Vitality of Sycamore maple (*Acer pseudoplatanus*) in southwest Sweden

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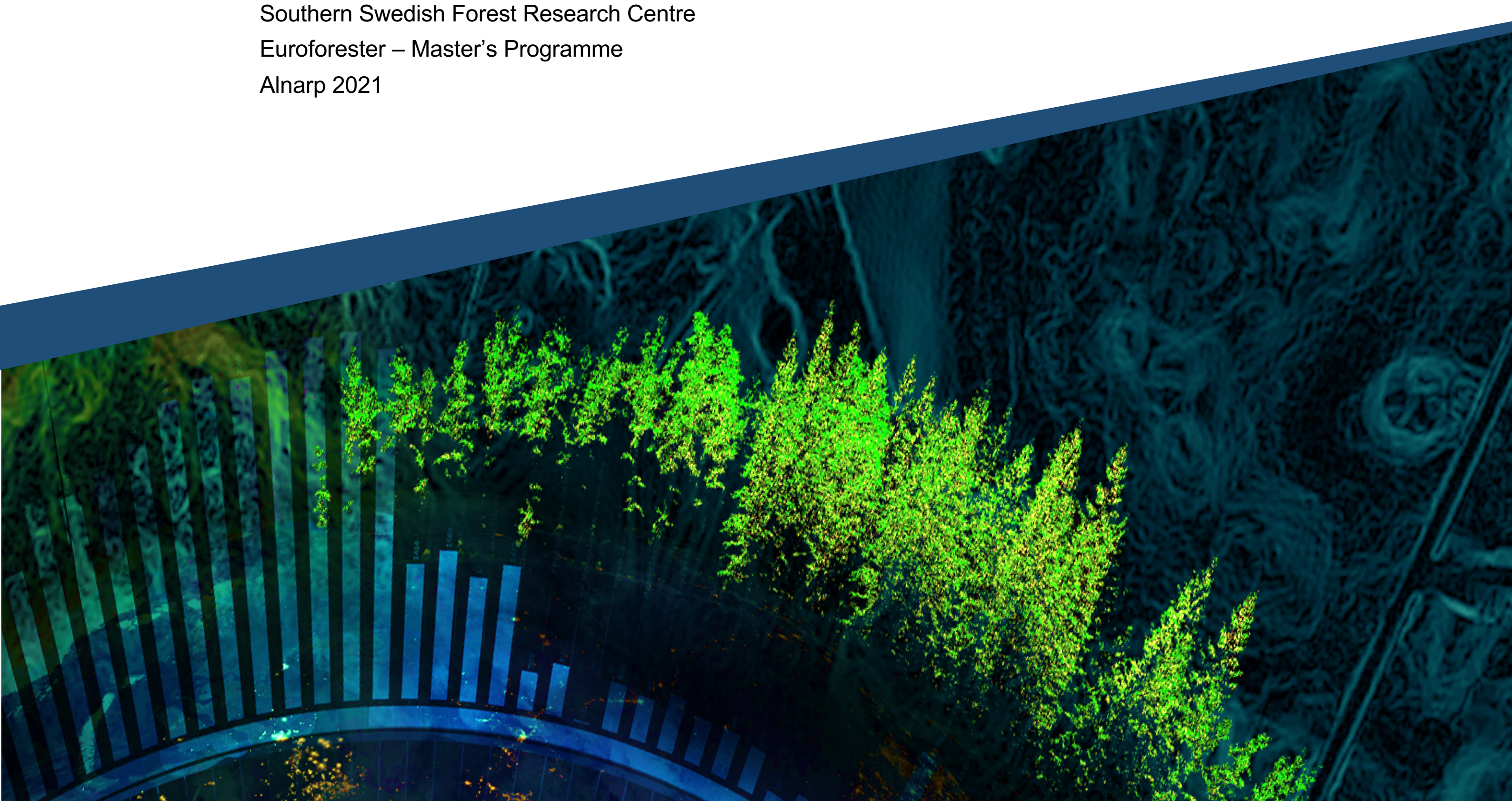

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Abstract

Non-native tree species provide alternatives for forestry that needs to adapt to climate change and multiple public demands. In Sweden, Sycamore maple (*Acer pseudoplatanus*) is a non-native tree species with potential, both in wood production and as a support to biodiversity in woodlands and in urban settings. However, due to its invasiveness it can also become a threat. The aim of this study is to contribute new knowledge about the current condition of Sycamore maple populations in southern Sweden. The focus was on comparing the status of the trees in urban and woodland settings and finding indicators for associated biodiversity (epiphyte coverage) and vitality (growth parameters and visible damage), with special attention to detecting potential first symptoms and signs of the pathogen *Cryptostroma corticale* which causes the lethal disease Sooty bark disease (SBD) in Sycamore maple. The method includes a literature study and a field study. In the field study 320 sycamore maple trees were visually examined for a set of vitality and biodiversity indicators (crown status, symptoms and signs of pests and pathogens) in two urban settings (Malmö, Helsingborg) and two woodland settings (Torup, Skabersjö) in southern Sweden. The surveyed Sycamore maples showed consistently high vitality, and most trees with reduced crown conditions were in urban settings. Urban trees also hosted a higher coverage of trunk-dwelling epiphytic lichens and mosses. No signs of the presence of the pathogen *Cryptostroma corticale* were detected on any of the surveyed trees. The study sheds light on the characteristics of Sycamore maples, its use as an urban tree, a replacement tree and as a component in admixtures. It also provides a baseline and valuable insights to design strategies for the species introduction and management in order to minimize any negative ecological effects.

Keywords: Invasive species, climate adaptation, tree vitality, epiphytes, sooty bark disease

Sammanfattning

Främmande trädslag ger alternativ för skogsbruket vilket behöver anpassas enligt klimatförändringar och allmänhetens många krav. I Sverige är sykomorlönn *(Acer pseudoplatanus)* ett främmande trädslag med potential, både som ett produktionsträd samt som ett stöd för biologisk mångfald inom skogar och urbana miljöer. Men på grund av artens invasivitet kan den även utgöra ett hot. Syftet med denna studie är att bidra med ny kunskap om det nuvarande tillståndet hos sykomorlönnens populationer i södra Sverige. Fokus låg på att jämföra träds status i urbana- och skogsmiljöer samt att hitta indikatorer för associerad biologisk mångfald (epifyters täckningsgrad) samt vitalitet (tillväxt parametrar och synliga skador). Särskild uppmärksamhet fanns på att upptäcka potentiella första symptom och tecken av patogenen *Cryptostroma corticale*, vilken för sykomorlönn orsakar den dödliga sjukdomen Sooty bark disease (SBD). Studiens metod inkluderar en litteraturstudie samt en fältstudie. I fältstudien undersöktes 320 sykomorlönnar visuellt enligt en uppsättning indikatorer avseende vitalitet och biologisk mångfald i två stadsmiljöer (Malmö, Helsingborg) och två skogsmiljöer (Torup, Skabersjö) i södra Sverige. De undersökta sykomorlönnarna visade en genomgående hög vitalitet. De flesta träd med reducerad kronstatus kunde noteras inom de urbana miljöerna. Urbana träd hade även generellt en högre täckningsgrad av epifytiska lavar och mossor. Inga tecken på förekomst av patogenen Cryptostroma corticale detekterades på något av studiens undersökta träd. Studien belyser sykomorlönnens egenskaper, användning som stadsträd, ersättningsträd och som en komponent i blandskogar. Den ger även en grund samt värdefulla insikter för att utforma strategier för artens introduktion och skötsel för att minimera eventuella negativa ekologiska effekter.

Nyckelord: Invasiv art, klimatanpassning, trädvitalitet, epifyter, sooty bark disease

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Abbreviations

CAB	The County Administrative Board
EEA	European Environment Agency
EPPO	European and Mediterranean Plant Protection Organization
MBD	Maple bark disease
NPPO	National Plant Protection Organization
RCP	Representative Concentration Pathways
SBD	Sooty bark disease
SLU	Swedish University of Agricultural Sciences
SMHI	Swedish Meteorological and Hydrological Institute
IAS	Invasive alien species
IPCC	The Intergovernmental Panel on Climate Change
IUCN	Union for the Conservation of Nature

1. Introduction

Sycamore maple (*Acer pseudoplatanus*) is a robust and durable tree species potentially having good properties as an urban and forest tree in Swedish conditions. Nevertheless, due to its high dispersibility and competitiveness that threatens native species, it is classified as invasive in Sweden. Although its suitability in Sweden is met with criticism from conservationists, it has also been suggested that it could support some of the native biodiversity, e.g., the trunk-dwelling epiphytic lichens and mosses, that are currently threatened because of destructive diseases on native broadleaved tree species (Elms and Ash).

However, a changing climate and globalization are affecting the conditions in Swedish forests, and the biodiversity supported by Sycamore maple could also include new tree diseases. With a milder climate, the introduction of new pests and pathogens increases. *Cryptostroma corticale* is a fungal pathogen that causes the lethal disease Sooty bark disease on maples. It is also a risk to public health, because the spores are allergenic. The disease is currently present in many European countries but has not yet been reported in Sweden.

Ensuring support to nature values including biodiversity in combination with maintaining a sustainable use of forest resources and ecosystem services is increasingly relevant for the society. In order to develop appropriate measures and limit the unwanted consequences, an improved understanding of the current status of the Sycamore maple populations in Sweden is required.

Systematic studies of Sycamore maple's health status in Sweden are currently lacking. The current study set out to contribute to filling this knowledge gap and to provide baseline information for assessment of the future potential of the non-native tree species and risks to the native species in Sweden.

2. Literature review

Introduced species (alien species, non-native species, exotic species) are species that have been integrated into the native environment, often by the activities of human migration, travel, global commerce, and trade with other species. Depending on the ecological behaviour and traits of an introduced species, their spread may become invasive in the new environment. The definition of invasive alien species (IAS) varies, but the Union for the Conservation of Nature (IUCN, 2000) provides the following definition:

"an alien species which becomes established in natural or semi-natural ecosystems or habitat is an agent of change and threatens native biological diversity".

According to Strand *et al.* (2018), alien species have an invasive potential if they establish and reproduce easily, have a strong dispersal ability and can outcompete native species in their original ecosystems. The absence of natural obstacles to the spread of species (e.g., natural enemies) can result in them gaining a competitive advantage in a new habitat, in which they are then likely to become invasive (Valéry *et al.,* 2008).

According to IUCN (2000), IAS pose effects of immense, insidious and commonly even irreversible significance on native nature. Therefore, IAS are considered one of the greatest threats to maintaining biodiversity. The European Network on Invasive Alien Species, NOBANIS (2020), has emphasized that the invasive characteristics of these species can lead to significant consequences for native biodiversity and ecosystems, e.g., because of their toxicity to native species, or competition or hybridization with them: The IAS can cause major alterations in food webs, and harbour new parasites. In the worst case the IAS can cause extinction cascades of native species (e.g., Hultberg *et al.* 2020).

In Sweden, ArtDatabanken (Swedish Species Databank) has performed a risk classifications of alien species with potential of invasiveness (table 2).

Table 1. Categorical assessments that describe the ecological impact and invasiveness of classified species. Modified from Strand et al., 2018.

NK	No known risk - species that don´t pose a risk and therefore don´t need to be managed.
LO	Low risk - species that have a low ecological impact and that are not prioritized for management.
PH	Potentially high impact - species that have a high ecological effect in combination with low invasion potential, alternatively species with a high invasion potential but without known ecological effect.
HI	High impact - species that have a limited / moderate dispersal ability in combination with moderate ecological effect, alternatively species with limited ecological effect but high invasion potential.
SE	Severe impact - species with a large or potentially large ecological effect that have the potential to be established over large areas

2.1. Factors driving species introductions in forests

Biological invasions are facilitated by anthropogenic activities. An inevitable consequence of globalization and the increased connectivity is intentional and unintentional transmission of species over national borders (Prospero and Cleary, 2017). Global trade in plants and plant products provides fast pathways for plant pathogens (i.e., viruses, bacteria, fungi, oomycetes) and insects to new habitats (Boyd *et al.,* 2013). For instance, planting of imported plants in urban environments may introduce new species that then establish and spread to the surrounding nature, including forests (Khdiar *et al.,* 2020).

The changing climate is expected to increase both the frequency and intensity of natural disturbances in forest systems (Dale *et al.,* 2001), affecting significantly their composition, structure, growth, health and dynamics (EEA, 2021).

Particularly forests on higher latitudes in central and north-eastern Europe and areas in southern Scandinavia are predicted to be strongly affected (Berg *et al.,* 2003; EEA, 2021). For example, in Sweden, the annual average temperature has increased by 1.7°C since the early 1990s, which is approximately twice as fast as the global average (SMHI, 2019). To monitor the changing climate, a number of climate related indicators are being annually updated by the Swedish Meteorological and Hydrological Institute (SMHI). A further analysis uses UN Intergovernmental Panel on Climate Change (IPCC) climate scenarios, so-called RCP (Representative Concentration Pathways) (IPCC, 2021). In considerations of different climate scenarios, SMHI continuously conducts general estimates of how Sweden's climate could change in the future.

In a report with the objective to estimate southern Sweden's future climate, two of the scenarios were used; RCP 4.5 and RCP 8.5 (Ohlsson *et al.,* 2015). In table 2 the underlying assumptions for the two scenarios are presented. RCP 4.5 represents a future with strategies for reducing greenhouse gas emissions that will lead to the stabilization of radiant power at 4.5 W / m² before the year 2100. Whilst RCP 8.5 involves current climate policy and increasing greenhouse gas emissions resulting in radiation power reaching 8.5 W / m² in 2100).

Table 2. Underlying assumptions for the climate scenarios RCP 4.5 and RCP 8.5. Based on Ohlsson et al., 2015.

RCP 4.5	RCP 8.5
o Emissions of carbon dioxide increase slightly and culminates around the year 2040 o Population slightly below 9 billion in end of the century o Low land requirements for agricultural production, due in part to larger harvests and changing consumption patterns o Extensive forest planting program o Low energy intensity o Powerful climate policy	o Carbon dioxide emissions are three times today o The earth's population increases to 12 billion, which leads to increased demands for grazing and arable land for agricultural production o Technological development towards increased energy efficiency continues, but slowly o High dependence on fossil fuels o High energy intensity o No additional climate policy

When using RCP 4.5, it was estimated that the average temperature in southern Sweden would increase by about 3°C towards the end of the century, when comparing the reference period 1961–1990 (Ohlsson *et al.,* 2015). On the other hand, when using RCP 8.5 it was estimated that the average temperature would increase by approximately 4°C (Fig. 1).

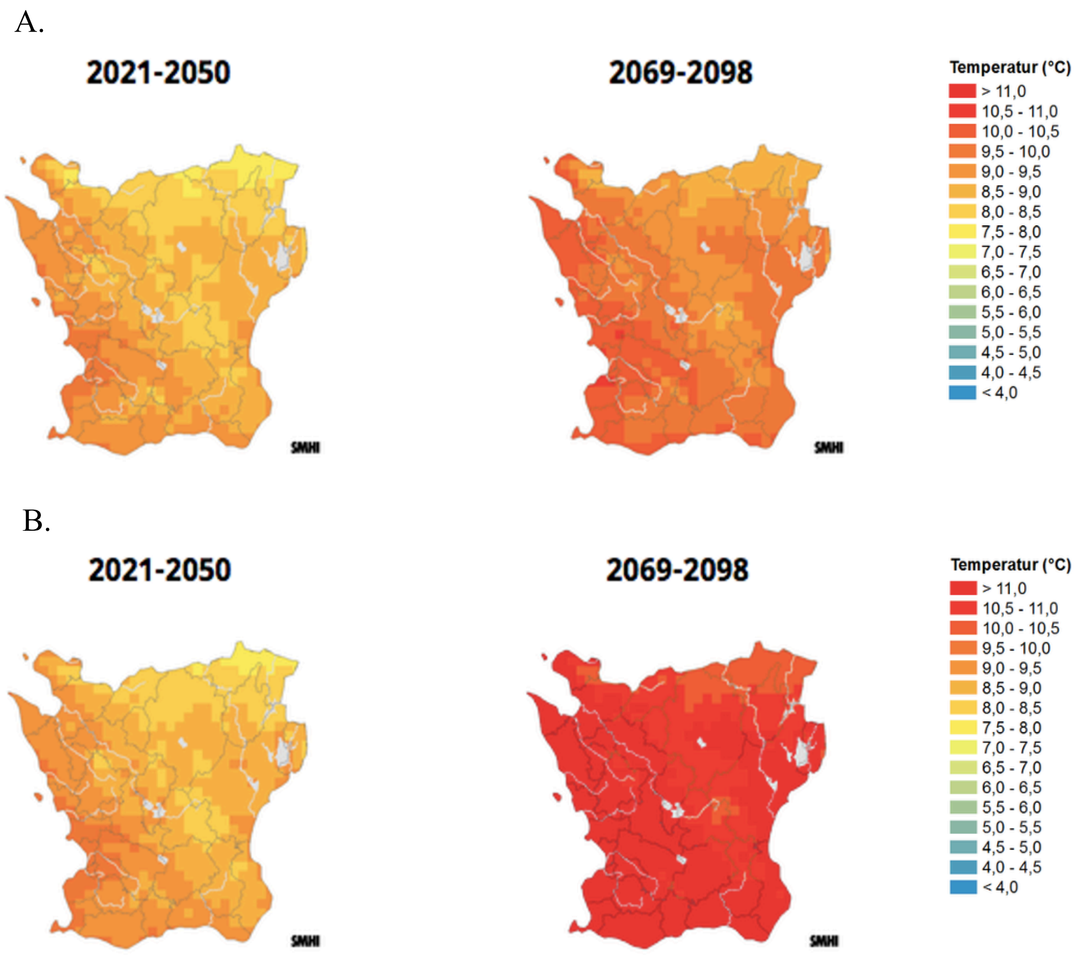

Figure 1. A. Future development according to scenario RCP 4.5, B. Future development according to scenario RCP 8.5. Mean values for the periods 2021–2050 and 2069–2098 in the county of Skåne, southern Sweden. Retrieved from SMHI, 2021.

It was additionally estimated in RCP 8.5 that the vegetation period is likely to increase by approximately 60–90 days during the same period of time (Ohlsson *et al.,* 2015). In accordance with this scenario the number of consecutive days, with a daily average temperature of >20°C, was likely to increase over the years (ibid.). Of equal importance, Ohlsson *et al.* (2015) additionally estimated that the annual average precipitation will increase by about 15–25%.

The effects of the changing climate will impact forests in southern Sweden, with both positive and negative impacts to forest ecosystems. Longer growing seasons, increased water availability and CO_2 fertilization could contribute to an increased forest vigor and growth (Swedish Forest Agency, 2009). Climate change may also increase the vulnerability of forests to both biotic and abiotic damage, e.g., by supporting favourable conditions and increased spread of existing and new forest pathogens and pests (Jactel *et al.,* 2017; SMHI, 2020). In addition, a climate driven change may also contribute to limited resources and increased stress (e.g., drought periods) for trees, resulting in reduced growth and increased mortality (Allen *et al.,* 2010). The warmer spring temperatures induce early flushing of trees, which increases the risk of exposure to early frost events (Langvall, 2011). In order to ensure continued delivery of multiple ecosystem services from forests, forest management needs to be adapted to the new climate (Millar *et al.*, 2007).

One of the potential measures to actively adapt the forest management to changing climate is assisted migration. This phenomenon is also called "climate-adapted planting", i.e., planting of tree species outside their current range (Koralewski *et al.*, 2015). Assisted migration aims at increasing the plasticity or an inherent ability of forests for acclimation by creating or maintaining diverse forests that are well adapted to climatic conditions (Keskitalo *et al.,* 2016 Ammer, 2019). For instance, in Sweden this could mean planting tree species that currently thrive in central Europe and Northern America as admixtures with the native species (Bräuner *et al.,* 2015).

It has been suggested that the use of alien tree species could support the production of ecosystem services by forests, e.g., in urban environments (Sjöman *et al.*, 2016). Kendle and Rose (2000) stated in a study from the UK that the non-native species could be suitable substitutes for native species, in instances where the loss of a native species has led to lacking ecosystem functions. In a global meta-analysis of 1683 case studies, Castro-Diez *et al.* (2019) concluded that more increases than decreases in ecosystem services were attributable to non-native trees. However, they also emphasized that there was a strong context dependency of the effects and that trade-offs exist between different ecosystem services (ibid.). Pötzelsberger *et al.* (2020) emphasized the contrasting views on use of introduced (non-native) trees: on one hand they provide opportunities to respond to global challenges such as climate change and increasing need of multiple ecosystem services from forests, but on the other hand there are also great risks for native ecosystems or the provision of ecosystem services. Therefore, it is important to develop environmental consequence analyses and knowledge-based management strategies for individual species in their new environment.

With the increasing awareness about the consequences of biological invasions, preventive work to reduce the spread and improve the management of IAS has become more relevant than before. In 2015, the European Union (EU) introduced common regulations for the prevention and management of invasive alien species (IAS) for its member states (Regeringen, 2018; Lange, 2020). Since August 2018, there has been a supplementary national regulation in Sweden (Riksdagen, 2018).

NOBANIS (2021) has evaluated a complete elimination of IAS as difficult, time consuming and costly. Thus, Swedish authorities work primarily preventively to minimize possible risks and to reduce the species' occurrence (Lange, 2020; Nitare, 2014). On the national scale, the Swedish Environmental Protection Agency is the responsible authority for IAS on land. Hence, the authority is responsible for guiding other societal authorities in the application of ordinances, laws and regulations (ArtDatabanken, 2020; Naturvårdsverket, 2021). On the regional scale, the County Administrative Boards are main responsible body for carrying out risk assessments, taking measures regarding transmission routes and informing and reporting on the discovery of IAS (Lange, 2020; Naturvårdsverket, 2021).

2.2. *Acer pseudoplatanus*

In Sweden, *Acer pseudoplatanus* (commonly called Sycamore maple in north America and Sycamore in Great Britain) is a forest tree species classified as IAS (ArtDatabanken, 2021; NOBANIS, 2021). ArtDatabanken (2021) has categorized and graded the ecological impact of this species as severe (SE). This is mainly motivated by the species' high median lifespan, seed dispersal and ability to adapt and compete with surrounding native species (ibid.). The Swedish Forest Agency (2009) has stated that the species can cause major ecological consequences, especially in nature reserves and national parks where the intention is to maintain a pure native flora. Sycamore maple has also been classified as invasive species in Norway, Latvia and Lithuania and as being potentially invasive in Finland (NOBANIS, 2021).

A. B.

Figure 2. A. Sycamore maple (Acer pseudoplatanus) has large, palmate, lobed and coarsely toothed or serrate leaves with long leafstalks that are often tinged with red. The colour of the leaves is dark green, with paler green underside. The yellow-green flowers hang in branched clusters in flowerheads (panicles) and attract insects with pollen and nectar. The seeds are winged (samaras) and develop in pairs. The ovoid and pointed buds occur in opposite pairs. B. The bark of Sycamore maple is smooth in young trees and develops cracks and small plates when the tree ages. Sources: A. https://sv.m.wikipedia.org/wiki/Fil:Acer_pseudoplatanusAA.jpg (21-08-15). B. Karin Pershagen.

Sycamore maple is a fast-growing broadleaved tree species that belongs to the genus *Acer* and the family Sapindaceae (Krabel and Wolf, 2013). The species is native to large parts of central Europe and its post-glacial origin can be traced to the regions of the Pyrenees, the Alps and the Carpathians (Vedel *et al.,* 2004; Pasta *et al.,* 2016; Fig. 3). In natural forest communities, it often occurs in mountainous areas and steep slopes (Pasta *et al.,* 2016). In addition, its occurrence and range in natural forest communities could be considered similar to that of European Beech (*Fagus sylvatica*) (Bartha, 2006; Sjöman and Slagstedt, 2015). However, it may be complex to concisely describe its current natural distribution due to its successful spread over the years (Sjöman and Slagstedt, 2015) and because it has become naturalized far beyond its native range (Rusanen and Myking, 2003; Pasta *et al.,* 2016). In recent decades, the distribution area of Sycamore maple has increased in southern Scandinavia (in Norway and Sweden up to 59th latitude) (Krabel and Wolf, 2013; De Keersmaeker *et al.,* 2016; Pasta *et al.,* 2016).

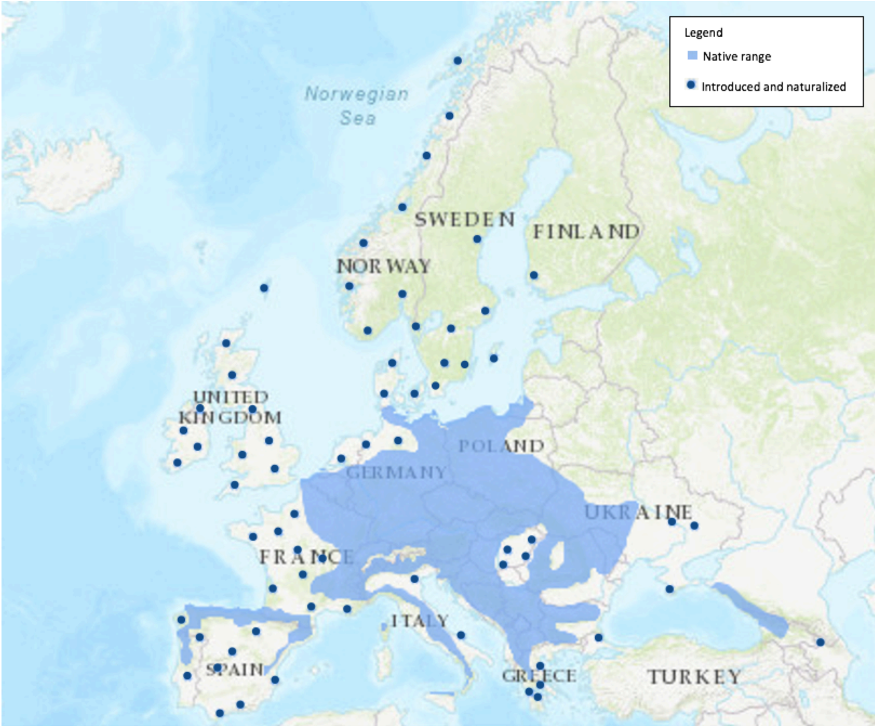

Figure 3. Distribution map of Sycamore maple (Acer pseudoplatanus) in Europe. Modified from EUFORGEN, 2021.

In Sweden, Sycamore maple was first introduced in 1770, and has ever since mainly been planted in urban park environments and gardens (Widén, 2002). Besides being planted for aesthetic reasons, it has additionally been established for production purposes within the larger estates in southern Sweden (Sjöstedt, 2012). Furthermore, since 2015 until April 2021 a total of over 2,200 finds have been reported to Artportalen (Artportalen, 2021). Reporting of species takes place in nature that falls under the Swedish right of public access, no reporting may thus take place in private gardens (ibid.). According to the reports, the majority of Sycamore maples are found from Skåne county in the south to Uppland county in the north (Fig. 4).

Figure 4. Map showing reported observations of Sycamore during the period 2015–2021. Light blue dots display cluster with a larger number of reported findings, while dark blue dots display a smaller number. From Artportalen, 2021.

There is a lack of collected statistics on Sycamore maple through national forest inventories in European countries, which is likely to reflect its relatively small importance in Europe (Krabel and Wolf, 2013). In Sweden it's usually recorded together with 'other broad-leaved tree species' or other *Acer* species (Riksskogstaxeringen, 2021). In accordance with a high-resolution map over estimated suitable habitats for Sycamore, the southern and the middle parts of Sweden could be considered convenient for the species, while the northern parts are clearly unsuitable (Fig. 5).

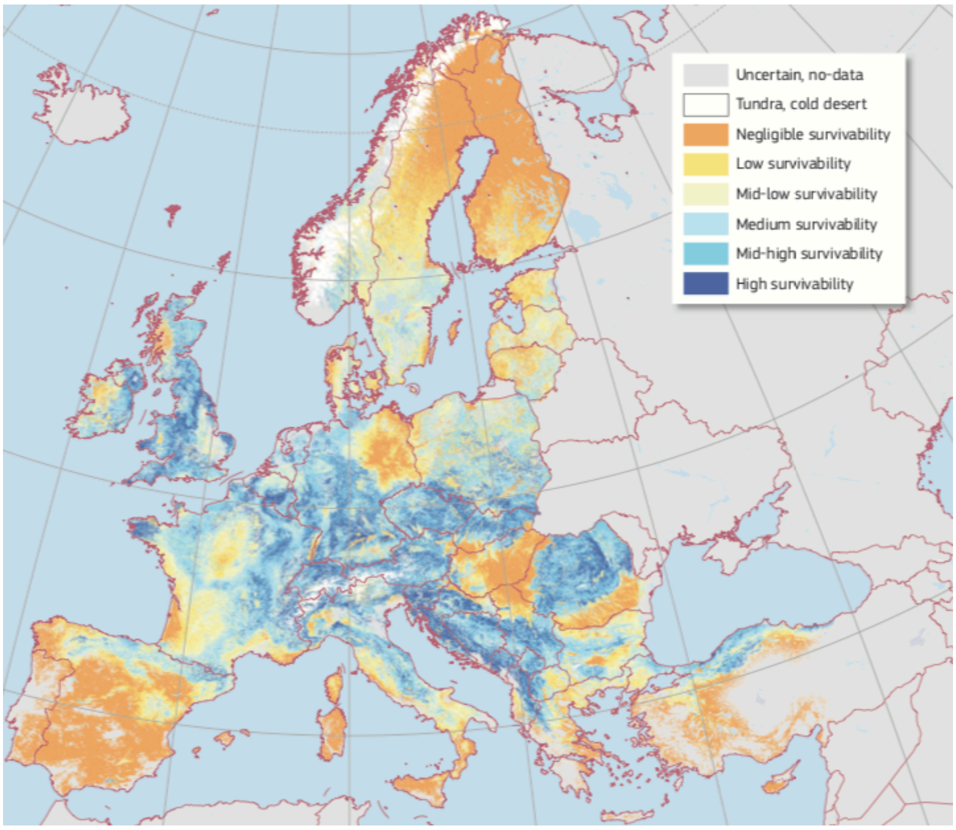

Figure 5. High-resolution map of Europe estimating the maximum habitat suitability for Acer pseudoplatanus, based on a model which compares the species 'distribution with data on climate and soil conditions (BioSoil data). Retrieved from Pasta et al., 2016.

Sycamore maple has high adaptability and tolerance of a large range of soil, pH and other site properties (Krabel and Wolf, 2013; Keersmaeker *et al.,* 2016). Nevertheless, for best growth it requires nutrient-rich soils with sufficient depth (Long, 1992), good access to groundwater (Sjöman and Slagstedt, 2015) and humidity (Malmqvist and Woxblom, 1991; Spohn and Spohn, 2008; Vacek *et al.,* 2017). Even though the species does not prefer dry or nutrient-poor soils (Krabel and Wolf, 2013), it is more resistant to drought when compared to Norway maple (*Acer platanoides*) (De Keersmaeker *et al.,* 2016).

The species prefers semi-shade and is less shade-tolerant than Beech (*Fagus* spp.), but slightly more than Ash (*Fraxinus* spp.) (Malmqvist and Woxblom, 1991). On suitable sites under Swedish conditions, Sycamore maple can grow to 25–30 meters and develop a broad crown (Sjöman and Slagstedt, 2015). The species rarely forms pure stands naturally and is more likely to be found in mixtures with other tree species, such as Beech (*Fagus spp*.), Ash (*Fraxinus* spp.), Oak (*Quercus* spp.), or Fir (*Abies* sp.) (Hein *et al.,* 2009; Krabel and Wolf, 2013). Young trees are sensitive to frost and browsing (Krabel and Wolf, 2013), while mature trees are more tolerant (Rusanen and Myking, 2003).

Figure 6. A homogeneous Acer pseudoplatanus stand. Photo: Karin Pershagen.

Figure 7. Undergrowth of Acer pseudoplatanus in a mixed stand with Fagus sylvatica. Photo: Karin Pershagen.

Sycamore maple has a good ability to establish and spread (Krabel and Wolf, 2013). Individual trees can produce over 100,000 seeds that are easily carried by wind (Rusanen and Myking, 2003). Bees and bumble bees are the primary vectors for its pollination (Rusanen and Myking, 2003; Sjöman and Slagstedt, 2015), and only a small proportion of its flowers are preferentially wind pollinated (Binggeli, 1993; Rusanen and Myking, 2003).

Sycamore maple is considered to be a soil improving tree species (Weber *et al.,* 1993; Leslie, 2005; Vacek *et al.,* 2017) since it contributes to phyto-stabilization of heavy metals (André *et al.,* 2006). In the Netherlands, the species is currently used to counteract soil acidification (De Keersmaeker *et al.,* 2016). It has been shown to promote humus formation (Leslie, 2005) and could therefore even improve nutrient cycling in oak- and beech-dominated forests (Hein *et al.,* 2009; De Keersmaeker *et al.,* 2016). In a review De Keersmaeker *et al.* (2016) deemed that a more varied flora can be found in forest stands with Sycamore maples than in Beech forests. In turn, Leslie (2005) stated that the species soil improving characteristic may even contribute to it being a convenient candidate for the improvement of degraded land. De Keersmaeker *et al.* (2016) underlined that the species has an exemplarily ability to colonize compacted soils, e.g., on abandoned agricultural land and land in urban areas.

The species is widely grown as an ornamental tree in urban and coastal areas due to its amenity values (Crowley *et al.,* 2017). It has an additional high tolerance against stress factors, such as salt spray, industrial pollution and wind (Krabel and Wolf, 2013; Keersmaeker *et al.,* 2016; Pasta *et al.,* 2016), which explains its amenability as an urban tree even outside its natural range (Felton *et al.,* 2013). It has additionally been planted for the function of wind break and for protection from soil erosion (Crowley *et al.,* 2017). Consequently, the species is also of significant importance in terms of risk prevention in high altitude forestry in Central Europe (Heumader, 2007).

Figure 8. Acer pseudoplatanus growing as an amenity tree in Malmö. Photo: Karin Pershagen.

The timber of Sycamore maple consists of hard-wearing and creamy-white wood that is considered to be of high value (Rusanen and Myking, 2003; Leslie 2005; Spohn and Spohn, 2008; Krabel and Wolf 2013). Occasionally, it also produces “wavy grained” wood, which poses one of the highest valued on the European market (Rusanen and Myking, 2003; Quambusch *et al.,* 2021). However, due to its lack of durability it is rarely used for construction purposes (Pandey, 2005; Krabel and Wolf, 2013). It is used more commonly for indoor purposes such as for furniture, joinery, flooring, and music instruments (Spohn and Spohn, 2008; Pasta *et al.,* 2016; Quambusch *et al.,* 2021). Consequently, due to its production potential, it has gained a growing interest for economic reasons (Rusanen and Myking, 2003; Hein *et al.,* 2009).

The assumed threat posed by Sycamore maples on the native biodiversity has been highlighted but also questioned in a large number of studies. Rusanen and Myking (2005) stated that its large seed set, and longevity has contributed to its strong invasive potential, which could partly explain its poor reputation among conservationists (Leslie, 2005). The Swedish Forest Agency (2009) has pointed out that the species has a negative effect on native flora and fauna. Attention should also be paid to toxicity of the Sycamore maple and its seeds to horses since it causes atypical myopathy, or seasonal grazing myopathy (De Keersmaeker *et al.,* 2016; Gröndahl, 2020). The poisoning causes severe muscle breakdown, and the acute mortality rate is high (Gröndahl, 2020). On the contrary, it is harmless to sheep and goats, which has contributed to the county administrative boards in southern Sweden using them to reduce its occurrence within Nature reserves. However, De Keersmaeker *et al.* (2016) stressed that the actual species richness associated with Sycamore maple is often underestimated, certainly compared to species such as Oak, Willow and Poplar. A study conducted in Great Britain showed that there is a lack of clear evidence showing that Sycamore maple suppresses and reduces native biodiversity (Peterken, 2001).

Sycamore maple is argued to host a moderate to rich biodiversity (e.g., Cundall *et al.,* 1998; Leslie, 2005; Mitchell *et al.,* 2016). A study from the Czech Republic concluded that Sycamore stands have the ability to reach high ecological stability and considerable biodiversity (Vacek *et al.,* 2017). Its pollen and nectar are an essential source of food for a large number of species (Krabel and Wolf, 2013; Sjöman and Slagstedt, 2015). According to the results of a European study comparing different tree species in urban environments, the species was considered one of the most valuable pollen resources for insects (Somme *et al.,* 2016). The species also hosts aphids (Binggeli, 1993), which attract a large number of insects and bird species (Leslie, 2005; De Keersmaeker *et al.,* 2016). Aphids produce large amounts of honeydew, which is an important food source for insects, such as butterflies, beetles, and bees (De Keersmaeker *et al.,* 2016). In a review, De Keersmaeker *et al.* (2016) argued that Sycamore maples can act as a more important food source for birds compared to the tree species Beech, Ash and hazel (*Corylus avellana*). A large variety of epiphytic lichens (about 170 taxa) and bryophytes are attached to the species base-rich bark (e.g., Binggeli, 1993; Leslie 2005; Moning *et al.,* 2009). That has led to their importance of posing ecological indicators of nature's condition (Rydlöv *et al.,* 2015; Sales *et al.,* 2016).

Due to its robustness, high tolerance and broad ecological niche, Sycamore maple has been considered well suited to current and also for predicted future climatic conditions (Krabel and Wolf, 2013; Hein *et al.,* 2009. In the UK, Sycamore maples have had the ability to form forest stands and decreased erosion where native species have been difficult to establish due to e.g., wind conditions in open landscapes (Kendle and Rose, 2000). In terms of growth rhythm and rotation time, European studies have concluded that Ash and Sycamore maple may overlap successfully (Keersmaeker *et al.,* 2016; Hein *et al.,* 2009). Due to outbreaks of the fungus *Hymenoscyphus fraxinus* of which causes Ash dieback, the future of common Ash (*Fraxinus excelsior*) as a forest tree is considered uncertain (Lind, 2020). In a British review, Sycamore maple has in turn been ranked as a suitable alternative tree to Ash in terms of a similar ecosystem function and by a high number of associated species (Mitchell *et al.,* 2016). Equally important, mixtures with *Acer* species and Ash have shown to reduce Ash dieback severity at stand level (Havdova *et al.,* 2017).

Similar to all other tree species, also Sycamore maple is attacked by pests and pathogens. Sooty bark disease (SBD) is a lethal disease on Sycamore maple, caused by an ascomycete fungus *Cryptostroma corticale* (Braun *et al.,* 2021; table 4). The disease is associated with *Acer* species, particularly Sycamore maple (e.g., Braun *et al.,* 2021). Nevertheless, the fungus may also infect other broadleaved tree species such as *Tilia* spp., *Betula* spp. and *Carya* spp. (Towey *et al*., 1932), suggesting a generalist nature for this pathogen. The fungus can additionally cause Maple bark disease (MBD) in humans, which is a hypersensitivity pneumonitis (Braun *et al.,* 2021). Symptoms of MBD are similar to allergic asthma, influenza or flu-like infections (Towey *et al.,* 1932; Gregory and Waller, 1951; De Keersmaeker *et al.,* 2016; Braun *et al.,* 2021). To protect the public and prevent the spread of its spores, areas with infested trees are recommended or obliged to be cordoned off and trees removed (Braun *et al.,* 2021). The risk group includes people who have professional contact with infected trees or wood but also people with weakened immune systems (ibid.). Thus, personal protective measures (workwear and mask) should be taken during management operations of affected trees (Douzon, 2007).

As MBD encompasses complex symptoms, Braun *et al.,* (2021) argue that the disease often is undiagnosed, misdiagnosed or delayed.

Since the end of the 19th century, SBD has been known from North America (Gregory and Waller, 1951). In Europe, it was first detected in the middle of the twentieth century in urban settings in England and France (Gregory and Waller, 1951; De Keersmaeker *et al.,* 2016). In recent decades, SBD has spread and reported observations confirm that it´s now widespread and present in many European countries (table 3). It has been shown to affect both natural environment (woodland settings) and semi-natural environments (urban settings), but a majority of infected trees have been found in urban areas and parks (Kelnarová *et al.,* 2017). In contrast, trees affected in Italy grew in woodland settings, and on higher altitudes (Longa *et al.*, 2016). It has additionally been reported that the pathogen has been found in asymptomatic trees (Kelnarová *et al.,* 2017). Due to its long latent phase and the lag time in reporting disease presence in the countries, it is difficult to accurately track and clarify the actual distribution of it in Europe (Cech, 2018).

Table 3. Distribution table with reported cases of SBD in Europe. The data was last updated on February 17, 2021. Modified from EPPO Global database, 2021.

Country	Distribution	Reference
Austria	Present	Cech, 2018
Belgium	Present	NPPO, 2019
Bulgaria	Present	Bencheva, 2014
Czech Republic	Present	Koukol *et al.,* 2014
France	Present	Bulletin de santé du vegetal, 2012
Germany	Present	Robeck, 2012
Italy	Present	Longa *et al.,* 2016
Netherlands	Present	NPPO, 2014
Switzerland	Present	Cochard *et al.,* 2015
United Kingdom	Present	Bevercombe & Rayner, 2007

The disease is characterized by wilt, dieback of crown, and bark shedding with a underlaying of dark brown or black spores (Gregory and Waller, 1951). In the initial stage, dark brown stromata can be observed under the bark, in a later stage the bark loosens and emits a sooty layer of spores (Braun *et al.,* 2021, Fig. 9), which develop in enormous numbers (Cech, 2018). In the early stages of infection, sparse foliage and death of individual branches in the crown can be observed (De Keersmaeker *et al.,* 2016). Minor wounds and openings in trees have shown to serve as gateways for the spores (Cech, 2018), which spread through the trees xylem before entering the phloem (Kelnarová *et al.,* 2017).

Figure 9. Symptoms caused by Cryptostroma corticale. Photos: Vincent Gaucet, bugwood.org.

The spores of *Cryptostroma corticale* are primarily spread by wind and rain (Gregory and Waller, 1951; table 4), but birds can also play a certain role as its vectors (Kelnarová *et al.,* 2017). Even squirrels may be involved in its spread, since they ingest the spores orally and then cause infections by peeling the bark from trees (Young, 1978).

Table 4. Main characteristics of the pathogen Cryptostroma corticale causing Sooty bark disease and Maple bark disease. Based on Braun et al., 2021; Kelnarová et al., 2017; Longa et al., 2016; Gregory and Waller, 1951; Towey et al., 1932.

Common Name	Sooty bark disease & Maple bark disease
Causal agent	*Cryptostroma corticale*
Host species	Major genus is *Acer*, in particular Sycamore maple (*Acer pseudoplatanus*). Minor genus is *Tilia* spp., *Betula* spp. and *Carya* spp.
Host symptoms	Peeling of the outer layers of bark to expose a mass of dry, dark brownish or black spores; leaf wilting; dieback of crown
Invaded range	North America, Europe
First detection in Europe	England in 1945
Introduction pathway	Globalization, trading
Primary dispersal pathway	Wind- and rain dispersed spores; mammalian vectors; movement of infected plants/wood by human force
Control	Remove, cover during transport and burn infected trees or wood

It has been shown that the spread of SBD is strongly influenced by climatic conditions. Several studies have clarified that longer vegetation periods in combination with drought would benefit its occurrence and spread in Europe (e.g., Young, 1978; Leslie, 2005; Thorpe *et al.,* 2006; Douzon, 2007; Cech, 2018; Braun *et al.,* 2021). In addition, during hot and dry weather periods, its ability to spread within its host tree has been shown to accelerate in warmer temperatures (Kelnarová *et al.,* 2017). In an experiment by Dickenson and Wheeler (1981) the fungal growth benefited more significantly on consecutive days at 25° C than at 15° C. Results from a study in England's concluded that the fungal is more likely to occur when the average daily temperature is 23°C or higher (Young, 1978). The trees´ stress due to alternating environmental factors is likely to increase their susceptibility to disease (Dickenson and Wheeler, 1981; Krabel *et al.,* 2013; Braun *et al.,* 2021). Heavier NOx pollution in combination with more paths and roads has additionally shown to increase the frequency of the disease occurrence (Kelnarová *et al.,* 2017).

Since *Cryptostroma corticale* seems to prefer hot summers and host trees that are weakened by various stress factors, SBD is predicted to become more common in the future climate (Braun *et al.,* 2021). Thus, also the risk of an increased spread of MBD could be assumed (ibid.). In consideration with reports of SBD spread, the disease may currently pose one extensive risk to the population of Sycamore maple in Europe (e.g., Kelnarová *et al.,* 2017), not least from an economic point of view (Braun *et al.,* 2021). Nevertheless, the disease has not yet been observed and reported in Sweden (Artportalen, 2021). In order to be able to limit damage and develop appropriate management measures for non-native trees and their pathogens, an understanding of the current and potential distributions and factors that affect the spread of its diseases are required (Prospero & Cleary, 2017).

Generally, trees have a high social, ecological and economic significance, not least as planted in urban green infrastructures. However, urbanization includes a massive influx and transitions of people and goods, which contributes to the entrance of new pests and diseases on the urban trees (Paap *et al*., 2017; Czaja *et al.,* 2020). The phenomenon that the human environmental impact and temperature are higher in urban areas compared to in natural forests also generates increased stress for the trees (Dale *et al.,* 2016). Extensive or accumulating stress can significantly affect the vitality[1] and resilience of the trees (ibid.), making the trees vulnerable to introduced pests and pathogens (Paap *et al*. 2017). Therefore, if new pests and diseases should appear, it is likely that these would first be identified in urban environments.

[1] Defined as a trees power to live, grow, and develop (Cherubini *et al.,* 2021).

3. Aim of the study

The aim of the study is to add new knowledge about the state of Sycamore maple populations in southern Sweden by observing indicators of its vitality. The study is focusing on detecting possible threats with special attention to first signs and symptoms of Sooty bark disease (SBD). The study´s specific objectives were to test the following hypotheses (1-3):

1. The health and vitality of Sycamore maple differs in woodland vs. urban settings. The expectation was that urban trees would show lower vitality due to exposition to greater environmental stress (e.g., soil compaction, air pollution) and potentially higher exposition to pathogens.
2. The occurrence of epiphytic biodiversity (mainly lichens and bryophytes) on Sycamore maple differs between trees growing in urban and woodland settings. The expectation was that the coverage of epiphytes would be higher in woodlands due to more favorable environment for their growth and spread (e.g., better air quality).
3. *Cryptostroma corticale* is already present on Sycamore maples in southern Sweden. The expectation was that it could already be present in particular in urban settings that are often an entry point for new pests and pathogens.

4. Method and Material

4.1. Study Areas

The study encompassed a total of four different areas in southern Sweden, of which two were in urban- and two were in woodland settings (Fig. 10). In Table 5 specifications of each study areas location, climatic condition and meters above sea level (MASL) are displayed.

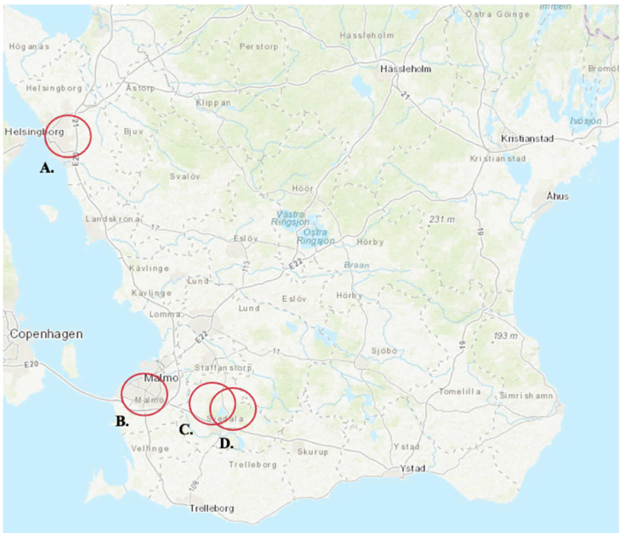

Figure 10. Geographical locations of study areas, urban settings (A. Helsingborg; B. Malmö) and woodlands (C. Skabersjö and D. Torup estates). From arcgis.com.

Table 5. Specifications of surveyed locations climatic conditions. MASL refers to meters above sea level. Retrieved from SMHI.se

Location	Average precipitation, mm	Average annual temperature, ºC	MASL
Malmö	652	9	6–16
Helsingborg	799	8.7	21–41
Skabersjö estate	673	8.9	51–71
Torup estate	673	8.9	48–54

4.1.1. Urban settings

Malmö is Sweden's third largest city with 348,600 inhabitants and the nation's fastest growing metropolis (SCB, 2021). Currently, there are about 64 000 trees within its park and street environments, of which 1 231 are Sycamore maples with age ranges from 40 to 131 years (Malmö stad, 2021). According to Malmö stad (2021), systematic tree level management is currently being implemented with the aim of developing various environments that focus on climate, human health and well-being.

Helsingborg is Sweden's eighth largest city with a population consisting of 149,400 inhabitants (SCB, 2021). The city is located near the coast and contains several parks and green areas. Urban trees are usually managed with consideration to their individually prevailing vitality status (Helsingborg stad, 2020). Since each urban tree fulfills an important function within its environment, the management emphasizes an individual adaptation at tree level (ibid.). According to Helsingborg stad's tree map, there are currently 264 registered Sycamore maple trees within the urban area, with an age range from 19 to 161 years.

A. B.

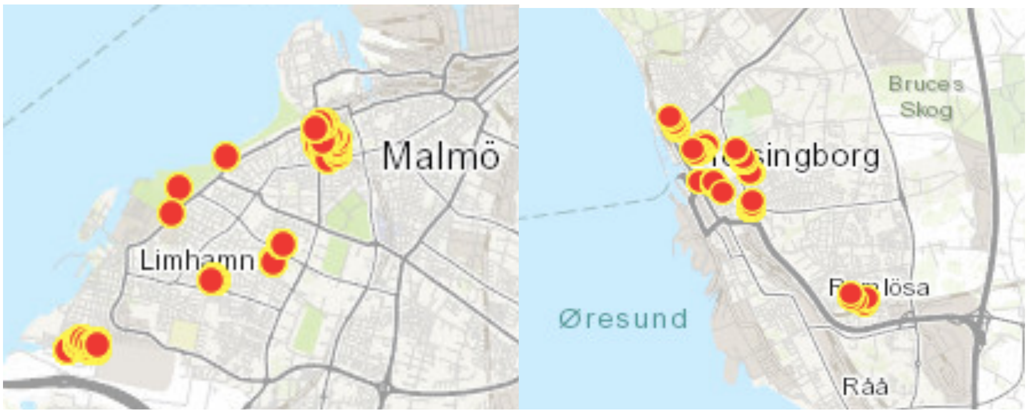

Figure 11. Inventory areas in A. Malmö and B. Helsingborg, where red dots mark the surveyed locations.

4.1.2. Woodland settings

Skabersjö estate is located about 12–20 km southeast of Malmö. Due to the proximity to Malmö, its forests are very popular to visit for recreation purposes. The estate´s forest holding is certified according to PEFC (Skabersjö, 2021). In total, the estate owns approximately 2 000 hectares of productive forest, of which 55% is deciduous and 45% is coniferous dominated forest (ibid.). Of the deciduous trees, Beech is the dominant tree species and of conifers is Norway spruce (ibid.). The estate holds both homogeneous and heterogeneous Sycamore maple stands. Stands have usually been established through planting, but natural regeneration also occurs.

Torup's estate is located about 20 km southeast of Malmö. Its forest holdings cover hundreds of hectares and consist mainly of Beech forest but also of Oak and other deciduous trees. Together with the nearby lake Yddingesjön and land belonging to Skabersjö estate, it constitutes Torup's recreational area (Naturskyddsföreningen Svedala, 2021). The recreation area is part of the southwestern Scanian ridge and lake landscape, which the parliament has judged to have special values for recreation and outdoor life (ibid.). The estate holds both homogeneous and heterogeneous stands including Sycamore maples.

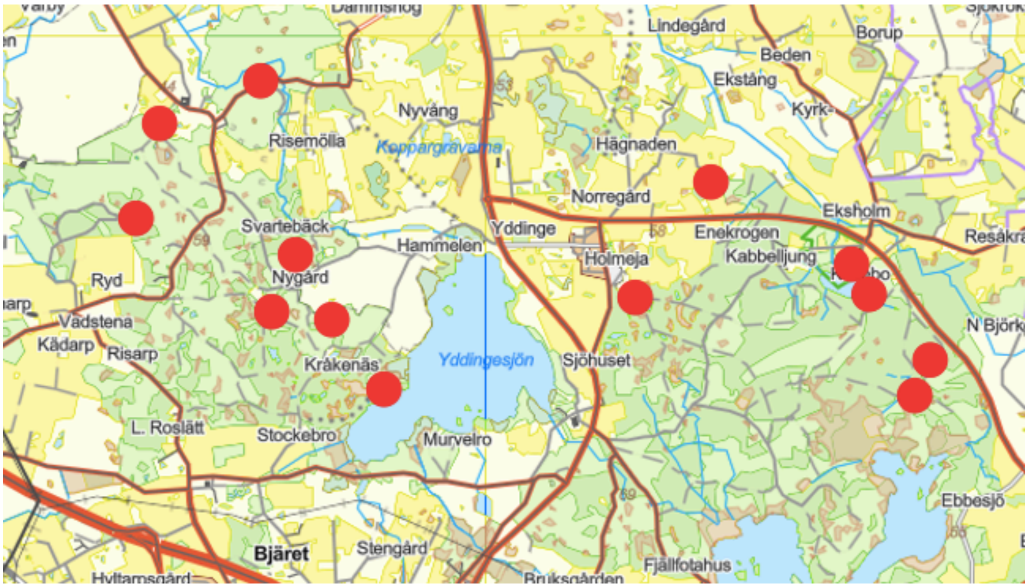

Figure 12. Inventory areas in Skabersjö and Torup estates, where red dots mark the surveyed locations. From arcgis.com.

4.2. Data Collection

A non-destructive field inventory was carried out in May 2021. The selection of trees and stands was done with the support of professors at SLU and estate and park administrators. General information regarding the sites location, age and previous land use was provided. In the urban settings, trees were mainly studied in park environments, but also along streets and in the vicinity of buildings. A total of 155 trees were inventoried, of which 80 in Malmö and 75 in Helsingborg. In the woodland settings, a total of 15 stands were visited and 165 trees were surveyed within Skabersjö (13 stands, 137 trees) and Torup (2 stands, 28 trees) estates. A continuous transect was placed in the central part of each stand, ensuring that all the trees to be examined were at a minimum distance of 10 meters from the stand edges and ensuring that at least 12 trees could be included into the transect. Within heterogeneous stands, each tree along the transect was inventoried, and within homogeneous stands every third.

4.2.1. Inventory equipment

The following equipment was used:

- Maps (topographic map, field maps with delimited areas)
- Mobile phone and field applications (online forms and maps)
- Height measurer
- Measure tape
- Binoculars
- Swedish Flora

4.2.2. Survey

As the vitality of a tree cannot be measured directly (Dobbertin, 2005), the surveys protocol contained several variables related to growth and the trees external conditions (Appendix I). For each tree, the GPS location (with an accuracy of 3–10 m) was noted. Tree height and crown diameter were noted in whole meters and rounded down. Trunk circumference was measured in cm. Measuring the diameter with a caliper at a height of 1.3 m is a common method when collecting tree data (Östberg, 2015). However, an estimate of diameter classes with a caliper may not provide the same precision as measuring the circumference with a measuring tape (Strindell and Fritz, 2011). Consequently, in this study the circumference of each tree was measured with a measure tape.

The vitality status was assessed on tree level based on a visual assessment of crown condition. Each surveyed tree´s crown was visually graded on a scale from 1–3, 1. good vitality (>80% vital); 2. moderate vitality (20–80% vital); 3. poor vitality (<20% vital). The light exposure of each tree crown was evaluated on a scale from 0–5, value 0 = no sun exposure; 1 = exposure from one side or above; 2 = exposure from two sides or/and above; 3 = exposure from three sides or/and above; 4 = exposure from four sides or/and above; 5 = exposure from four sides and from above (e.g., a solitaire tree). The coverage of epiphytic lichens and bryophytes on the lower two meters of each of the examined trees' trunk was estimated and categorized into five coverage groups, 1. 0–10%; 2. 11–30%; 3. 31–50%; 4. 51–70%; 5.71–100%. This was because it has been shown to be an effective variable for monitoring the environmental conditions of deciduous trees (Strindell and Fritz, 2011). The trees were studied for signs of SBD and other damaging agents (e.g., presence of insect damage and fruiting bodies of wood-rotting fungi, bark-free areas on the main stems, or sap flow). In addition, observations were made to detect a set of indicators for environmental or biodiversity values, such as surrounding vegetation (other tree species, field layer vegetation species), bird nests, coarse dead branches, or hollows in the trunk of the living trees.

4.2.3. Data Analysis

Microsoft Excel 2020 was used for organizing data. Non-parametric tests were applied since most of the data was categorical and did not meet the requirements for parametric testing. Pearson ChiSquare was used to study the relationship between categorical data. Differences between the four study areas were studied using Kruskall-Wallis test, and Wilcoxon Each Pair test was used for multiple comparisons. Because of unequal variances (Bartlett's test), Welch's unequal variances *t*-test was used for comparisons of growth parameters between trees grown in woodland vs urban environments. Linear regression was used to test the relation between age and growth variables. All statistical tests were conducted using JMP ® Pro 16.0.0 software (SAS Institute Inc., 2021) and evaluated at α-level 0.05.

5. Results

Growth parameters and age distribution of the surveyed trees

The height growth of trees differed between the four study sites (Kruskall-Wallis χ^2=68.48, p<0.0001; Fig. 13). Similarly, Kruskall-Wallis test indicated significant difference in CBH (χ^2=178.49, p<0.0001; Fig. 14) and crown diameter (χ^2=231.79, p<0.0001; Fig. 15). For the latter two growth variables, however, no difference was detected between the two urban sites Malmö and Helsingborg (Wilcoxon Each Pair test, Figs. 14 and 15),

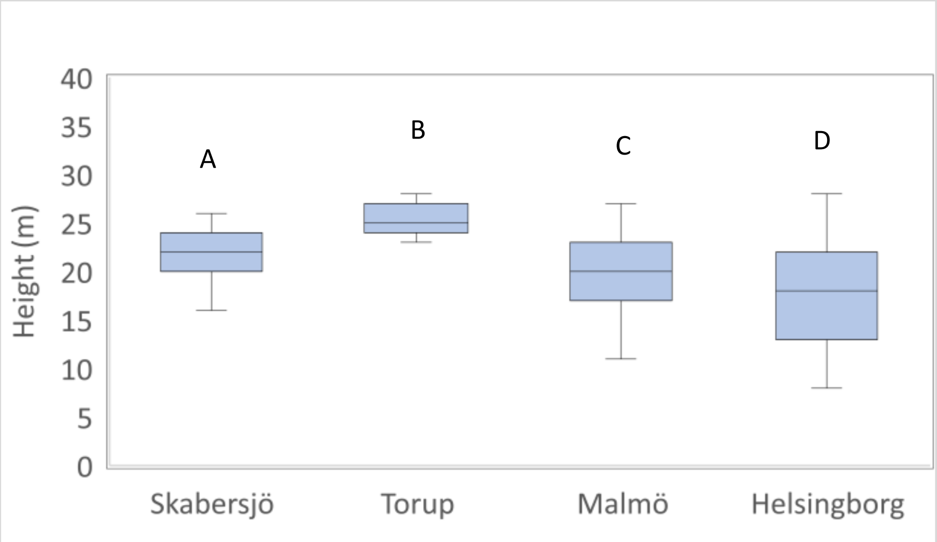

Figure 13. Box plot of height (m) of the surveyed Sycamore maple (Acer pseudoplatanus) trees in the four sites (n= 137 for Skabersjö, 28 for Torup, 80 for Malmö and 74 for Helsingborg). The different letters indicate significant difference according to Wilcoxon Each Pair test (α=0.05).

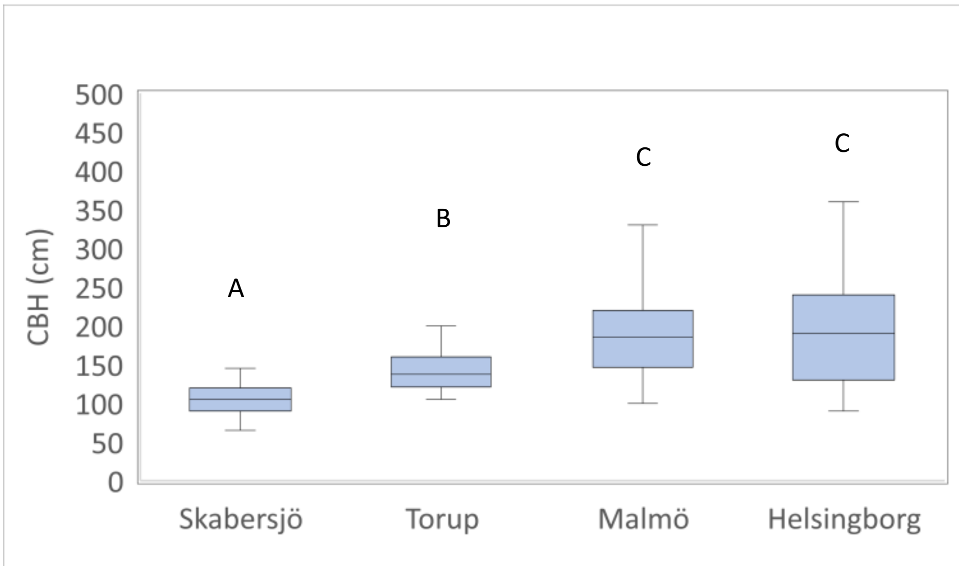

Figure 14. Box plot of circumference (cm) of the surveyed Sycamore maple (Acer pseudoplatanus) trees in the four sites (n= 137 for Skabersjö, 28 for Torup, 80 for Malmö and 74 for Helsingborg). The different letters indicate significant difference according to Wilcoxon Each Pair test (α=0.05).

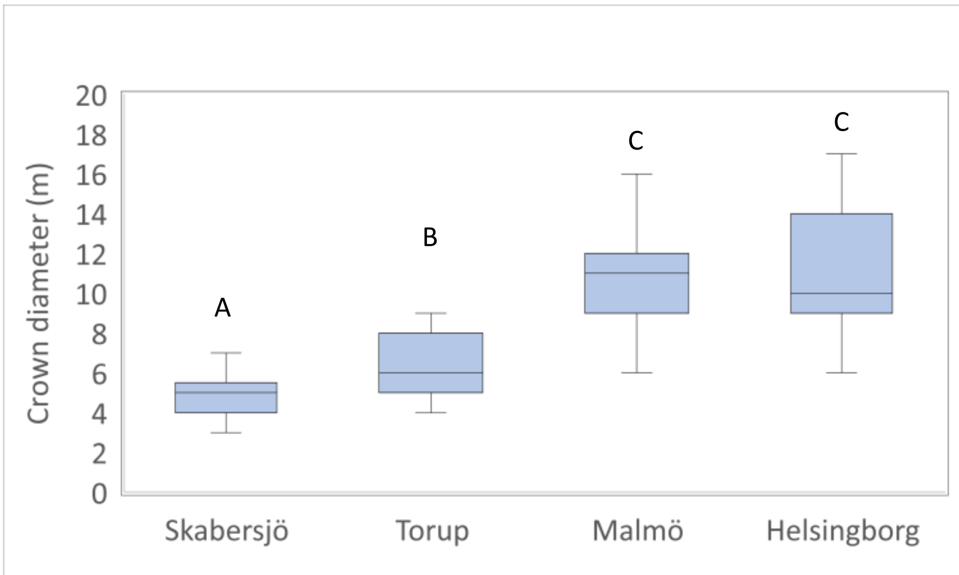

Figure 15. Box plot of crown diameter (m) of the surveyed Sycamore maple (Acer pseudoplatanus) trees in the four sites (n= 137 for Skabersjö, 28 for Torup, 80 for Malmö, and 74 for Helsingborg). The different letters indicate significant difference according to Wilcoxon Each Pair test (α=0.05).

With a median age of 62 years, the trees in Skabersjö were younger than in the other areas (χ^2=74.35, p<0.0001; Fig. 16). In general, the age of urban trees was higher than that of the woodland trees (Welch *t*-test value = 8.39, p< 0.001; Fig. 16).

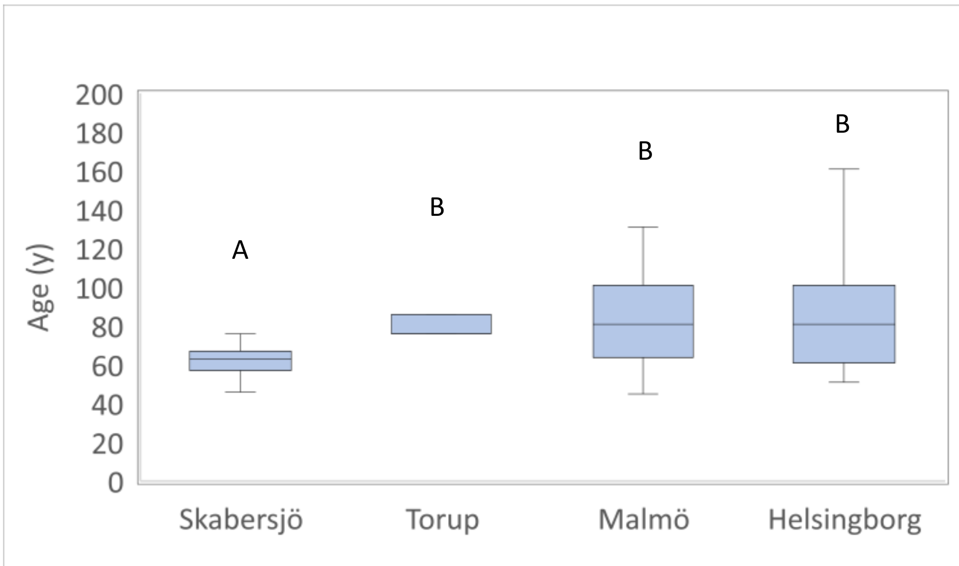

Figure 16. Box plot of age (years) of the surveyed Sycamore maple (Acer pseudoplatanus) trees in the four sites (n= 137 for Skabersjö, 28 for Torup, 80 for Malmö, and 74 for Helsingborg). The different letters indicate significant difference according to Wilcoxon Each Pair test (α=0.05).

Tree age correlated positively with the growth variables (Figs. 17, 18 and 19).

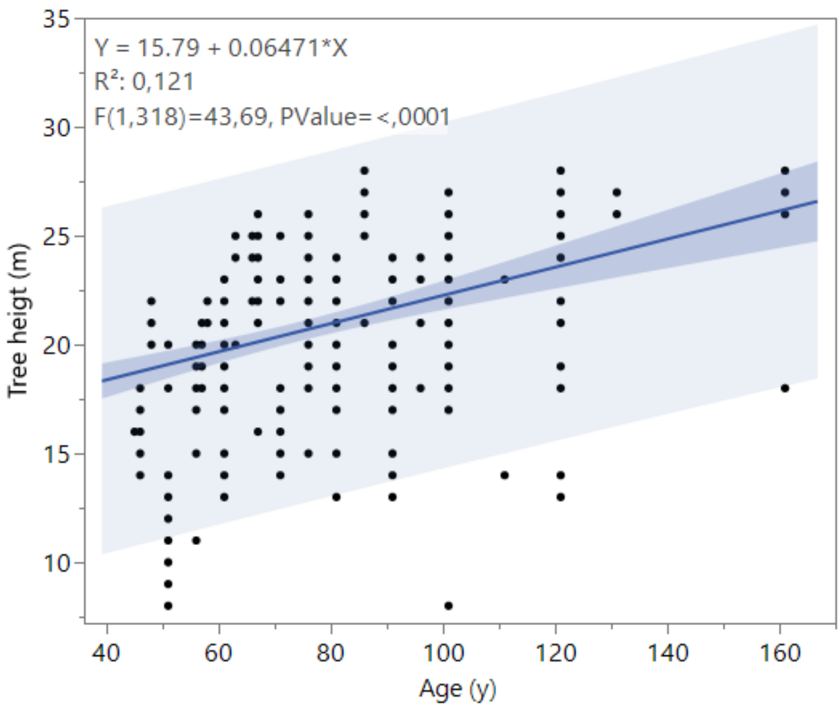

Figure 17. Tree height (m) in relation to age of the surveyed trees.

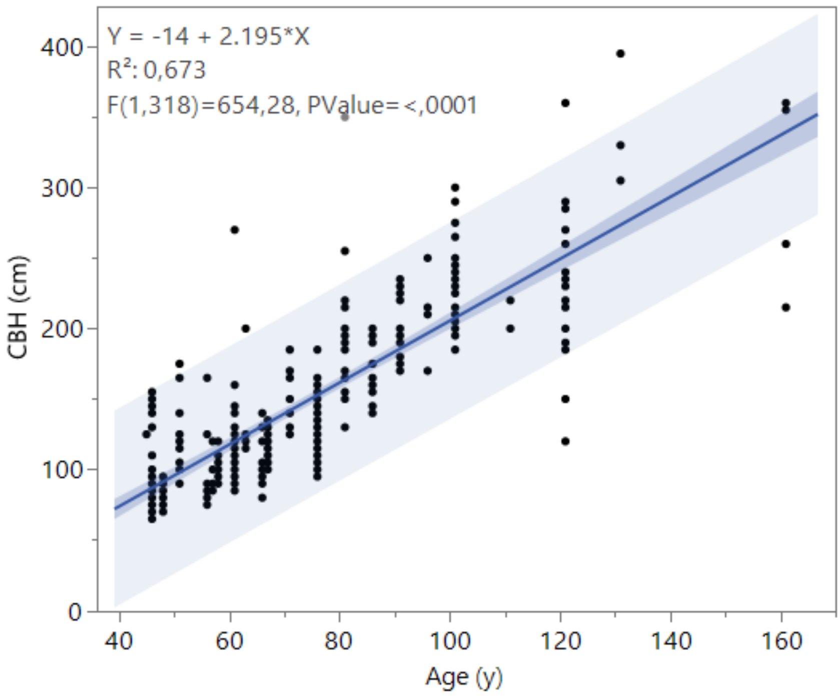

Figure 18. CBH (cm) in relation to age of the surveyed trees.

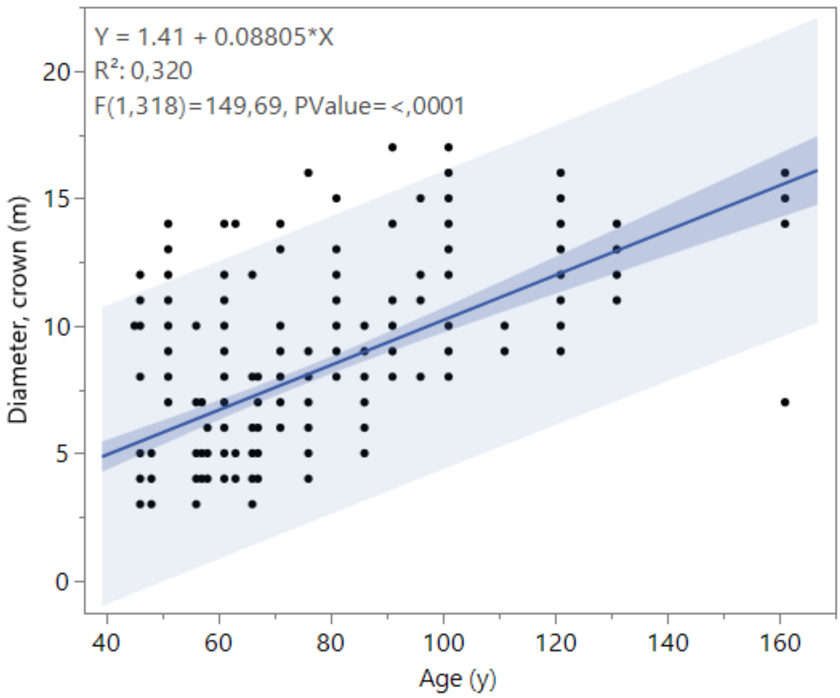

Figure 19. Crown diameter (m) in relation to age of the surveyed trees.

Vitality of the trees in urban vs. woodland settings

Vitality decreased with increasing age. The mean age for trees in vitality class ‘high’ was 72.6 years, for vitality class ‘medium’ 83.7 years and for vitality class ‘low’ 88.9 years. There was a significant difference between the tree’s vitality in the urban and woodland settings (Pearson χ^2 (2, N=320) = 26.05, $p < 0.0001$). A higher proportion of woodland trees were classified as vital (94%) as compared to urban trees (73%). Only 6% of woodland trees were classified to moderate vitality category, where the proportion was 22% for urban trees. None of the woodland trees, and about 5% of urban trees were classified to low vitality category (Fig. 20).

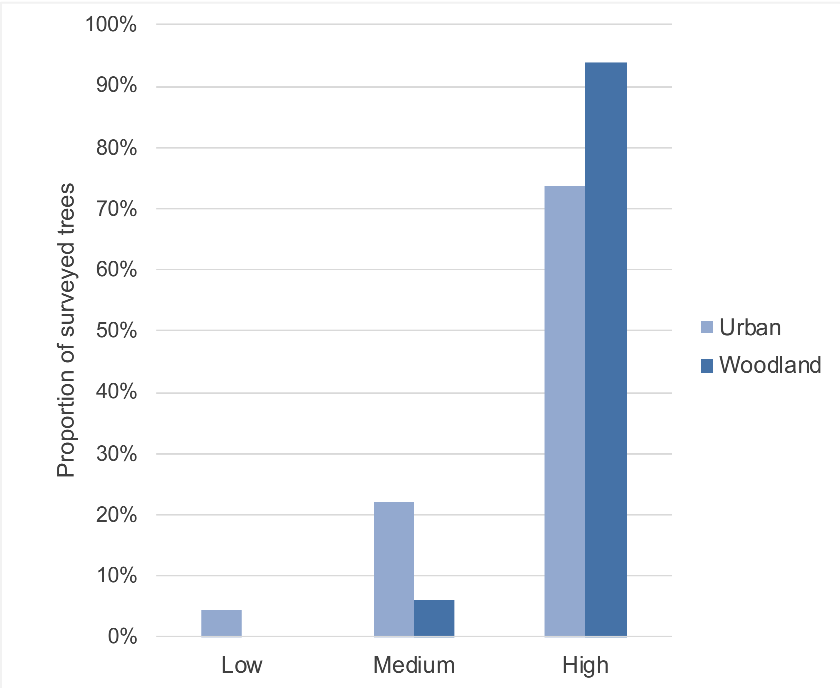

Figure 20. Vitality status (percentage of surveyed trees organized in three vitality classes) of the surveyed Sycamore maple trees in the urban (n=155) and woodland (n=165) settings.

Epiphyte coverage on trees in urban vs. woodland settings

The coverage of epiphytic lichens and bryophytes differed significantly between the trees in woodland and urban areas (p<0,001; Fig. 24, 25). Trees in the woodland settings were evenly classified to coverage classes 2 to 5 (21 to 27% of trees in each group; table 6), whereas majority of urban trees (74.8%) were assessed to have high (51-100%) coverage on their trunks (corresponding percentage for woodland trees was 52.7%).

Table 6. Coverage of lichens and bryophytes on stems of surveyed trees (Acer pseudoplatanus) comparing trees growing in woodlands and urban settings (1=1–10%, 2=11–30%, 3=31–50%, 4=51–70%, 5=71–100%).

Count, Row %	1	2	3	4	5	Total
Woodland	2	40	36	45	42	165
	1,21	24,24	21,82	27,27	25,45	100
Urban	4	25	10	24	92	155
	2,58	16,13	6,45	15,48	59,35	100

In the woodland settings, a trend was observed between vitality and coverage of lichens and bryophytes; the proportion of moderately vital trees increased in the higher coverage-classes, with about 15% of the trees in class 5 having reduced vitality (Fig. 21). It was also observed that while the proportion of lichens appeared to decrease slightly in woodland settings, bryophytes increased (personal observation). However, a non-linear relationship was noted in the trees within the urban settings where the category for coverage by 11-30% included a high proportion of the low vitality trees (Fig. 22).

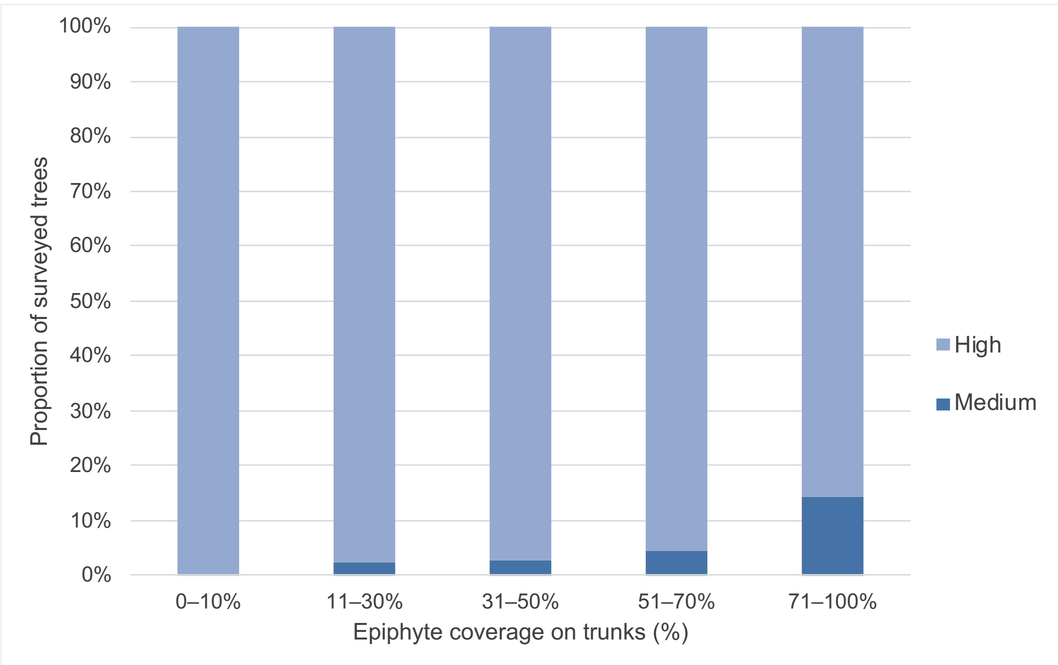

Figure 21. Relationship between vitality and epiphyte coverage on trunks in woodland settings.

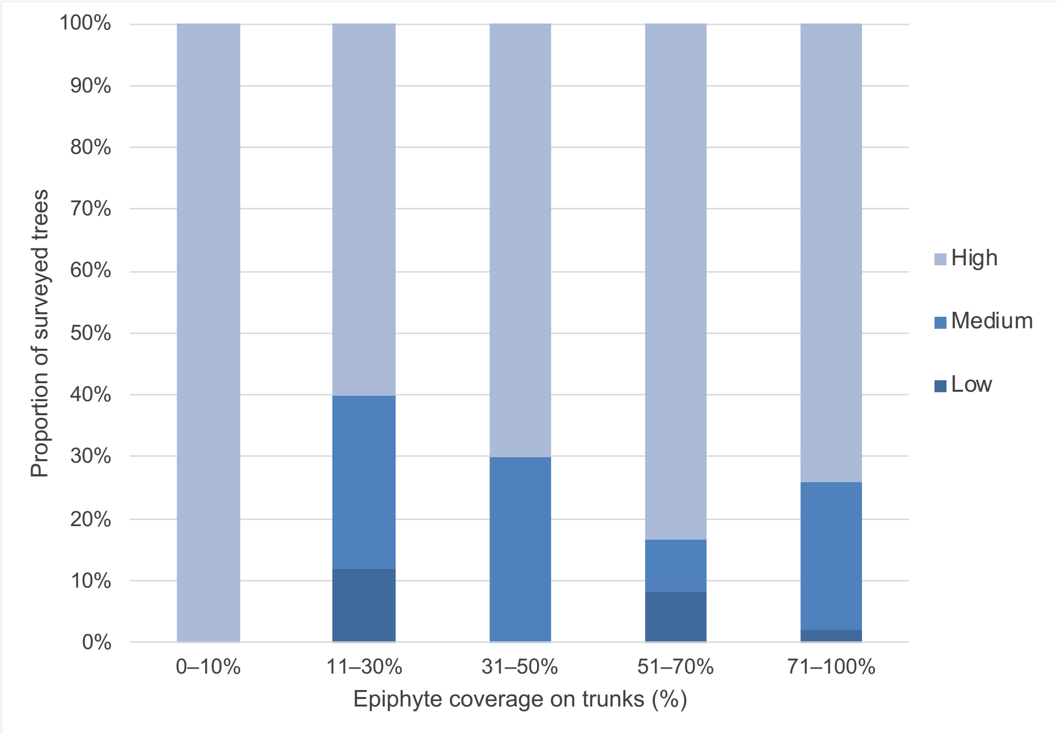

Figure 22. Relationship between vitality and epiphyte coverage on trunks in urban settings.

Over the whole data, the higher epiphyte coverage was found to be exposed to the most variable light exposure conditions (colours, the darker blue the more light exposed tree crown; Fig. 23, 24). A breakdown of the records shows that most of the variation was recorded in urban environments (Fig. 24). Trees with higher epiphyte coverage (class 5) were also found to be exposed to the most variable light exposure conditions.

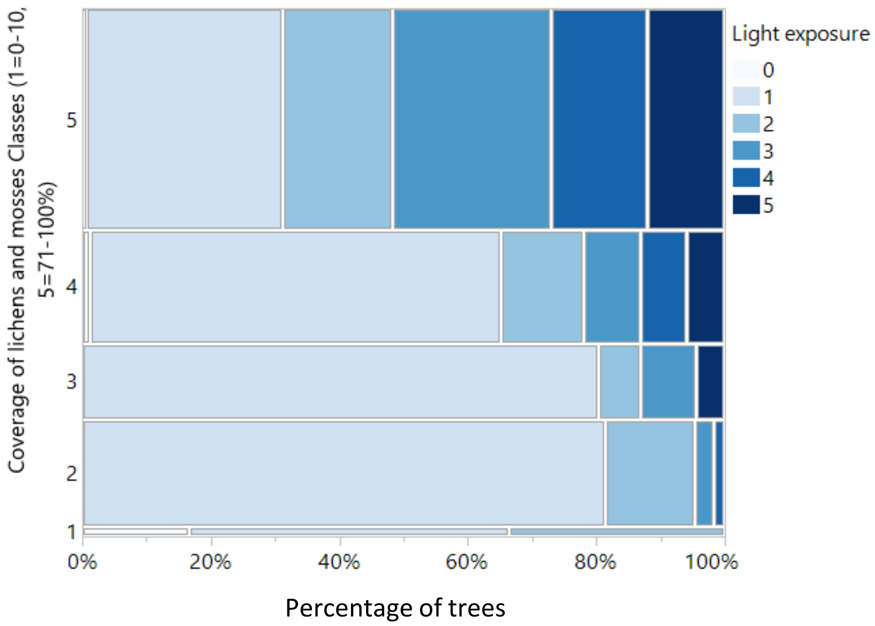

Figure 23. Relationship between coverage of lichens and bryophytes (class 1–5; 1. 0–10%; 2. 11–30%; 3. 31–50%; 4. 51–70%; 5. 71–100%) and light exposure of the surveyed Acer pseudoplatanus crowns (class 0–5; 0 = no sun exposure; 1 = exposure from one side or above; 2 = exposure from two sides or/and above; 3 = exposure from three sides or/and above; 4 = exposure from four sides or/and above; 5 = exposure from four sides and from above).

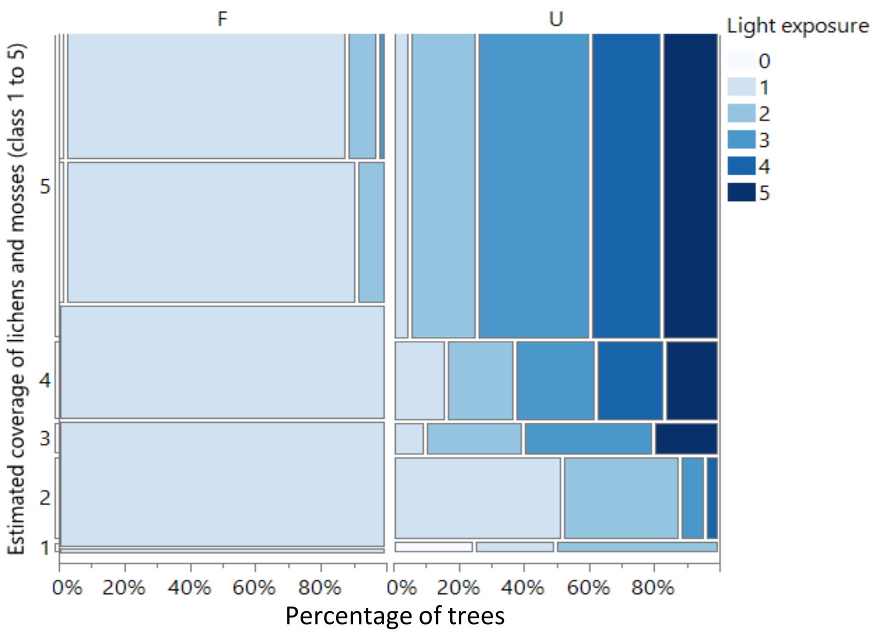

Figure 24. Relationship between coverage of lichens and bryophytes (class 1–5) and light exposure (class 0–5) of the surveyed Acer pseudoplatanus crowns in the urban (U;n=155) and woodland (F;n=165) settings.

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Signs of Cryptostroma corticale and other damaging agents

No signs of *Cryptostroma corticale* (nor symptoms of SBD) or any other pathogen were detected on any of the surveyed Sycamore maples. Within Malmö only one fruiting body was noted on a tree trunk. It was identified based on macromorphology as *Auricularia auricula-judae* (Fig. 25), a basidiomycetous fungus, which is classified as common and reproducing in Sweden.

Figure 25. A fruiting body identified as Auricularia auricula-judae was noted in Malmö on a trunk of a surveyed Sycamore maple. Photo: Karin Pershagen.

Insect damage was commonly found on the surveyed trees (58% of all trees; Fig. 26), and most of the insect-infested trees belonged to vitality class 1 (table 7). Of the urban settings, trees in Malmö appeared to be infested by insects more frequently (51% of surveyed trees) than those in Helsingborg (27% of surveyed trees).

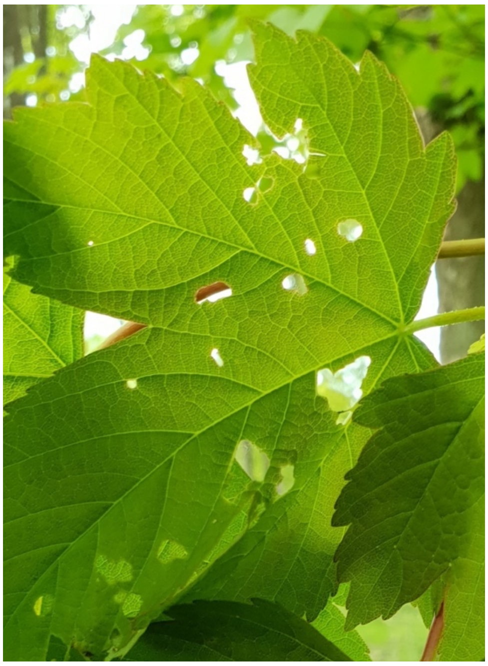

Figure 26. Leaf damage due to insect infestation of a surveyed Sycamore maple. Photo: Karin Pershagen.

Table 7. Presence vs. absence of insect damage on Acer pseudoplatanus leaves in urban and woodland settings by three vitality classes (1=high, 2=medium and 3=low).

Insect damage	1	2	3
Absent	105	27	4
Present	164	17	3

Indicators of environmental/nature values

The presence or absence of some general indicators of environmental and nature values in the study areas and in the surveyed trees was noted. The most commonly observed were bird nests (5%), dead coarse branches (3.4%) and bark-free stem wood (3.2%). Tree species that usually grew in the vicinity of surveyed trees were commonly *Acer* species, but also European Beech (*Fagus sylvatica*), pedunculated Oak (*Quercus robur),* European linden (*Tilia cordata*) and Wych Elm (*Ulmus glabra*) occurred. On the forest floor commonly species occurring were common dog-violet (*Viola riviniana*)*,* yellow archangel (*Lamiastrum galeobdolom* and various grass (Poaceae) species (Fig. 27).

A. B.

Figure 27. Species commonly occurring on the forest floor of the surveyed Sycamore maples in the woodland settings were A: Viola riviniana, B: Lamiastrum galeobdolom. Photo: Karin Pershagen.

6. Discussion

The surveyed Sycamore maple trees were generally evaluated as vital and healthy, but the results provide some support for the hypothesis that Sycamore maple trees in urban settings would show lower vitality, compared with the con-specific trees growing in woodland settings. This could indicate that mature trees in urban environments were growing in an environment with higher influence of stress factors that affected their vitality and way of growing. Urban environments usually place significant demands for trees (Sjöman *et al*., 2016). However, although a higher proportion of the urban trees were found to have lower mean height, their larger circumference and wider crown does not clearly indicate higher environmental stress level on the urban trees. Therefore, another explanation could be the correlation between age and vitality; woodland trees were slightly younger than urban trees. In addition, low vitality trees are often cut during thinning in production stands. More studies are needed to better understand the impact of environmental conditions and possible stressors on the vitality of Sycamore maple trees in different settings.

Contrary to the second hypothesis, the study showed that the trees in the urban settings had a significantly higher coverage of epiphytic lichens and bryophytes compared to trees in the woodland settings. While the taxonomic composition of the coverage was not detailed in this study, this result suggests that urban trees were a good substrate for trunk-dwelling epiphytes' biodiversity. It is possible that part of this may be due to the fact that the study areas' urban environments are covered by a varied light regime in combination with relatively good air quality (personal observation), which supports habitats for epiphytic diversity. It could also be discussed that epiphytic growth is affected by tree age, which in turn is related to coarser bark structure and more time for colonization (Fritz *et al.,* 2009). The older trees in urban areas could provide more and better habitats for epiphytes. Thus, a combination of external and internal factors may have affected the observed patterns in epiphyte coverage.

Interestingly, it was observed that while the proportion of lichens seemed to decrease slightly in woodland settings, bryophytes increased. This could be attributed to the fact that bryophytes are likely to benefit from more shady microclimates while many lichens prefer more light and open environments providing better air quality (Sales *et al.,* 2016). The results also indicated that while the Sycamore maples in woodland settings had a higher coverage of lichens and bryophytes at lower vitality, this phenomenon could not be confirmed as a linear pattern within urban settings. These inconsistent patterns may reflect the complex regulation of epiphytic flora by both environmental and trees' internal traits. Some of the other factors that have been indicated important for epiphyte distribution are, e.g., bark pH, chemistry (including nutrients), temperature and texture (Fritz *et al.,* 2009; Spier *et al.,* 2010 and references therein). While these were not measured in this study, they may have been important drivers behind the observed patterns.

Interestingly, a higher incidence of insect damage was noted in Malmö's green infrastructure when comparing the two urban settings. However, the study finds no explanation for this event, but it could be related to the surrounding environment: the surveyed trees in Helsingborg's urban area were surrounded by adjacent larger buildings and roads with high traffic (personal observation). This may have been a less suitable environment for insect fauna. Part of the insect damage seemed to be caused by sucking insects, aphids. Urban environment may have promoted population growth of aphids. Factors such as climate change and altering temperatures has been discussed for being likely to affect the aphids' occurrence and populations (Mackoś-Iwaszko *et al.,* 2015). However, a recent study showed no signs of clear correlation between aphids' population growth and increasing temperature or precipitation (Senior *et al.,* 2020).

In this study, no signs of *Cryptostroma corticale* were detected in the examined trees. According to previously reported observations from other European countries, there is a clear link between *C. corticale* and various stressors such as elevated temperatures during consecutive days and high levels of pollutants (e.g., Kelnarová *et al.,* 2017; Cech, 2018; Braun *et al.,* 2021). Urban green areas have previously been pointed out to have a higher susceptibility to invasion by pests and pathogens (Santini *et al.,* 2012). This is probably due to their artificial ecosystems, harsher and increasingly globally exposed conditions.

Given the strong evidence that *C. corticale* is closely linked to stressors and climatic factors, the lack of signs of it in the surveyed trees may indicate that the current climatic conditions are less favourable for the pathogen at present. It may also reflect the relatively recent spread of Sycamore maples to the area, pathogens may "catch up" with the invasive species only later, accumulating over time. Admittedly, previous studies have shown that the pathogen has been found in asymptomatic trees (Kelnarová *et al.,* 2017). Thus, there is a probability that it may occur even if it has not yet been detected and reported. Because of the health risks associated with MBD to humans, active monitoring of the disease presence especially in urban areas would be warranted.

Implications for the future of Swedish forests

The case of Sycamore maple in Sweden illustrates some of the multifaceted aspects of globalization and environmental change. While the species is spreading, there is no clear national acceptance for it as a forest tree and it constitutes only a minor component of Swedish forests at present. While some believe that it is an interesting species that provides extra structure, diversity and opportunities for Sweden's nature and industry, others approach the species rather indifferently or see it mainly as a threat to the native nature and which must therefore be combated (Felton *et al*., 2013). The results from this study show that Sycamore maple could be a vital alternative for future, with potential to contribute to the Swedish national environmental quality goal regarding sustainable forests (SEPA, 2021) and also several targets of the UN' Sustainable Development Goal 15 (Life on Land; UN, 2021) in future climate, in particular in urban settings. For instance, it has been shown that Sycamore maple is likely to be relevant in terms of being a viable replacement tree for *Fraxinus* spp. that are suffering of Ash disease (Mitchell *et al.,* 2016). Establishing mixtures with *Acer* species has also been shown to reduce the Ash disease severity at the stand level (Havdova *et al.,* 2017).

Despite the promising potential of Sycamore maple, planting of Sycamore maple entails certain risks of primarily ecological and economic significance. Due to its extensive regenerative ability and good adaptability to grow under different site conditions, Sycamore maple can disadvantage native forest trees and their associated species and be difficult and very costly to control. Active monitoring of its population and development of contingency and management plans are therefore needed to avoid or mitigate risks. In order to minimize the risks and create new conditions for healthy and resilient forests for the future, a constant adaptation of forestry measures and the use of diversified planting material is required. Specific measures and strategies can include planting and establish heterogeneous stands with broadleaved tree species. Future research should focus on exploring the ability of Sycamore maple to support native biodiversity and to contribute to multiple ecosystem services in woodlands and urban environments.

Possible sources of biases in the study

As the study is based on measurable assessments and assumptions based on visible conditions at tree level, a possible source of bias is the human factor. Assessments based on visual cues are bound to be subjective. Other possible sources of bias may be that the surveys were carried out relatively early in the season. Thus, the symptoms or damage from the pathogen may not have developed or become sufficiently visible for detection and identification. There may also have been more or other variables that would have been interesting to study. While the total number of trees in this study was reasonably high (320) it could have been advantageous to study more stands in various silvicultural settings within specific regions. Moreover, the lack of information about the background history of the surveyed trees, such as their provenience, planting and management methods, may obscure a holistic understanding of the results and observed trends.

7. Conclusion

In conclusion, the survey showed that the mature Sycamore trees in southern Sweden are vital and healthy. Although *Cryptostroma corticale* occurs in large parts of Europe, it is not yet observed in Sweden.

The results of this study provide a baseline of the condition, health status and presence of *C. corticale* of Sycamore maples in southern Sweden. For reducing disease prevalence of the pathogen, future surveys and follow-up studies are essential for early detecting of symptoms. Field surveys and mapping of SBD make it possible to trace disease patterns in relation to management strategies to reduce disease prevalence. The baseline in this synthesis may provide guidance for future mapping and early detecting of SBD.

There are several benefits and advantages to accepting Sycamore maple's presence in the Swedish forests. This not least as a replacement tree species of *Fraxinus* spp. and *Ulmus* spp. or as a resistant and vital component in mixtures. Maintaining a diverse flora and fauna contributes to a high forest resilience and sustainability. This can buffer the climate impact and benefit biodiversity in the coming century. The results of the study additionally justify the use and improved acceptance of Sycamore maple in mixed forests under Swedish conditions in more controlled forms. Nevertheless, it is of utmost importance to design strategies for its introduction and management in order to minimize any negative ecological effects.

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10. Appendix I

10.1. Inventory Protocol

The observers name and date	Purpose of the inventory	Location, coordinates (SWEREF99)
Elevation (m above sea level)	Annual rainfall (mm)	Mean annual temperature (°C)

Variables	**Units (quantitative variable) / Categories (categorical variables)**
Scientific name	*Latin*
Estimated age	years
Settings	urban/woodland
Previous land use	1. agricultural land; 2. forested land; 3. field or meadow; 5. urban
Tree height	m
CBH	cm
Diameter of the crown	m
Light exposure	value 0–5 (e.g., a solitaire: 5 = four sides + crown)

Crown, vitality status	1. >80% vital; 2. 20–80% medium; 3. <20% low
Vegetation close to the tree, <5 m	1. herbs; 2. grass; 3. shrubs; 4. conifers; 5. deciduous trees; 6. other
Surrounding environment, <20 m	1. park; 2. roadside; 3. deciduous forest; 4. coniferous forest; 5. felling area; 6. field or meadow; 7. water; 8. buildings; 9. other
Coverage of lichens and bryophytes, <2 m height	1. 0–10%; 2. 11–30%; 3. 31–50%; 4. 51–70%; 5.71–100%
Tree damage (trunk)	1. no visible; 2. pruning; 3. digging; 4. collision; 5. other
Presence of bark injuries, <2m height	presence or absence
Fruit bodies	1. absence; 2. occurs on the ground, adjacent to the trunk of the tree; 3. occurs on the ground, under the crown of the tree; 4. occurs on the trunk of the tree; 5. other
Leaf damage	1. dark spots; 2. mildew; 3. insects; 4. rust; 5.no visible damage
Nature value	1. dead branches; 2. hollow; 3. barkless stem wood; 4. sap flow; 5. bird nest; 6. other no; 7. visible values
Signs and symptoms from pathogens or pests	presence or absence
General comments	