPherson, 1998). In order to provide holistic and overarching measures to manage e.g. the entire urban tree population, inclusive governance structures need to be applied, since the private part of an urban forest are dependent in large part on what local governments encourage and support (Revi *et al.*, 2014). This involves appropriate frameworks to plan and manage key ecosystem services, regardless if they originate from public, semi-public or private land. However, residential area development and trees owned by private individuals, are from a public management perspective, inherently difficult/complex to monitor (Conway &

Lue, 2018), and constitute many dilemmas in relation to overviewing, recording, monitoring and data gathering.

According to a recent survey in Sweden, only 2 out of 85 municipalities runs an inventory including private trees (Wiström *et al.*, 2016), which means that the data gathered from urban tree inventories is limited to predominately public park and street trees. Remote sensing data from California has shown that residential developments can contribute to one percentage urban tree canopy loss per year due to construction of impermeable surfaces (Lee *et al.*, 2017). For the future efforts of urban forestry, this gap needs to be addressed, since most municipalities already include urban trees in their strategic environmental plans, but the actions of private residents can severely offset these efforts and can threaten the provision of ecosystem services in the future. Measures need to be taken to stimulate active citizen participation (Buijs *et al.*, 2016), and to include an overall policy approach to the gathering of urban tree data.

There are a lot of pitfalls when setting up a new monitoring system. Over time, some methods can skew the data series and give an inaccurate description of the resource. This is due to inherent variabilities and dynamics of the urban space, changing boundaries, land use and development driven by the high rates of urbanization processes (Nuissl *et al.*, 2009). The common use of spatial groupings within urban boundaries (stratification) can be problematic in this regard, since urban land is often re-classified, re-developed or re-purposed.

Sampling among the local urban tree population is the most common approach to assess the structure of the urban forest. Many local governments struggle with the lack of resources to conduct or maintain an urban tree monitoring program (Nielsen *et al.*, 2014; Roman *et al.*, 2013), and many different approaches to overcome resource constraints exist, mainly derived from forest management and ecology (Nowak *et al.*, 2015), using remote sensing or field measurements. The sampling design of these methods offers a lot in terms of variability, but some of them are less suitable for long-term monitoring and representativeness in an urban setting.

It goes to say that inventories are the basis of good natural resource management practice (Fischer *et al.*, 2007) and use of urban tree inventories is a thoroughly researched topic. However, a critical evaluation using a long-term perspective and sampling design as criteria seems to be missing. Practitioners in urban forest management often turn to scientific literature for guidelines in designing inventories, but do these articles offer best solutions for the urban setting from the perspective of long-term comprehensive management?

Based on this, we will study the academic literature in order to generate a framework for:

1. Sampling design in urban tree inventories, especially by inclusion of privately owned trees
2. Use of stratification and with emphasis on long-term representation.

In doing so, we will also study the governance arrangements of urban tree inventories in order to understand if and how focus is given to use of inventories in policymaking (e.g. in relation to climate change and human health issues).

Urban tree sampling methodology and definitions

Urban tree inventories are widely recognised as a key to conducting urban tree monitoring frameworks (Morgenroth & Östberg, 2017; Rogers *et al.*, 2017; Kielbaso, 2008; Nowak *et al.*, 2001). Despite the dictionary definition of the word inventory (a complete list of items), the colloquial use in forestry research more often refers to assessment based on incomplete data. Commonly we encounter the term as national forest inventories which do not make a complete list of all trees or forests, but instead make estimates based on incomplete assessments. This is how the word inventory will be used throughout this text. Inventories provide a snapshot of the current state of the trees in an urban forest, while multiple repeated inventories over time (monitoring) provide understanding on how tree populations change over time and offer better information for policy and decision making with respect to urban forest management (Morgenroth & Östberg, 2017).

If an incomplete number of trees are measured, the estimates yielded have inherent variation (Nowak *et al.*, 2015). However, the variation can be minimized by increasing the number of samples (Miller *et al.*, 2015). Different strategies have been developed to obtain more accurate estimates from sampled data that is representative of the urban forest as a whole. These include random, systematic, cluster, and stratified sampling (Hansen *et al.*, 1953).

Use of stratification is widespread in sampling, the main benefit is use of powerful analysis options it provides. Stratification method entails dividing the population into sub-populations (strata) using stratification factors and then sampling at uneven densities for each strata. In urban forestry, land-use is commonly used as a stratification factor, as well as local management units or other delineations.

Sampling inventories can also make it possible to estimate the state of privately-owned trees. However, this appears to rarely be donees (Wiström *et al.*, 2016). By private-owned trees we refer to trees that grow on privately owned residential lots in urban areas, mainly consisting of multiple household dwellings and detached or semi -detached housing.

Urban forest management and decision-making hinges on having representative data at the disposal, which is why a critical assessment of urban tree inventories is critical.

Material and method

Structured search and bibliographic overview

We applied a broad structured search of the literature, in order to get a comprehensive overview on contemporary scientific papers published about sample urban tree inventories. To focus on contemporary studies the search included literature from year 2001 onward. In July 2017, the following search string was applied to Web of Science and Scopus: *(cit* OR urban*) AND forest* AND tree* AND (monitor* OR invent*) AND (sampl* OR plot*).* The search string components were; location (cities and urban), population (trees and forests) and method (sampling, plots, monitoring, inventory), representing the frame of tree population and method being used. Results were later refined to include only publications written in English and being peer-reviewed.

After consolidating results from the two databases, 359 unique scientific articles were identified. All abstracts were reviewed, later on evaluated over several iterations, until it came down to a total of 62 articles that were included in the study. Excluded articles were e.g. non-tree inventories, inventories in non-urban environments or articles from other fields including similar keywords. The remaining 62 articles all included a tree inventory described in the method section of the manuscript. The selected publications were sorted in a spreadsheet using Microsoft Excel 2016 (Microsoft Corporation 2016).

The bibliographic information collected constituted of number of publications per year and the geographical area of each publication.

Validating contemporary sampling methods for long term monitoring

The 62 articles were categorized based on i) Type of stratification, ii) Stratification factor, iii) Possibility for long term monitoring, iv) Sampling method. Information was also included on the repeated use of existing frameworks (e.g. the USDA Forest Service's Forest Inventories and Analysis, National Forest Inventory), or when the study used a new design.

The categorization of stratification types was developed based on…….

The stratification factors were ranked on the basis of susceptibility to change over time based on the Urban Forest Ecosystem Classification framework (Steenberg *et al.*, 2015).

An analysis was conducted of the contemporary sampling methods' usefulness for long term monitoring of urban trees, in terms of their stability over time, where we defined the three categories as:

- **High stability**. The basis for stratification has a low probability to change over the coming 50 years. This was applied when the stratification was based on houses, infrastructure and set distances from a specific point.
- **Medium stability**. The basis for stratification has a medium probability to change over the coming 50 years. This was applied when the stratification was based on human demographics (e.g. population), and urban forest structure.
- **Low stability**. The basis for stratification has a high probability to change over the coming 50 years. This was applied when the stratification was based on socio economics and pollution rates.

Sampling methods were categorised as either systematic or random based on method description

Governance analysis approach

The policy arrangement model (PAM) is a conceptual framework, developed in environmental policy studies to assist understanding content and organization of a policy domain (Arts *et al.*, 2006). According to Arts et al., a policy arrangement is the state in which the interaction between *actors*, *resources*, *rules of the game* and *discourses* solidifies into an institutionalization. This is an unstable construct, which will be forced to readjustment as their interdependency changes. However, the four dimensions of the PAM model all give insights to how a tree inventory may be arranged within any political framework.

The 62 articles were categorised according to the PAM model and its four profoundly interconnected dimensions: *actors*, *resources*, *rules of the game*, and *discourses* (Arts *et al.*, 2006), each being modified to suit our course of studying urban tree inventories (see below). Any mention of their cross-sector engagement was recorded and categorized.The four categories were defined as:

Actors: actors and coalitions. The initiative for the inventory was classified as the origin of the idea that led to conducting an inventory. In the study the actors were differentiated between *public*, *private* and *academic initiative*. Academic initiatives were defined as using inventories formulated for the purpose of answering a scientific question. The inventories that had a pronounced role of public office or an institution were classified as public initiatives, where cases when private individuals or organisations were the driving force were classified as private initiatives. The actors involved in the inventory were then categorized as politicians, public servants, academics, private owners or end users.

Resources: benefits, values and resources mentioned in the inventory. These were broadly categorized in economic, cultural/historical, environmental and social categories, based on the management model framework described by (Randrup & Persson, 2009).

Rules of the game: formal rules and boundaries related to the inventories, interpreted as the organisational level where the inventory operates. We differentiated between three different scales of inventories: local, national and international, as defined by the boundaries of the surveyed area. Local scale was classified as scaling from site to multi-regional inventories.

Discourses: views and narratives of the actors presented in the discussion and application of the data compiled in the inventory. Special focus was given to articles that involved views other than of the actors themselves and on what the potential implications of the results might be.

Results

Bibliographic Overview

We found an uneven distribution of published articles during the selected study period (2001- June 2017). In 2011, we found for the first time more than three papers within this subject to be published. From there, there an uneven, but gradually increasing number of articles have been published (Figure 1). There was a relatively low number of articles published in 2015, but this was followed by a large increase in 2016. The search was done in July of 2017 which explains the low number of publications that year. The number of publications per region was dominated by North America and Europe, accounting for 51.6 % and 29 % respectively of the total number of publications, compared to Asia with 9.7%. No publications from Africa were found in the search (Figure 1).

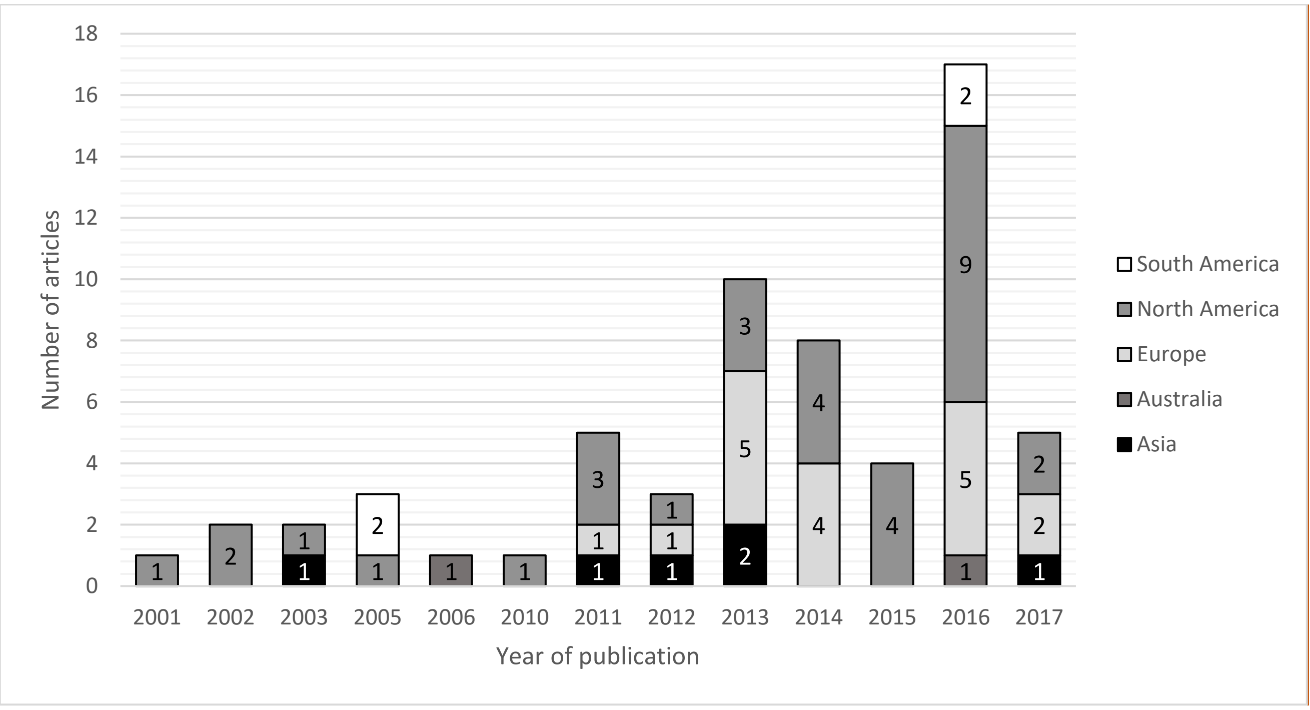

Figure 1: Number of publications per year in different world regions.

Validating contemporary sampling methods for long term monitoring

In total, we identified 5 different types of stratification (Climate, Infrastructure, Management, Social and Vegetation). Each of these types used different stratification factors, we identified 14 in total. In Table 1 the identified stratification factors are listed in relation to their respective stratification types. For each stratification factor, we have assessed the stability for long term studies (low, medium or high), as well as the chosen sampling method.

Almost half of the articles (29 of 62) described a type of stratification used in their sampling design. In some cases, post-stratification was applied (Escobedo *et al.*, 2016; Strunk *et al.*, 2016). The stratification factors were primarily based on infrastructure, vegetation or social factors as shown in Table 1.

Out of articles that utilized stratification, 13 were designed as long-term trials and none discussed validation of stratification factors and likelihood of change over different time scales. To better illustrate examples when validating stratification factors, Figure 2 outlines our interpretation of different decision-scenarios that occur during sampling design related to the necessity of validation.

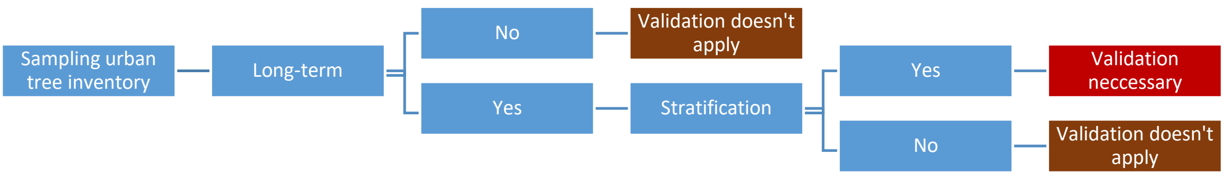

Figure 2: A key illustrating when validation of stratification factors is necessary for future representability

Only one type of stratification (Infrastructure), yielded stratification factors which were categorized as providing longitudinal stability and reliability to create a long-term network (Age of housing and Vicinity to city center). Only one paper reported on a stratified, systematic sample method (Dale & Frank, 2014), as all others used a stratified, random approach.

Table 1: Articles from the search grouped by stratification factor and sampling method.

Type of stratification	Stratification factor	Stability for long term studies?	Sampling method	References from the literature studied in this article
Climatic	Thermal differences	Medium	Stratified systematic	(Dale & Frank, 2014)
Infrastructure	Age of housing, landscape types	High	Stratified random	(Nitoslawski & Duinker, 2016)
Infrastructure	Traffic, traffic density, pollution and specific urban structure	Medium	Stratified random	(Kosiorek *et al.*, 2016; Nitoslawski & Duinker, 2016; Steindor *et al.*, 2016; Van Wittenberghe *et al.*, 2014)
Infrastructure	Land use, land cover	Medium	Stratified random	(Blood *et al.*, 2016; Intasen *et al.*, 2016; Larondelle & Strohbach, 2016; Nowak, 2012)
Infrastructure	Vicinity to city centre	High	Stratified random	(Huang *et al.*, 2013)
Management	Management units within a city (neighbourhood, homogenous units within a city)	Medium	Stratified random	(Escobedo *et al.*, 2016; Ren *et al.*, 2013; Schmitt-Harsh *et al.*, 2013; Ren *et al.*, 2011; Maco & McPherson, 2003)
Social	Combination of socio-economic indicators	Low	Stratified random	(Reynolds *et al.*, 2017; Alvarez *et al.*, 2005)
Social	Index of human interference	Low	Stratified random	(Nock *et al.*, 2013)
Social	Size and location of a community	Medium	Stratified random	(Gartner *et al.*, 2002)
Vegetation	Urban forest stand structure	Medium	Stratified random	(Pippuri *et al.*, 2013; Ren *et al.,* 2011)
Vegetation	Vegetation properties	Medium	Stratified random	(Ferrari *et al.*, 2017; Possley *et al.*, 2014; Brack, 2006)
Vegetation	Tree cover and other vegetation data	Medium	Stratified random	(Strunk *et al.*, 2016; Staudhammer *et al.*, 2015; Possley *et al.*, 2014; Nowak *et al.*, 2013)
Vegetation	Tree species composition	Medium	Stratified random	(Ferrari *et al.,* 2017)

Governance analysis

All included articles were initiated by academia. Nineteen articles additionally included public perspectives (municipalities or government agencies) to the research topic, primarily by discussing the results in a public management perspective, (e.g. none mentioned a private stakeholder perspective). The majority of the studies were conducted at the local governmental scale (59), some also venturing to national scale (4), but only one study (Nowak, 2012) put its findings into an international perspective.

All studies highlighted ecological aspects of trees in the urban environment. Economic impact was featured 8 times, social aspect 4 times while only one article referred to cultural values of urban trees.

Thus, the results showed that no studies were initiated by private stakeholders, which may not be surprising considering that the articles in the review were all academic articles. However, the lack of inclusion of private individuals or institutions was significant. This finding was emphasised by the fact that only six studies included private owners.

Table 2 summarize the qualitative governance analysis. Based on this, the contemporary urban tree inventories mentioned in the academic literature are based on an academic (scientific) initiative and approach, with focus on local environmental perspectives. Any deviation from this is rare, in the studies that do include multiple actors we detected a higher potential for management application (Intasen, 2016, Mills, 2016, Nock, 2013) and a pragmatic approach to a local issue.

Table 2: Governance analysis results according to the policy arrangement model. The number of articles that registered multiple answers is listed at the bottom of the table

Actors	**Resource**	**Rules of the game**	**Discourses**
Academic (62)	Economic (8)	Local (59)	Academic (62)
Public (19)	Environmental (62)	National (4)	Public servants (19)
Private (0)	Social (4)	International (1)	Private owners (6)
	Cultural (1)		Users (4)
			Politicians (0)
Multiple categories (19)	Multiple categories (2)	Multiple categories (22)	Multiple categories (9)

Discussion

In line with Nielsen *et al.* (2014) we found that European and North American publications dominate the field of urban forestry in general, and in our case urban forest inventories specifically. The varying number of articles per year could be explained by the low number of publications included in the study, but there is nevertheless an increasing trend since 2010, in the number of publications, which also is in line with Nielsen *et al.* (2014).

Inventories and monitoring constitute key aspects of planning and management of any resource (Morgenroth & Östberg, 2017; Nowak *et al.*, 2015). Urban forestry focuses on tree inventories (Roman *et al.*, 2013), and the importance of continuous long term monitoring is gaining more attention. However, even if the knowledge of the importance of monitoring is increasing only less than 10 % of the stratification methods identified in this review was rated as having a high stability, allowing for long term studies. In an urban forestry and green space management context, a transition from single inventories, (a snapshot of the urban forest at a specific time), to long term monitoring is critical. Practitioners often turn to scientific literature for examples of sampling design and our data shows that a critical reflection on long-term representability is lacking. Therefore, there is a need to revise the use of stratification in ways of stratification factors being stable enough to create the possibility for long term monitoring.

There is an increasing trend of using remote sensing (Reynolds *et al.*, 2017; Nowak *et al.*, 2013), or testing remote sensing accuracy against other types of inventories (Rougier *et al.*, 2016; Verlič *et al.*, 2014) with 25.8% of the studies (16 studies) using remote sensing. These articles were primarily focusing on plot selection, as was also found by (Reynolds *et al.*, 2017). This indicates that remote sensing methods are becoming cheaper, more accessible and widespread. They however lack in ability to detect important site-specific management information (vitality, risk, root intrusion, human factors etc.), meaning some form of field measurements (even just to validate photo-interpretation) will often be required. This means that elements of sampling design will remain relevant and the selection of the methods may affect accuracy of results.

Few articles represented more than just a singular point of view, on environmental aspects. It is not surprising that all of the scientific articles were driven by academics, but the lack of focus on important aspects of social, cultural and economic value is surprising and this single focus risk reducing urban forests to only be an environmental study instead of the multi-disciplinary field as many researchers and politicians argue(Konijnendijk *et al.*, 2005; Harris *et al.*, 2004)

The same can be said for the very narrow focus, where only one study had an international perspective, even though urban forestry to a very high degree is an international field (Nowak, 2012). More international meta-studies could be valuable to understand the international urban forest inventories and methods, which could lead to greater harmonization of inventory methods between countries to combine efforts and share data-backed experiences dealing with global issues. Also, we see a need for detailed data of the entire urban forest, as varying information and documentation of effects of urbanisation on the actual tree resource seem scattered and varied in its conclusions. Recent research has shown that there is no general green space decline or loss in European cities (Kabisch & Haase, 2013; Larondelle & Haase, 2013), but the same cannot be said for study of major metropolitan areas in US (Nowak & Greenfield, 2012).

When looking at the background for performing the tree inventories (here denoted as discourses), none of the studies focused on policy implication, four on users and six on private owners. This lack of inclusiveness risk limiting urban tree monitoring to only being an academic and public servant exercise without connecting them or the field of urban forestry to a larger contact which included non-public trees and politicians.

Conclusion

There are many inventory methods being used in urban forestry to aid management for the future challenges, all come with their set of advantages and disadvantages. Predominant use of sampling at different densities can be the best at solving the immediate management issues but unless stratification factors provide long-term stability, it will not provide representative longitudinal data.

With the majority of inventories having a local approach, there is a great potential to engage a broader range of local actors, in order to secure a shared ownership of the inventory and its results, e.g. to make sure that the resources spent and data gathered are likely to be used beyond the academic purposes.. According to our data, local studies did not show a greater likelihood to involve multiple actors instead, this depended on the individual study aims (Intasen *et al.*, 2016; Strunk *et al.*, 2016). This could also refer to private-public collaboration between local government and residents that own a large proportion of trees in the city.

References:

Alvarez, I.A., Velasco, G.D.N., Barbin, H.S., Lima, A.M.L.P. & Couto, H.T.Z.d. (2005). Comparison of two sampling methods for estimating urban tree density. *Journal of Arboriculture,* 31(5), pp. 209 - 214.

Arts, B., Leroy, P. & van Tatenhove, J. (2006). Political Modernisation and Policy Arrangements: A Framework for Understanding Environmental Policy Change. *Public Organization Review,* 6(2), pp. 93-106.

Blood, A., Starr, G., Escobedo, F.J., Chappelka, A., Wiseman, P.E., Sivakumar, R. & Staudhammer, C.L. (2016). Resolving uncertainties in predictive equations for urban tree crown characteristics of the southeastern United States: Local and general equations for common and widespread species. *Urban Forestry & Urban Greening,* 20, pp. 282-294.

Bowler, D.E., Buyung-Ali, L.M., Knight, T.M. & Pullin, A.S. (2010). A systematic review of evidence for the aded benefits to health of exposure to natural environments. *Public Health,* 10(456).

Brack, C.L. (2006). Updating urban forest inventories: An example of the DISMUT model. *Urban Forestry & Urban Greening,* 5(4), pp. 189-194.

Buijs, A.E., Mattijssen, T.J.M., Van der Jagt, A.P.N., Ambrose-Oji, B., Andersson, E., Elands, B.H.M. & Steen Møller, M. (2016). Active citizenship for urban green infrastructure: fostering the diversity and dynamics of citizen contributions through mosaic governance. *Current Opinion in Environmental Sustainability,* 22, pp. 1-6.

Conway, T.M. & Lue, A. (2018). Resident Knowledge and Support for Private Tree By-Laws in the Greater Toronto Area. *Arboriculture & Urban Forestry,* 44(4), pp. 185-200.

Dale, A.G. & Frank, S.D. (2014). The Effects of Urban Warming on Herbivore Abundance and Street Tree Coditions. *PLoS ONE,* 9(7), pp. 1 - 9.

Escobedo, F., Palmas-Perez, S., Dobbs, C., Gezan, S. & Hernandez, J. (2016). Spatio-Temporal Changes in Structure for a Mediterranean Urban Forest: Santiago, Chile 2002 to 2014. *Forests,* 7(6), p. 121.

Ferrari, B., Corona, P., Mancini, L.D., Salvati, R. & Barbati, A. (2017). Taking the pulse of forest plantations success in peri-urban environments through continuous inventory. *New Forests,* 48(4), pp. 527-545.

Fischer, A., Petersen, L., Feldkötter, C. & Huppert, W. (2007). Sustainable governance of natural resources and institutional change–an analytical framework. *Public Administration and Development,* 27(2), pp. 123-137.

Gartner, J.T., Treiman, T. & Frevert, T. (2002). Missouri urban forest - A ten-year comparison. *Journal of Arboriculture,* 28(2), pp. 76 - 83.

Gill, S.E., Handley, J.F., Ennos, A.R. & Pauleit, S. (2007). Adapting cities for climate change: The role of green infrastructure. *Built Environment,* 33(1), pp. 115-133.

Grahn, P. & Stigsdotter, U.A. (2003). Landscape planning and stress. *Urban Forestry & Urban Greening,* 2(1), pp. 1-18.

Hansen, M.H., Hurwitz, W.N. & Madow, W.G. (1953). *Sample Survey Methods and Theory*Volume 1 Methods and Applications). New York: John Wiley & Sons, Inc.

Harris, R.W., Clark, J.R. & Matheny, N.P. (2004). *Arboriculture: Integrated Management of Landscape Trees, Shrubs, and Vines*. 4th. ed: Prentice Hall.

Huang, L., Chen, H., Ren, H., Wang, J. & Guo, Q. (2013). Effect of urbanization on the structure and functional traits of remnant subtropical evergreen broad-leaved forests in South China. *Environ Monit Assess,* 185(6), pp. 5003-18.

Intasen, M., Hauer, R.J., Werner, L.P. & Larsen, E. (2016). Urban forest assessment in Bangkok, Thailand. *Journal of Sustainable Forestry,* 36(2), pp. 148-163.

Jackson, L.E. (2003). The relationship of urban design to human health and condition. *Landscape and Urban Planning,* 64(4), pp. 191-200.
Jones, N. (2008). Approaches to Urban Forestry in United Kingdom. In: Carreiro, M.M., Song, Y. & Wu, J. (eds) *Ecology, Planning, and Management of Urban Forests*. New York, NY: Springer.
Kabisch, N. & Haase, D. (2013). Green spaces of European cities revisited for 1990–2006. *Landscape and Urban Planning,* 110, pp. 113-122.
Kielbaso, J.J. (2008). Management of urban forests in the United States. *Ecology, Planning, and Management of Urban Forests: International Perspectives*, pp. 240-258.
Konijnendijk, C.C., Nilsson, K., Randrup, T.B. & Schipperijn, J. (2005). *Urban Forests and Trees*: Springer-Verlag Berlin Heidelberg.
Konijnendijk, C.C., Ricard, R.M., Kenney, A. & Randrup, T.B. (2006). Defining urban forestry – A comparative perspective of North America and Europe. *Urban Forestry & Urban Greening,* 4(3-4), pp. 93-103.
Kosiorek, M., Modrzewska, B. & Wyszkowski, M. (2016). Levels of selected trace elements in Scots pine (Pinus sylvestris L.), silver birch (Betula pendula L.), and Norway maple (Acer platanoides L.) in an urbanized environment. *Environ Monit Assess,* 188(10), p. 598.
Larondelle, N. & Haase, D. (2013). Urban ecosystem services assessment along a rural–urban gradient: A cross-analysis of European cities. *Ecological Indicators,* 29, pp. 179-190.
Larondelle, N. & Strohbach, M.W. (2016). A murmur in the trees to note: Urban legacy effects on fruit trees in Berlin, Germany. *Urban Forestry & Urban Greening,* 17, pp. 11-15.
Lee, S.J., Longcore, T., Rich, C. & Wilson, J.P. (2017). Increased home size and hardscape decreases urban forest cover in Los Angeles County's single-family residential neighborhoods. *Urban Forestry & Urban Greening,* 24, pp. 222-235.
Maco, S.E. & McPherson, E.G. (2003). A practical approach to assessing structure, function, and value of street tree populations in small communities. *Journal of Arboriculture,* 29(2), pp. 84 - 97.
McPherson, E.G. (1998). Structure and sustainability of Sacramento's urban forest. *Journal of Arboriculture,* 24(4), pp. 174 - 190.
Miller, R.W., Hauer, R.J. & Werner, L.P. (2015). *Urban forestry: planning and managing urban greenspaces*. 3. ed. Long Grove, Illinois, USA: Waveland Press, Inc.
Morgenroth, J. & Östberg, J. (2017). Measuring and monitoring urban trees and urban forests. In: Ferrini, F., Konijnendijk van den Bosch, C.C. & Fini, A. (eds) *Handbook of Urban Forestry*. London and New York: Routledge Taylor & Francis Group.
Nielsen, A.B., Östberg, J. & Delshammar, T. (2014). Review of Urban Tree Inventory Methods Used to Collect Data at Single-Tree Level. *Arboriculture & Urban Forestry,* 40(2), pp. 96-111.
Nitoslawski, S.A. & Duinker, P.N. (2016). Managing Tree Diversity: A Comparison of Suburban Development in Two Canadian Cities. *Forests,* 7(6).
Nock, C.A., Paquette, A., Follett, M., Nowak, D.J. & Messier, C. (2013). Effects of Urbanization on Tree Species Functional Diversity in Eastern North America. *Ecosystems,* 16, pp. 1487 - 1496.
Norton, B.A., Coutts, A.M., Livesley, S.J., Harris, R.J., Hunter, A.M. & Williams, N.S.G. (2015). Planning for cooler cities: A framework to prioritise green infrastructure to mitigate high temperatures in urban landscapes. *Landscape and Urban Planning,* 134, pp. 127-138.
Nowak, D.J. (2012). Contrasting natural regeneration and tree planting in fourteen North American cities. *Urban Forestry & Urban Greening,* 11(4), pp. 374-382.

Nowak, D.J. & Greenfield, E.J. (2012). Tree and impervious cover change in U.S. cities. *Urban Forestry & Urban Greening,* 11(1), pp. 21-30.

Nowak, D.J., Hoehn, R.E., Bodine, A.R., Greenfield, E.J. & O'Neil-Dunne, J. (2013). Urban forest structure, ecosystem services and change in Syracuse, NY. *Urban Ecosystems,* 19(4), pp. 1455-1477.

Nowak, D.J., Noble, M.H., Sisinni, S.M. & Dwyer, J.F. (2001). People & trees - Assessing the US urban forest resource. *Journal of Forestry,* 99(3), pp. 37-42.

Nowak, D.J., Walton, J.T., Baldwin, J. & Bond, J. (2015). Simple Street Tree Sampling. *Arboriculture & Urban Forestry,* 41(6), pp. 346-354.

Nuissl, H., Haase, D., Lanzendorf, M. & Wittmer, H. (2009). Environmental impact assessment of urban land use transitions—A context-sensitive approach. *Land Use Policy,* 26(2), pp. 414-424.

Possley, J.E., Maschinski, J.M., Maguire, J. & Guerra, C. (2014). Vegetation Monitoring to Guide Management Decisions in Miami's Urban Pine Rockland Preserves. *Natural Areas Journal,* 34(2), pp. 154-165.

Randrup, T.B. & Persson, B. (2009). Public green spaces in the Nordic countries: Development of a new strategic management regime. *Urban Forestry & Urban Greening,* 8(1), pp. 31-40.

Ren, Y., Wei, X., Wang, D., Luo, Y., Song, X., Wang, Y., Yang, Y. & Hua, L. (2013). Linking landscape patterns with ecological functions: A case study examining the interaction between landscape heterogeneity and carbon stock of urban forests in Xiamen, China. *Forest Ecology and Management,* 293, pp. 122-131.

Ren, Y., Wei, X., Wei, X., Pan, J., Xie, P., Song, X., Peng, D. & Zhao, J. (2011). Relationship between vegetation carbon storage and urbanization: A case study of Xiamen, China. *Forest Ecology and Management,* 261(7), pp. 1214-1223.

Revi, A., Satterthwaite, D.E., F. Aragón-Durand, Corfee-Morlot, J., Kiunsi, R.B.R., Pelling, M., Roberts, D.C. & Solecki, W. (2014). *Urban areas*. (Climate Change 2014: Impacts, Adaptation, and Vulnerability. Part A: Global and Sectoral Aspects. Contribution of Working Group II to the Fifth Assessment Report of the Intergovernmental Panel on Climate Change). New York, NY, USA: Intergovernmental Panel on Climate Change.

Reynolds, R., Liang, L., Li, X. & Dennis, J. (2017). Monitoring Annual Urban Changes in a Rapidly Growing Portion of Northwest Arkansas with a 20-Year Landsat Record. *Remote Sensing,* 9(12), p. 71.

Rogers, K., Andreucci, M.-B., Jones, N., Japelj, A. & Vranic, P. (2017). The Value of Valuing: Recognizing the Benefits of the Urban Forest. In: Pearlmutter, D., Calfapietra, C., Samson, R., O'Brien, L., Krajter Ostoić, S., Sanesi, G. & Alonso del Amo, R. (eds) *The Urban Forest - Cultivating Green Infrastructure for People and the Environment*7) Springer, Cham.

Roman, L.A., McPherson, E.G., Scharenbroch, B.C. & Bartens, J. (2013). Identifying Common Practices and Challenges for Local Urban Tree Monitoring Programs Across the United States. *Arboriculture & Urban Forestry,* 39(6), pp. 292-299.

Rougier, S., Puissant, A., Stumpf, A. & Lachiche, N. (2016). Comparison of sampling strategies for object-based classification of urban vegetation from Very High Resolution satellite images. *International Journal of Applied Earth Observation and Geoinformation,* 51, pp. 60-73.

Schmitt-Harsh, M., Mincey, S.K., Patterson, M., Fischer, B.C. & Evans, T.P. (2013). Private residential urban forest structure and carbon storage in a moderate-sized urban area in the Midwest, United States. *Urban Forestry & Urban Greening,* 12(4), pp. 454-463.

Shakeel, T. & Conway, T.M. (2014). Individual households and their trees: Fine-scale characteristics shaping urban forests. *Urban Forestry & Urban Greening,* 13(1), pp. 136-144.

Staudhammer, C.L., Escobedo, F.J., Holt, N., Young, L.J., Brandeis, T.J. & Zipperer, W. (2015). Predictors, spatial distribution, and occurrence of woody invasive plants in subtropical urban ecosystems. *Journal of Environmental Management,* 155, pp. 97-105.

Steenberg, J.W.N., Millward, A.A., Duinker, P.N., Nowak, D.J. & Robinson, P.J. (2015). Neighbourhood-scale urban forest ecosystem classification. *Journal of Environmental Management,* 163, pp. 134-145.

Steindor, K.A., Franiel, I.J., Bierza, W.M., Pawlak, B. & Palowski, B.F. (2016). Assessment of heavy metal pollution in surface soils and plant material in the post-industrial city of Katowice, Poland. *J Environ Sci Health A Tox Hazard Subst Environ Eng,* 51(5), pp. 371-9.

Strunk, J.L., Mills, J.R., Ries, P., Temesgen, H. & Jeroue, L. (2016). An urban forest-inventory-and-analysis investigation in Oregon and Washington. *Urban Forestry & Urban Greening,* 18, pp. 100-109.

Tyrväinen, L., Mäkinen, K. & Schipperijn, J. (2007). Tools for mapping social values of urban woodlands and other green areas. *Landscape and Urban Planning,* 79(1), pp. 5-19.

UN (2014). *World Urbanization Prospects: The 2014 Revision, Highlights*): United Nations (UN), Department of Economic and Social Affairs, Population Division.

Van Wittenberghe, S., Alonso, L., Verrelst, J., Hermans, I., Valcke, R., Veroustraete, F., Moreno, J. & Samson, R. (2014). A field study on solar-induced chlorophyll fluorescence and pigment parameters along a vertical canopy gradient of four tree species in an urban environment. *Sci Total Environ,* 466-467, pp. 185-94.

Verlič, A., Đurić, N., Kokalj, Ž., Marsetič, A., Simončič, P. & Oštir, K. (2014). Tree species classification using Worldview-2 satellite images and laser scanning data in a natural urban forest. *Šumarski list,* 9-10, pp. 477-488.

Wiström, B., Östberg, J. & Randrup, T.B. (2016). *Data report for SLU's survey of municipal management of greenspaces and trees*).