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Bengt Persson & Johanna Deak Sjöman**

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Foreword

This report is the latest contribution to the FoMA funded project Miljöövervakning av Sveriges urbana trädbestånd (Environmental monitoring of Sweden's urban tree resource), decisions made 20-12-2018, and 11-09-2019. SLU's Environmental Monitoring and Assessment program (Swedish acronym is FoMA), is linked to Sweden's national environmental objectives and international environmental cooperation. As part of FoMA is the Built Environment Program, in which surveys and analysis of cities and its environment are performed. Since 2009, FoMA has contributed to SLU's development of urban tree inventorying as a specific focus area. The project has, among other things produced a unique national standard for inventorying urban trees, which is now generally applied in Swedish urban tree management organizations. Also, with the standard as an outset, an urban tree data base has been initiated.

The aim of the project is to assess the Swedish Tree Inventory Standard (STIS), and the related database, and to discuss what possible trajectories can be identified for its further development. As a part of this, it has also been an objective to assess to which degree STIS can be used to include a broader perspective than urban trees, in order to also perform long-term monitoring of urban green spaces, e.g. to be used in future development of descriptions of the Swedish green sector. Two scenarios have been developed; (i) a continuation of the urban tree inventorying work, (ii) a development from focus on single tree monitoring to urban green space monitoring.

We want to extend a special thank you to Neil Sang and Åsa Ode Sang for valuable insights on the conclusions and recommendations of the report.

The authors,

Alnarp, April 2020

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Summary

In 2009, FoMA began its funding of various projects to establish a national standard for urban tree inventories in order to aid urban tree planners and professionals within green space management in conducting consistent tree inventories. A national tree inventory standard was created in 2012 (Swedish Tree Inventory Standard, STIS), which was updated in 2015. At that time call was made, encouraging the tree management organisations to upload their local data to a global database called Curio.
The purpose of this evaluation has been twofold:
1) based on STIS, to present and analyse the Swedish inputs to the Curio database, and
2) to assess to which degree STIS and experiences from the Curio database can be used to include a broader perspective than urban trees, in order to also perform long-term monitoring of urban green spaces, e.g. to be used in future development of descriptions of the Swedish green sector.

It is concluded, that the ambition to create a national standard for urban tree inventorying has proven to be successful, and STIS is now frequently referred to in Swedish outsourcing documents and contracts. However, in its current form, the Curio database does not provide an optimal foundation for national monitoring of urban trees. The data set is too small to be nationally representative. Envisioning total inventories and relying on municipalities to provide data is not a sustainable approach in order to ensure longitudinal monitoring with given frequencies between updates and a baseline quality of the included data.
It is recommended that FoMA and SLU provide a longitudinal spatial registration coupled with an assessment of the Swedish green sectors development. It is described how this can be done based on experiences from the STIS, and the latest Green Sector Description and SCB reports on urban spatial development.

1. Introduction

Urban areas are undergoing transformation, with climate change and urbanisation being some of the many contemporary challenges (UN, 2014). International research shows that residential developments are known to cause a 1% loss in urban tree canopy per year due to construction of impermeable surfaces (Lee et al., 2017). Urban green spaces (UGS) are increasingly being perceived and documented as a vital element in the urban fabric (e.g., Qureshi et al., 2013; Wolff et al, 2018), and for enabling wellbeing for the ever-increasing urban population (e.g., Lee et al., 2015; WHO, 2016). UGS range from playgrounds through highly maintained park settings to informal and natural landscapes located in urban and peri-urban settings (Haase et al., 2020). Often UGS are publicly accessible (e.g., Randrup & Persson 2009; de Magalhães & Carmona, 2009), and regarded as a source of numerous benefits and values, expressed as e.g. ecosystem services (MEA, 2005).

An important factor in the effective supply of ecosystem services in UGS is the long-term process of park planning and ongoing maintenance (Jansson & Randrup, 2020). Planning and management of UGS is a multibillion industry, with the majority of resources being spent in the maintenance sector. The Swedish green sector (here defined as professional planning and management of green, and primarily recreational spaces) is roughly estimated to have an annual turnover of almost SEK 24 Bn, of which SEK 17 Bn is maintenance, and 7 Bn SEK is dedicated development or renovation (Ekelund et al., 2017). The total turnover is almost as much as the primary production value of Sweden's forestry industry which is SEK 27 billion, (Skogsstyrelsen, 2018). In comparison, the Swedish commercial fishing industry has a total turnover of approximately SEK 1 billion. In total, there are approximately 40,000 companies and organisations, including 290 local governments responsible for public and semi-public UGS.

Even though the UGS sector is large, it is not organised as one common sector with a common trade or industry body carrying out national surveillance, influence and lobbying activities. Therefore, it is difficult to estimate the total size or turnover of the sector. The description of the Swedish green sector (Ekelund et al., 2017), includes among other sources, spatial data from the Swedish Statistical Bureau (SCB). In December 2019, SCB published a report on green spaces in urban areas, based on 2015 data (Statistics Sweden, 2019). In this report a number of important measures and results were presented, indicating among others that the amount of green spaces increase with decreasing size of urban areas. In some municipalities, the amount of forest is equal in amount to 'open green space', and that almost 50% of green areas in urban settings are privately owned.

In order to gain a proper overview of this large, but complex sector, there is a need to assess the total area of not only green spaces as forests and 'open green space', but to distinguish between the many different typologies seen within the urban matrix (Haase et al., 2020). Such an overview is needed for assessment of long-term dynamics of the urban green resource, and for maintaining access to and use of UGS for an ever growing urban population.

Trees are important elements within the urban matrix. Urban trees' positive properties for the cities include, among other things, purifying air and contribute in creating much-needed green spaces for the city's residents; they help reduce storm water, mitigate temperatures during hot days and increase the attractiveness of properties. Thus, trees also contribute financially and make it possible to not only create a good life for people in the city, but also provide resources, (see e.g. Konijnendijk et al., 2005). However, public management of urban trees and green spaces is primarily performed by local governments or housing companies (Konijnendijk et al., 2006; Randrup & Persson, 2009; Persson et al., 2020), and are often not including privately owned properties.

1.1. The Swedish Tree Inventory Standard

In the beginning of the 2010's a number of significant urban tree inventory studies took place at SLU (Sjöman et al., 2012; Sjöman & Östberg, 2012; Östberg et al., 2013; Nielsen et al., 2014), with Johan Östbergs dissertation as a central milestone (Östberg, 2013). In 2009, FoMA, together with Movium Partnerskap and a number of urban tree and green space management organisations funded a project to establish a national standard for urban tree inventories in order to aid urban tree planners and professionals within green space management in conducting consistent tree inventories. A national tree inventory standard was created in 2012 (the Swedish Tree Inventory Standard, STIS), (Östberg et al., 2012). In 2015, STIS was updated and as a follow up, a database was developed in cooperation with European Space Agency, in order to allow comparisons beyond Sweden (Östberg, 2015). In addition, in 2015, a survey was sent to all urban tree management organisations about how they had actually used the standard.

1.2 Relation to the Curio database

Breadboard Labs, with funding from the European Space Agency, have developed a software platform, focusing on improving the effectiveness of local environmental management, planning and awareness activities (www.curio.xyz). This resulted in a global database, and today it has over 2.4 million trees registered. In 2015, when version 2.0 of the STIS was released, all organisations that had downloaded the standard were asked and advised to upload their data to the Curio database. The purpose was to allow individual urban tree management organisations, or individuals, to upload data and by doing so to create a national urban tree database. This should enhance the longevity of the data collected locally. Since then, GDPR legislation have presented challenges in relation to use of certain data, limiting the amount of data available.

1.3 Objectives

FoMA's continued funding of the project environmental monitoring of Sweden's urban tree resource, provided the STIS to collect and store national urban tree data in the Curio database. However, other significant initiatives have been carried out, including a larger survey, which was conducted in 2016 among all Sweden's municipalities' urban tree and green space management organisations. The survey was developed and coordinated with a similar US urban tree management study (Hauer & Patterson, 2016), and in relation to management of UGS, based on an UK survey (Neal, 2016). This survey was reported by Randrup et al., (2017) and Östberg et al., (2018). FoMA has until 2017 continued to fund the project. The administration of STIS was transferred to the Swedish Tree Associaton (Svenska Trädföreningen) in 2018 (www.inventering.nu). An English version is available via their homepage (www.treeinventory.nu). Since early 2019 a project evaluation has been ongoing, with this report as the final outcome. The purpose of the evaluation has been twofold:
1) based on the Swedish Tree Inventory Standard (STIS), to present and analyse the Swedish inputs to the Curio database, and
2) to assess to which degree STIS and experiences from the Curio database can be used to include a broader perspective than urban trees, in order to also perform long-term monitoring of urban green spaces, e.g. to be used in future development of descriptions of the Swedish green sector (Ekelund et al., 2017).

In the following, we will present the Curio database, and discuss the potential of the Curio database for a national Swedish urban tree database. We briefly present some relevant projects and initiatives related to monitoring of urban green spaces (primarily Swedish), before concluding on the potential to use the FoMA-based STIS as an outset for further development, including the potential to monitor urban green spaces as well as asses their related management costs.

2. The Curio database

In order to establish a national tree database, its parameters and data collection method have to support its purpose to be meaningful. In the following, we briefly describe different inventory approaches and specifically the current Curio database. An in depth view of the parameters is presented as well as concluding remarks on the experiences gained.

2.1. Tree inventory basics

A tree inventory is a systematic collection of tree data and information for assessment or analysis. The tree inventory information is typically compiled into databases used by local authorities (e.g. municipalities, cemeteries and housing companies) to gain an overview of the urban tree population. It is then used not only to inform the planning and prioritization of day-to-day management activities and the development of long-term management objectives and strategies, but also as a tool to help quantify and communicate the values and services provided by urban trees (Östberg, 2013; Östberg et al., 2013). In general, tree inventories are basis for sustainable resource management to provide a current record of resources being managed, and providing data for decision-making (Basset, 1978).

All inventories depend first and foremost on their purpose, setting parameters of interest, and defining the right approach to data collection. Thus, the scope all depend on which aspects the inventory takers are interested in. Ciesielski & Sterenczak, (2019) described three basic types of (urban) tree inventories: partial, total, and random. Partial inventorying incorporate parts of the resource, often a specific location, a specific species or similar. A total inventorying includes the entire resource, while random inventorying is a sampling method often carried out so that the sample is representative of the entire resource.

There are two main approaches to collecting data for these inventories; top-down aerially based approaches; and bottom-up ground-based assessments (Nowak, 2018). The most common methods for top down include remote sensing include airborne (ALS), terrestrial (TLS) and mobile laser-scanning (MLS), satellite imaging, aerial photography, and more recently unmanned aerial vehicle technology (e.g., drones) (Ciesielski & Sterenczak, 2019). Bottom-up is characterized by fieldwork, either by professionals/managers or as a form of citizen science, where citizen volunteers often get instructions on how to take inventory and then perform the inventory taking.

The data sets compiled in the Curio database comprises a collection of Swedish municipalities' and organisations' ground-based assessments, but also allowing individuals to upload data. Such contributions have been denoted as crowd sourcing or citizen science, with its advantages of creating inputs to the database, but also acknowledging its pitfalls (see e.g. Lukyanenko et al., 2019). As the various inputs to the database are work in progress, they can be considered to be bottom-up, and partial approaches. Curio cannot be denoted as either partial, total or random, but has the (theoretical) potential to be total (including all urban trees in Sweden).

2.2. Method of analysis, and parameters

In order to analyse the Swedish data included in the Curio database, a data extract was based on all the data submitted to Curio on the basis of STIS or that was directly related to that project. In July 2019, SLU received the data that had been in the care of Curio. Expectations were to receive additional data uploaded by private individuals within the Swedish borders, but the previously mentioned GDPR legislation has limited the data to inputs related to the project. The data was received as a comma separated text file, which was converted to Excel-format for further analysis. A minor segment of the set (200 entries) where adjusted by hand in order to fit the formatting. Since 2015 no SLU based projects have been active in regards to maintaining and developing the content of the Curio database, entailing that very little work has been done to it since, with only parts of the data-set being updated up to June 2019. The data set consist of 144 950 entries and has 13 inventory parameters, all based on the STIS (Östberg, 2015), see table 1.

2.3. Swedish inputs to the Curio database

The submitting organisations are Malmö Stad, Göteborgs Stad, Familjebostäder in Göteborg, Halmstad kommun and SLU Alnarp (see Figure 1). The organisations contributing to the database have all been involved in establishing the STIS.

It is not specified exactly how the data has been collected, and by which individual(s). A small part of the data (1 290 entries) does not have information on what organisation that has conducted the inventory, but is geographically situated in Malmö municipality in areas owned by the municipality. The following gives a more in-depth analysis of the included data. Malmö Stad has the largest data set with 75 215 entries comprising more than half of the total data. Malmö Stad also has the most comprehensive data with 99% of entries containing species, 97% vitality, and 100% on both registration date and last updated date. There is also a relatively high number of entries containing information on the planting date. See table 2 .

The following sections contain a deeper analysis of each parameter, together with a selection of examples on how the data can be useful from a monitoring perspective.

Height

The height parameter has zero entries across all organisations, suggesting that it is not a prioritised parameter by the concerned organisations. This is seconded by the mean value of the rated importance of the height parameter in the STIS.

Status

The parameter describes whether the tree is living, dead or removed. It has a 100% rate of completion. It is unclear why this specific parameter has such high rate of completion since it is not a parameter derived from the STIS (Östberg 2015).

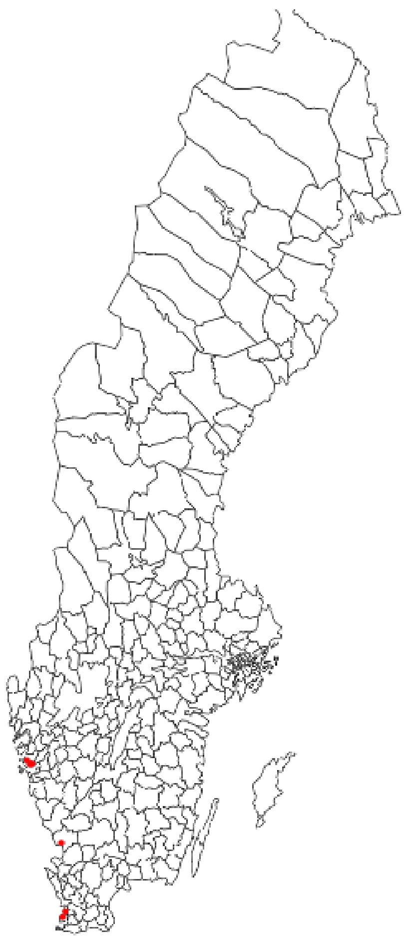

Fig. 1: Red dots indicate geographical positions of the contributing organisations; i.e. the general location of the data entries.

id
The current database's ID- number for each post.

org_tree_id
The id-number that the inventorying organisation have given each post.

Species
The scientific name of the tree including genus, species and variety. The name should be printed in accordance with SKUD (Svensk kulturväxtdatabas). If any insecurities arise, only the part of the name that the inventory taker is sure of should be stated.

DBH
Diameter in breast height, measured on the trunk of the tree at 1.3 meter height.

Vitality
Vitality is stated as a visual assessment of the tree crown structure, on a scale from one to four, one being the most vital.

Height
Height is measured from the base of the trunk to highest living top shoot.

Organisation
The inventorying organisation.

Status
Specifies whether the tree is alive, dead or removed. This parameter is not included in STIS.

inv_registration_date
The date when the post was added to the database. The information is often automatically added when the post is added.

inv_last_updated
The date when the post was last updated. The information is often automatically added when the post is changed.

planted_date
What year the tree was planted, (known or estimated).

Latitude
Latitude position of the tree.

Longitude
Longitude position of the tree.

Table 1: The thirteen inventory parameters included in the Curio data set

id	org_tree_id	species		dbh*		vitality		height	organisation	status		Reg. Date		last upd.		plant date	
75215	75215	74805	99%	43810	58%	73189	97%	0	Malmö	75215	100%	75215	100%	75215	100%	65975	88%
40833	40833	24765	61%	3131	8%	0	0%	0	Göteborg	40833	100%	0	0%	27229	67%	8808	22%
13872	13872	13537	98%	2888	21%	1750	13%	0	Halmstad	13872	100%	4116	30%	4116	30%	7517	54%
8420	8420	8420	100%	3267	39%	5627	67%	0	SLU	8420	100%	0	0%	2	0%	4154	49%
1160	1160	1066	92%	7	1%	1135	98%	0	unknown	1160	100%	1160	100%	1160	100%	0	0%
5450	5450	5389	99%	0	0%	0	0%	0	Familjebost.	5450	100%	0	0%	0	0%	0	0%
1E+05	138340	1E+05		53096		80566				1E+05		79331		106562		86454	
	100%	88%		38%		58%				100%		57%		77%		62%	

Table 2: An overview ov the completeness of each parameter, sorted by organisation. Percentage (in blue) indicates to what degree the set is complete.

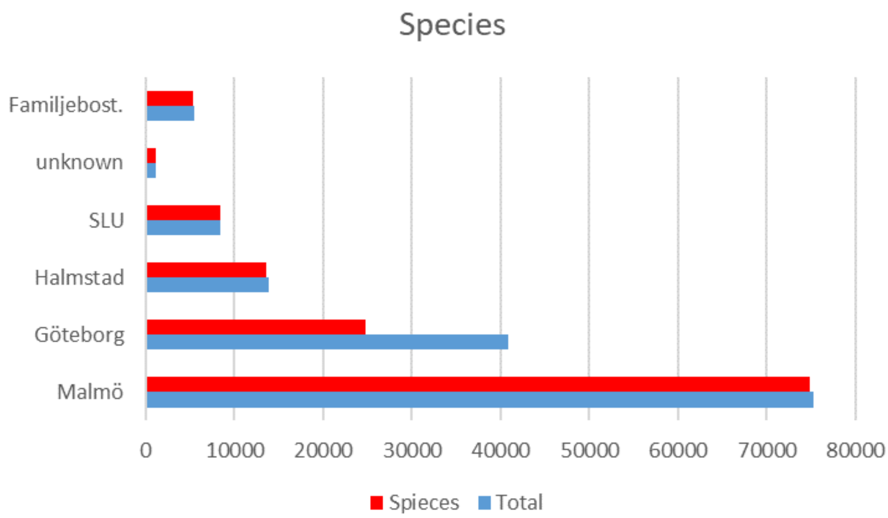

Fig. 2: Completeness of the species parameter

Species

Figure 2 (above) shows the number of posts with a registered value of Species (in red) as compared to the total number of posts (in blue), sorted by organisation. Malmö Stad has by far the highest rate of registered values, but there is a general high grade of completion throughout the set, Göteborg being the exception.

Example Species – Total dataset

Species distribution is one of the parameters that are relatively well represented within the dataset. When comparing the entire dataset with regard to species, it is worth noting that the top 20 genera comprise 77% of the set, whereas 480 species with less than 1000 specimen recorded comprise only 10% of the set. The six largest genera together comprise almost 50% of the entire dataset. This replicates the findings in Sjöman et al (2012) and Sjöman & Östberg (2019), describing the vulnerabilities to specific pests. See Figure 3 (below).

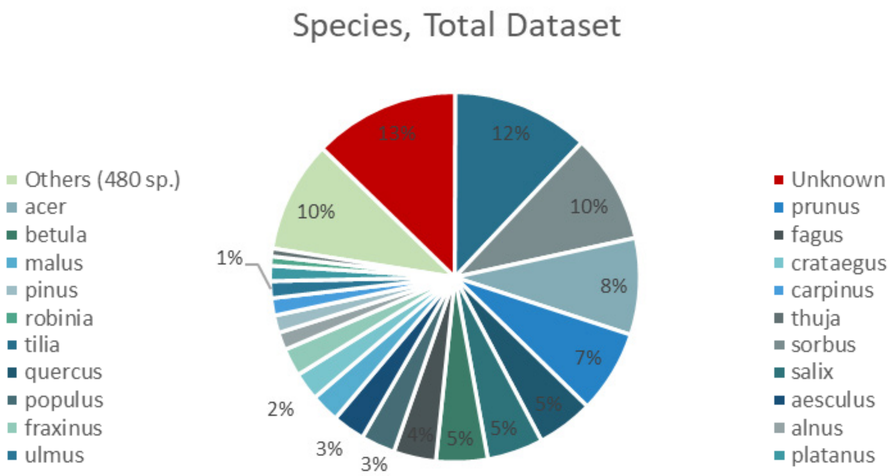

Fig. 3: Comparison of the genera distribution of the total data set.

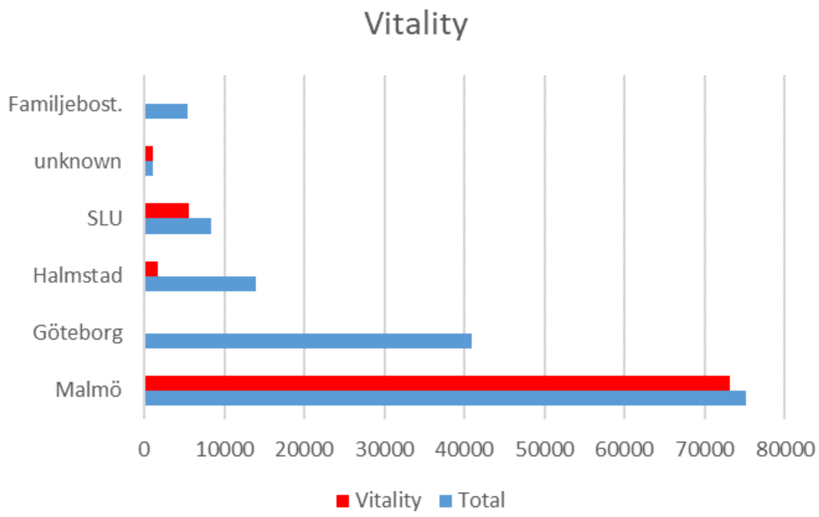

Fig. 4: Completeness of the vitality parameter

Vitality

Figure 4 shows the number of posts with a registered value of vitality (in red) as compared to the total number of post (in blue), sorted by organisation. Malmö Stad has by far the highest rate of registered values with a rate of 97%, followed by SLU at 67%. It is important to not confuse vitality with risk, which is a parameter not represented in this database.

Example Vitality – Malmö Stad

Looking deeper into the vitality measure in Malmö Stad, a vast majority of the trees are stated to be at vitality rate 1. This parameter could give a crude assessment of upcoming investments needed, as e.g., 0,6% trees with a vitality grade of 4 is equivalent to 423 trees. Assessed as grade 3, 3.9% corresponds to almost 3000 trees which could need maintenance measurements or alternatively replacement depending on placement and function. See Figure 5.

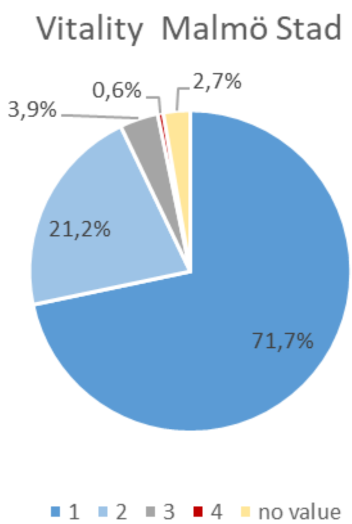

Fig 5. Distribution of trees with a vitality grading 1-4 from the data set of Malmö Stad distributed by decade.

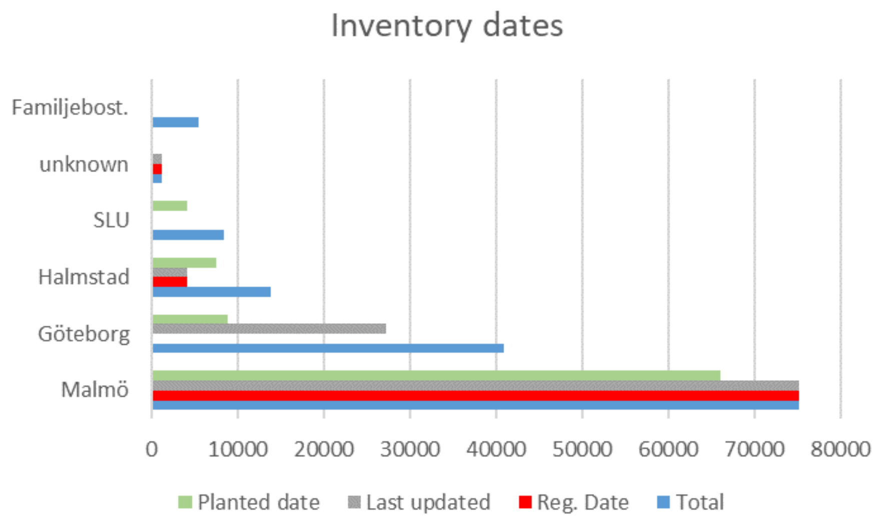

Fig. 6: Completeness of parameters on when the tree was planted, registered in the database and last updated.

Inventory dates

Figure 6 shows a compilation of the date-related parameters, including when the tree was planted, or an estimation of the date, when it was first registered and when the inventory was last updated. In total, 62% of the entire data set has a registered value on when the tree was planted. 57% of the total data set has a registered value on registration date, whereas 77% has a registered value on last updated. This could depend either on the feature being added, or on organisations as Göteborgs Stad only using the parameter 'last updated'. Again, the rate of registered values varies a lot, with Malmö Stad again being by far the most complete.

Example Inventory dates – trees planted by decade in Malmö Stad

Figure 7 shows the distribution of planting dates of the still living trees (i.e. not registered as dead or removed). Patterns can be discerned, e.g. the surge in plantings 2000-2009, probably related to the Dutch elm disease and its effect on the city's tree population. Note that the last segment only covers half the time-period, indicating a continuously higher rate of plantings. The most recent segment only comprises five years, but giving an indication to a similar rate of plantings.

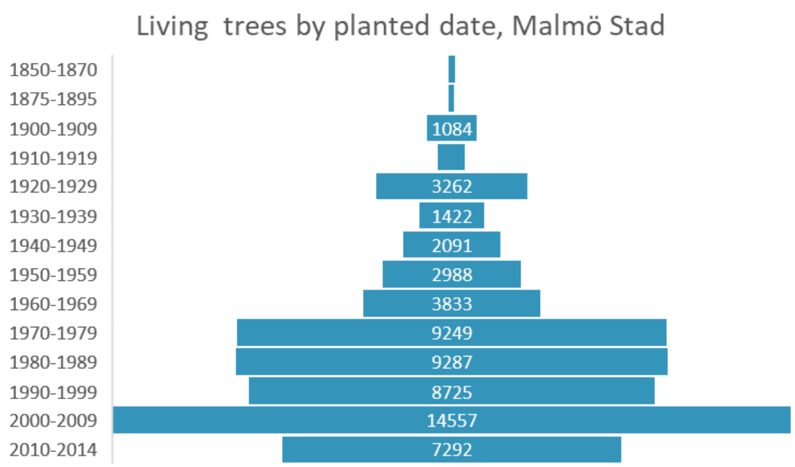

Figure 7: The number of trees planted in Malmö Stad, distributed by decade.

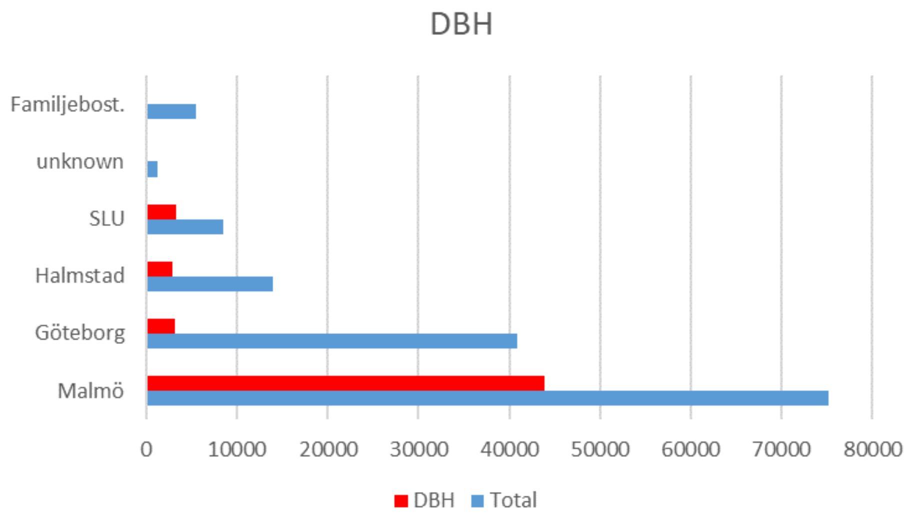

Fig. 8 Completeness of the DBH parameter

DBH

Figure 8 shows the number of posts with a registered value of DBH (in red) as compared to the total number of posts (in blue), sorted by organisation. The total dataset has a completion rate of 38%. Malmö Stad has by far the highest rate of registered values, at 58%. The other organisations have lower rates, SLU and Halmstad at 39% and 21% respectively.

2.4. Curio's potential as a Swedish national database for urban trees

The STIS and the Curio database both represent large ambitions. The STIS must be perceived as unique, even in an international perspective. The ambition to create a national standard for urban tree inventorying has proven to be successful (it has been downloaded 2011 times (Nov. 2018), since its presentation), and STIS is now frequently referred to in Swedish outsourcing documents and contracts. It is also incorporated into Geosecma (https://www.sgroup-solutions.se/ Produkter/GEOSECMA/Park), and is incorporated by the Swedish Envirionmental Protection Agency (Naturvårdsverket) in their work on urban trees, as a potential part of 'ArtDatabanken' (Swedish observation of species). However, the transformation of locally adapted tree inventorying data to the national, and even global database of Curio, has had limited success. As the background and subsequent analysis indicates, the Curio database is in its current form in the very beginning of being a viable foundation for developing future national monitoring of urban trees. Using Curio or similar platforms has some obvious advantages: the data becomes accessible to the public, it lays the foundation for possible crowdsourcing projects, etc. but it could also present certain disadvantages. It is feasible to expect that contributing organisations are going to be reluctant to share data that could be considered sensitive, e.g. risk classifications. This is further explained by the following factors:

From local to national

It has proven to be a challenge to convince local managers/data holders to submit their data. Further, the individual inventories were not taken with a national tree database in mind, but rather a local focus. Each inventorying organisation volunteered to upload the data using only parameters they saw fit for their needs. Thus, the representativeness of the included data on a national scale is currently questionable, as very few organisations have actually provided input to the database.

Inventories requires constant resources

It is time consuming to collect and clean the data, and it is not resource effective to add data sets little by little. Since its establishment in 2015, very limited resources, have been allocated to manage, develop and extend the Curio database. In order to collect the data after the STIS project ended, the approach was to inform participating organisations of the win-win situation: their uploaded data is cleaned by Curio, allowing them to do analyses directly in the online web-based tool provided by Curio.xyz. The resulting numbers of data sets indicate that this was, at least in 2015, not an attractive enough offer. The reason for this probably varies between organisations.

The number of organisations that are currently included in the data set is a further limitation. As Figure 1 shows, the current data set includes five contributing organisations indicating that the data set today is not viable as a national database. A national survey among all Swedish tree managers showed that there are at least 85 municipalities that has an inventory, where 52 of these have been digitalised (Wiström et al., 2016). This proves a potential for expanding the data base. The current digitalization trend indicate that more data bases could be expected to be digitalized, which suggest that if resources were put into actively collecting and uploading data to the Curio database, it could potentially be expanded. On the other hand, contributing organisations rarely have the resources to follow up and manage their data in a reliable manner, and few organisations update their inventories continuously, or even with intervals regularly enough to be relevant from a longitudinal monitoring perspective.

Bottom-up / Top-down

According to STIS there is a set of parameters considered the main six: Scientific name, Vitality, Coordinates, Risk, ID and DBH. These should be included more or less regardless of the purpose of the inventory (Östberg 2015). Certain minimum requirements, or parameters, are also necessary to ensure that the data contributed is relevant to longitudinal monitoring. The parameters included in the Curio data set consist of some, but not all recommended parameters. The recommendations from STIS are probably a good starting point, also supported by Ciesielski & Sterenczak, (2019) and partly by Nowak (2018), promoting, species, DBH, crown dimensions and vitality. The major dilemma seems to be that data is collected locally, with each management organisation having its own needs, priorities and methodological foci. This specific type of inventory is based on the condition that it is done by the municipalities themselves or by citizen volunteers. The applied method for collecting data to the Curio database (bottom up, ground based and total) presents challenges in regards to its use and upkeep as a base for long term monitoring of urban trees. It is not feasible to expect actors such as SLU to take total inventories by a bottom-up based approach in urban environments in Sweden.

The possibilities of citizen science could present an alternative to putting the main responsibility on municipal actors (see e.g. Roman et al., 2017). Similar projects have been done in projects as Trees Count! in New York, USA, with an interval of ten years (www.nycgovparks.org/trees/treescount). Such initiatives are performed with a local focus, and will probably still be challenged in terms of providing inputs to a national data base as Swedish urban tree organisations would be relying on a high number of other organisations to upload data, in order for them to see the benefits of providing own data to the national dataset. A study on the use of volunteers to contribute in tree inventories in Sweden and USA was conducted in 2014 (Roman et al., 2017), as a part of the development of the Curio database.

The bottom up approach entails both opportunities and challenges. In its current form, it is not possible to obtain information on who did the inventories and what skills they possess. Depending on how and where it is collected, qualitative data on specific parameters can be obtained using a fixed number of professionals ensuring the quality and comparability between the inventories. An example of this is NILS (Nationell inventering i landskapet), a project which in part is executed by plot-based field work, done by personnel with the necessary skills to ensure qualitative data. NILS will be presented in the following chapter.

In its current form, the Curio database does not provide an optimal foundation for national monitoring of urban trees. The data set is too small to be nationally representative. Using total inventories and relying on municipalities to provide data is not a sustainable approach in order to ensure longitudinal monitoring with given frequencies between updates and a baseline quality of the data.

3. National initiatives

— for monitoring green spaces in Sweden

When monitoring landscape typologies, there is a wide range of parameters to take into consideration. Similar to the inventorying of individual trees, an array of methods and approaches are possible, related to what kind of result that is of interest. In the following, four projects related to monitoring of urban green spaces in Sweden are briefly presented. The projects are representing both ongoing as well as previous investigations for initiating urban green space monitoring.

3.1. National Land Cover Data (NMD – Nationella marktäckedata)

The Swedish Environmental Protection Agency (Naturvårdsverket), in collaboration with an array of other Swedish agencies (Havs- och Vatten-myndigheten, SCB, MSB and SLU), presented a national database on land cover, i.e. Nationella marktäckedata (NMD), in 2019, a new basis for mapping land cover in Sweden (SCB, 2019). The maps are rasterized in 10 x 10m squares, allowing a level of detail of 0,01ha. This entails a top-down approach, containing information on all land cover on a national scale, including all urban areas in Sweden. The data is based on multispectral satellite images classified into 25 classes, detailing e.g. open land, different types of forest, water, farmland, open wetlands, exploited land, and non-classifiable lands. In 2019, SCB published a report based on this data (SCB, 2019), including all green spaces in Swedish urban areas, based on data from all 2 000 urban areas in the country.

Statistics Sweden has made recurring reports or data compilations on a five-year basis, describing green spaces in urban areas starting in 2000. The previous Statistics Sweden (SCB, 2015) presented a statistical report on urban green spaces, based on 37 locations of more than 30 000 inhabitants. The shift from 37 to almost 2 000 urban areas describes the unprecedented possibilities to create quantitative overviews of green spaces in urban areas. An ongoing project, 'Agenda för landskapet' (Vinnova, 2020-04-01) is currently developing forms for managing and updating the land cover data base (NMD). Updates of the data set is expected every five years.

Although the completeness of the data is unprecedented, it is important to note that the resolution of the satellite imaging being 10 x 10m. This entails that the level of detail is relatively low, as compared to e.g. aerial photographs. The data is thus sufficient for the kind of national overviews on areas presented in SCB (2019), but additional methods are required if a more detailed analysis is expected.

3.2. Green Sector Description (Branschbeskrivning Trädgård)

Parallel to the work with the national landcover database, SLU has been engaged in developing a detailed description of the green sector. The most recent updated description was published in 2017 (Ekelund et al., 2017). Data from Statistic Sweden (SCB, 2015), was used as one of several inputs to describe the size of the Swedish green sector (Ekelund et al., 2017). During this work, a dialogue was initiated with SCB in order to gain more detailed information of the provided data. However, the reported data proved to be as detailed as statistically possible. Thus, the green sector assessment is based on estimates of urban green spaces, which are coupled with cost data related to professional management. The project has proven

Type of urban open space	*Size of UOS, ha*	*Annual maintenance cost, million EUR*
Green spaces (parks)	80,000	435
Housing estates	26,000	650
Cemeteries	9,500	330
Sports grounds	3,150	95
Institutions, i.e. day care, schools, hospitals	-	145
Industrial and office estates (only office estates)	-	100
Green areas along streets and roads	-	15
TOTAL	**118 500**	**1 770**

Table 1. Primary typologies of urban green spaces, related to size and maintenance costs. From Persson et al., (2020).

to generate valuable data and documentation in relation to the size as well as turnover of the green sector.

According to Ekelund et al., (2017), three kinds of urban green space (UGS) typologies comprise the majority of professionally maintained UGS in Sweden, all with different accessibility, responsibility, organisation and governance structures. These includes; i) Multi-family housing areas, ii) Parks and iii) Cemeteries. However, parks comprise, spatially, the majority of these areas, being managed by local governments (the 290 Swedish municipalities) (Persson et al., 2020). (See table 1).

3.3. National Inventory in Landscapes (NILS – Nationell inventering i Landskapet)

The NILS project was initiated in the 1990's with initial inventories beginning in 2003. The project focuses on long term monitoring of the Swedish landscape. The project developed a method for creating statistically significant data on a national level as well as regional (landsdel) level. The mapping method is sample-based, combining aerial photography interpretation and field inventory, a combination of top-down and bottom up approaches. The Swedish landscape is stratified with regards to agrarian production areas resulting in 631 test squares, each 5 x 5 km. These squares are being interpreted as polygon, line and point objects to support a field based inventory. In the centre of each square, an additional square of 1 x 1 km is more carefully inventoried. Each year 120 of the 1 x 1 km squares are inventoried, rotating through all squares in a five year period. The 1 x 1 km squares have a further division into smaller and smaller segments, circles with a radius of 20, 10 and 0,28 m. As the circles get smaller, the inventories get more detailed: Land cover, land use and trees are inventoried in the 20 m radius circle, mosses and lichens in the 0,28 m radius circle.

3.4. Monitoring biodiversity and recreation in urban areas (Övervakning av biologisk mångfald och friluftsliv i tätorter)

In 2007, a project was initiated to evaluate how NILS could be expanded to monitor nature in urban areas (Hedblom & Gyllin 2009), with an additional focus on qualitative parameters such as recreation, perceived values and quality. It was concluded that existing NILS plots were not sufficient do to conduct mappings in urban areas, and suggestions for new methodologies included a partial scope on of 113 urban areas being larger than 10 000 inhabitants (in 2009). It also proposed using many of the existing NILS indicators as well as e.g. access to greenspaces, distance to urban forests and noise levels. Following this, a complementary project on methods for perceived values and cost estimates was conducted (Hedblom et al., 2011), extending the suggestions made by its predecessor. The project proposed visual characteristics based on the VisuLands framework (Tveit et al 2006; Ode et al 2008; Fry et al 2009 and Ode et al 2009): Stewardship, Coherence, Disturbance, Historicity, Visual scale, Imageability, Complexity, Naturalness, and Ephemera. Similar to NILS the approach is a combination of top down and bottom-up approaches with statistical scope. The method is qualitative, and projects from aerial photo assessments and protocol based field inventories on quality in urban green spaces assessing biodiversity and visual landscape characters. The samples are based on the NILS method and SCB's satellite images on urban areas with a statistical significance on both national and regional scale.

The needs for knowledge on green spaces in urban centres in relation to longitudinal monitoring was initially surveyed in the project (stakeholders included SCB, Boverket, Riksantikvarieämbetet, Skogsstyrelsen, Regionplane- och trafikkontoret (RTK) in Stockholms län and Örebro kommun representing local municipalities). The results were to a large extent similar, requesting biological and recreational values as well as both qualitative and quantitative data. They also expressed a need for longitudinal data, not in the least to indicate changes on a national level. The conclusion of the assessment of these needs and wishes was that the NILS based plots is not sufficient to satisfy all the potential stakeholders, but rather that a total inventory was required, as described by Hedblom & Gyllin (2009).

As indicated by Hedblom & Gyllin (2009), there are needs and wishes for longitudinal data on an array of qualitative parameters. However, as they also note, this data is often required to be both detailed and comprehensive. The amount of field-work required to assess these types of inventories vary. Some parameters might be able to assess from top-down generated material (e.g. aerial photography interpretation, noise assessments), while others require ground based assessments, entailing a workload that could prove too extensive for a longitudinal monitoring approach.

4. Suggestions

— for long term monitoring of green spaces in Sweden

Based on the findings in this report, we project two future scenarios for a continued FoMA and SLU specific monitoring, related to the urban environment; (i) a continuation of the urban tree inventorying work, (ii) a development from focus on single tree monitoring to urban green space monitoring.

There is a general need to develop a nomenclature related to monitoring and management of urban green spaces, and trees. Within governance and management the Park, User, Management model has been widely used (Randrup & Persson, 2009), see Figure 9. The model illustrates three dimensions, all being equally important when creating long-term management of green spaces, and for each dimension there is a need for further detailing and defining the typologies:

This report indicates that there is a need to distinguish between different types of spaces. Haase et al., (2020), defined the urban matrix as consisting of green, blue, grey and brown spaces, but both the Green Sector Description (Ekelund et al., 2017), and the latest SCB report (SCB, 2019) use different typologies and terminologies for areas as well as delimitations of studied areas.

Likewise there is a need to distinguish between different types of managers. Usually management organizations will follow administrative borders. However, even within a municipality there are many different types of sub-management organizations (Randrup et al., 2020b), just as the Sector description distinguish between professional organizations and private. In order to monitor and assess the sector, there is a profound need to clarify the typologies of the individual management organizations.

Users are also usually divided into different groups, according to use, perception and preferences (Fors et al., 2020). Thus, in order to perform a qualitative monitoring of green spaces, related to user qualities as discussed by Hedblom and Gyllin (2009), there is a need to make a distinguish between various user types and user groups.

The STIS focuses on one element of many potential green space types. We recommend that the single perspective from STIS and the related Curio database is enlarged to also include other perspectives on green spaces, as e.g. used in the Sector description. However, the Sector description has a delimitation as well, being based on available spatial data, and not including e.g. sports fields and golf courses. SCB on the other side, define areas based on an accessibility perspective, and thus overlooks the professional / private perspective encountered by the Sector description. Finally, the studies carried out by Hedblom and Gyllin (2009) have a profound qualitative and user oriented perspective with emphasis on some, but far from all user groups.

In the following, we give some recommendations to how the existing STIS and related Curio database may be further developed, but put emphasis on the potential in combining the work from the Green Sector Description with the latest version of the Nationella marktäckedata (SCB, 2019).
We see a huge potential for FoMA, and SLU to provide a longitudinal spatial as well as monitory monitoring of the Swedish green sectors develop-

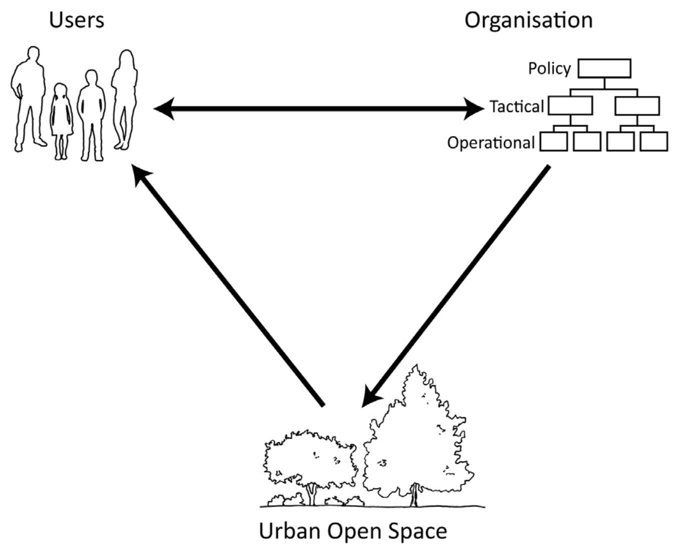

Fig. 9:The Park, User, Management model. Reproduced from Randrup & Persson(2009) ILL.: HANNA FORS

ment, based on the substantial experiences from the STIS, and the latest Sector description and SCB reports on urban spatial development.

4.1 Further development of monitoring urban trees

We have concluded that in its current form, the Curio database does not provide an optimal foundation for national monitoring of urban trees, primarily due to the lack of a data collection process from tree management organisations (private or public) that fill the needs of a longitudinal monitoring on a national scale. Thus, the data set is currently too small to be nationally representative and is not likely to become so. However, there are several trajectories to be further explored based on the existing work:

Recommendations

A suggestion for future development of the Curio database could be to use the above analysis as an outset for which parameters are most frequently sampled, and to hold this against which parameters would be perceived as most valuable for a single management organisation. Thus, the Curio database could define relevant parameters of general interest for a local organisation to be part of, e.g. in order to compare local data with national data. Such parameters need to be specified in conjunction with methods and overall purpose in future monitoring projects.

It should also be considered that efficiencies and synergies are to be found in coordinating monitoring of trees with production of datasets which represent larger system concepts such as ecosytem services (for example soil and ecology data).

In addition, the already collected data, despite of its limited national representation, may pose a potential to create scenarios on how the urban tree population will be affected by e.g. climate change, pests and diseases and densification. Use of e.g. i-Tree Eco (https://www.itreetools.org/tools/itree-eco), to complement existing inventories with ecosystem data, and assessments of urban tree values is another possibility already being pursued by a number of Swedish municipalities, under guidance of SLU.

A survey similar to the 2016 survey (Randrup et al., 2016) could be performed in the near future to study how Swedish municipalities have developed over time with regards to management of urban trees and urban green space. This will give valuable insight, not only in the development of urban tree inventories, but also about strategic contexts of Swedish green space management.

4.2 Developing quantitative monitoring of urban green spaces

Current trends regarding densification and urban sprawl, has re-generated a general interest in surveying the distribution of green space in urban areas, i.e. the amount of green spaces, their individual size and their placement within the city. This is primarily based on a policy driven need to document the impacts of urban densification, and its effects on the distribution or urban green spaces.

Increase of small green spaces, loss of unprogrammed spaces

In a recent project initiated by Boverket, and performed by SLU, Nordic municipal green space managers have clearly stated that they experience an increase in green spaces related to previous 'grey' or 'brown' spaces, (Randrup et al., 2020). This indicates that the re-development of brownfields, industrial areas and harbor areas to new housing areas creates new green spaces. However, the report indicates that these new green spaces managed by municipalities in general are small, and not connected. While more green space may be developed, there is an overall threat to the quality of these areas, as they do not necessarily provide good recreational spaces due to their limited size and intense usage (Jansson, 2014; Cameron & Hitchmough, 2016). This is further amplified by the indication that municipal managers do not necessarily experience a maintenance budget to follow the management of these new areas (Randrup et al., 2020).

In addition, municipal green space managers experience a general threat towards existing, and especially non-programmed green spaces (Randrup et al., 2020). Often such are located in the periphery of the city centers. These spaces are also being developed due to the increased densification of urban areas. Therefore, the actual fragmentation, and re-distribution of grey to green, and green to grey areas needs to be quantified and documented in order to express what is believed to be a general trend - that urban areas are losing quality green spaces, even though the total area might be increasing.

As the national land cover database (NMD) shows, it is now possible to get a comprehensive overview on the national scale of the sum of green spaces in urban areas (SCB, 2019). We believe that SCB (2019) constitute a good outset for further developing an urban green space inventorying system. However, in order to capture the many changes currently experienced in urban green space provisioning, as e.g. expressed in the Randrup et al. (2020) report, there is need for continued monitoring and analysis of the green space data including stratified elements to target specific policy prioirities and randomised elements for continunity as prioties change.

Relations between SCB and the Swedish Green Sector Description

The SCB-reports in general have a different approach to collection of data, than what is intended in the Sector reports. While the SCB monitoring have focus on green area distribution in a very general perspective, the wish from the Sector descriptions, is to combine the spatial distribution with ownership related to professional management of the spaces. Similar to STIS, there may be a need to find a joint typology and assessment approach for urban land use categorization as cities and municipalities have different systems and classifications today – if at all. To link green space (and tree) inventories to spatial contexts and qualitative indicators found in different land use areas would help understand the role of green spaces depending on functions required. This will also help assess the costs of the areas. This (slightly) more detailed level can be regarded as a relatively rough measure of information, still it is finer than the one currently being provided by SCB.

The additional cost of more detailed monitoring can be offset by a considered approach which uses existing opperational capacity where relevant, plus in situ "IoT" (Internet of Things) monitors and drone technology to bridge the gap between local and larger scales.

The largest typology according to SCB (private gardens) is not included in the Sector description, simply due to its focus on public management. A central typology for the Green Sector Description is cemeteries, which has not been in focus by SCB so far. Cemeteries are included in the Sector description, because of its significant contribution to the sectors professionally managed turnover.

SCB (2019) reports that the total sum of 'readily accessible green spaces' (>0,5 ha) is about 170 000 ha. Included in this are areas not formally managed by e.g. a municipality green space organisation, which can include forests or pastures. Private housing is estimated to cover an area of totally 280 000 ha. Further, the amount of 458 m2 green area / inhabitant is given. In 2015, the number of inhabitants living in Swedish urban areas (tätorter) was 8 570 000. This gives a total number of areas of 392 000 ha, based on SCB data.

In the latest Green Sector Description, the total urban green space area, professionally managed, was estimated to be around 120 000 ha. (Ekelund et al., 2017). This figure includes parks, cemeteries, sports fields and green spaces around housing companies, and institutions. If the SCB areas for private housing (280 000 ha) is added to the descriptions of professionally managed green spaces (120 000 ha), the total area of urban green spaces is 400 000 ha, which indicates that the estimations made by both SCB and the Green Sector Description are comparable, even though they have different outsets and applies different measurements methods.

Taking the results from the Nordic Urban Green Space Survey (Randrup et. al 2020) regarding a general concern about the size of the newly built green spaces, and comparing to the SCB definition of 'readily accessible green spaces' being >0,5 ha, it becomes clear that there is a discrepancy. SCB (2019) also notes that around 80% of green spaces are classified as small (>0,5-3ha). This means that there is a potential risk of a very large amount of heavily used "even smaller green spaces (<0,5ha) being excluded from these types of overviews, skewing the perspectives on the changes that are taking place. This further indicates the need to find typologies that are based on administrative contexts as well as being grounded in the political reality that urban green spaces exist in today.

Inspiration from standards and manuals

The STIS has proven to be a successful standard for urban tree inventorying in Sweden. Despite this, it can only to a limited extent be used as an outset for a similar process for longitudinal green space monitoring, by helping to fulfil the need for detailed, longitudinal urban green space monitoring, coupled with an assessment of management costs.

Sweden has since the late 1980's had a national manual for description of green space maintenance (Persson, 1989). Similar documents have been developed in Norway and Denmark, where as in Finland this has been developed into a national classification guide for maintenance of green areas (RAMS, 2020). Thus, manuals and standards for description of green spaces as well as urban trees exist, but as discussed above, STIS and the related Curio database, is experiencing a gap between the actually collected tree data and the final database in which it is stored. A major reason for this seem to be the fact that the use of standards and manuals is done and applied locally (being it inventorying urban trees or describing green space maintenance), and therefore the derived data does not necessarily lead to a comprehensive national overview.

Recommendation

With STIS as an outset, and inspired from standard classification for maintenance descriptions, we recommend that a Swedish Green Space Monitoring Manual is developed to specify actual green space monitoring needs, which can be accompanied by costs assessments. This would require SLU /FoMA to initiate a detailed dialogue between stakeholders (municipalities, housing companies, cemeteries, agencies etc), and SCB in what is needed to gain sufficiently detailed spatial data for updating the sector description, in order for this to be complemented with e.g. management costs.

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