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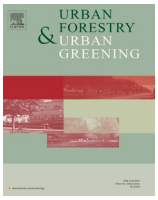

Do we have enough space for the trees we need?

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ABSTRACT

In 2021, two guidelines were introduced with the purpose of increasing cities' tree canopy coverage (TCC): Konijnendijk's 3–30–300 rule, where 30 represents the goal to achieve at least 30 % TCC, and the Swedish Environmental Protection Agency's (SEPA) guideline, aiming for all Swedish cities to increase their TCC by two percentage points (%pts) within a period of 10 years. While these ambitious goals are positive, not least from a sustainability perspective, there is a lack of research on whether these goals are feasible and how to reach them in practice. The overall TCC in Uppsala, Sweden's fourth largest city, is 28 %, with considerably lower TCC in the eastern parts of the city. In this study, we will investigate, and visualise, how a 2 %pts increase as well as 30 % TCC could be achieved in two areas in eastern Uppsala: Fålhagen, a residential area, and Boländerna, a commercial and industrial area. We used geographical information systems (GIS) and a scenario approach to calculate the number of trees needed, and possible locations for them, to achieve a 2 %pts increase or the 30 % TCC goal. The results show that an increase of 2 %pts seems possible in both areas, particularly if the municipality and private property owners collaborate. However, it is difficult to estimate the time needed until the canopies of the proposed trees have become large enough to reach the 2 %pts increase. It does not seem likely to reach 30 % TCC in eastern Uppsala with today's land use. To be able to reach the goals presented in this paper, it seems necessary to include them in municipality policies. Perhaps Konijnendijk's and SEPA's guidelines can be starting points for such policies and applied as rules-of-thumb rather than applicable planning tools.

1. Why more trees in the city?

Cities make up only 3 % of the Earth's entire land surface (Konijnendijk van den Bosch et al., 2019), but as much as 55 % of all humans live in them (UN Habitat, 2020), a number expected to increase (United Nations, 2019). Why should we then try to fit more trees into the cities? The reason is that humans have a huge impact on the planet. The parts we choose to inhabit are often areas with high biodiversity, with many of the largest cities located within what has come to be called biodiversity hotspots (Weller et al., 2019). These cities are expanding, threatening ecosystem services and the habitats of endangered species (ibid.). Old forests are important for biodiversity, but in Sweden they constitute only a small part of the entire forest area, which is mostly used for production purposes (SLU Riksskogstaxeringen, 2023). However, a large part of the oldest woods can be found in or near cities (Hedblom and Söderström, 2007), and several species depend on them for their survival. Urban trees also supply several ecosystem services on a local level, including wind shelter, pollination, fruit production and shading (Dobbs et al., 2019). The latter can lower the temperature and prevent deaths caused by overheating (Lungman et al., 2023). Urban trees can also clean the air from pollutants (Sæbø et al., 2019), which is considered the world's greatest climate-related threat to our health (WHO, 2021). Taken together, urban trees can provide significant benefits for urban dwellers, both human and other species, many of which cannot be provided to the same degree by trees planted elsewhere. With the ongoing densification of cities this becomes an increasingly important subject in need of ambitious goals and methods for how to safeguard trees in cities.

Two guidelines with the goal to increase trees in cities have recently been suggested. The 3–30–300 rule is one of them, where '3' means that everyone should be able to see at least three trees outside their window, '30' means that the tree canopy coverage (TCC) should be 30 % or higher, and '300' indicates that everyone should have a green space within 300 m of their home, school and workplace (Konijnendijk, 2022). The 3–30–300 rule has gained a great deal of interest internationally, and in Sweden it has, for example, been tested in all municipalities in Region Skåne (2023). Even though the 3–30–300 rule is spreading around the world, there is a lack of research on how to best achieve an

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increase in TCC. Numerous tree planting initiatives exist worldwide. Even if these initiatives mobilize financial resources for planting new trees, they are criticised for not following up with stewardship activities (Eisenman et al., 2021; Sousa-Silva et al. 2023) thereby risking the label of unsustainable greenwashing initiatives.

The second guideline is one on a Swedish national level, introduced by the Swedish Environmental Protection Agency (SEPA). It proposes a 25 % TCC as well as an improvement by 2 percentage points (%pts) regardless of the current TCC (Sandberg, 2021). In 2023, Boverket (2023) conducted a mapping of the current TCC of 200 towns and cities in Sweden, which is a great starting point for improvement. Both guidelines wish to see these increases not only on a city level, but down to neighbourhood level, leading to an evenly distributed TCC within cities. Therewith contributing to reduce inequality in access to urban vegetation. This pilot study tests the 3–30–300 rule and the 25 % TCC guideline and discusses how realistic and applicable they are in practice.

2. Current situation in Uppsala

The Swedish city Uppsala was chosen as a case study. It is the fourth largest city in Sweden, located 50 kilometres north of Stockholm. Today, it has a TCC of about 28 % (Uppsala Municipality, 2022b). If it increased its TCC by 2 %pts, Uppsala would also reach the goal of a total TCC of 30 %. The distribution is however very uneven when comparing different districts within the city, with the lowest TCC found in the eastern parts (Fig. 1).

The focus of this study has been on examining the possibility to increase TCC in two eastern Uppsala districts: Fålhagen, with a current TCC of 18 %, and Boländerna, with a current TCC of 6 % (Fig. 1). Even though the areas are located right next to each other, the prerequisites of the two areas differ greatly. Fålhagen is mainly a residential area with single-family detached houses, row houses and three- and four-story apartment buildings. Boländerna, on the other hand, is occupied by industries and shopping centres. Both types of areas are comparable to what is found in numerous Swedish cities. Selecting two areas with distinct characteristics enabled us to examine the functionality of the guidelines across diverse land use contexts. The way Uppsala has been divided, as illustrated in Fig. 1, is based on the Swedish *nyckelkodssystemet* (the key code system), a way of dividing urban areas into smaller districts to be able to account for various statistics (SCB, n.d.). There are, however, other ways of setting boundaries, and this can affect the result of a TCC assessment.

3. Method

Two scenarios were tested for each district. The first scenario examined the possibility of achieving an increase of 2 %pts, while the other focused on reaching a TCC of 30 %. The total area of the districts, as well as their current area of TCC, was provided by the municipality of Uppsala (Uppsala Municipality, 2022b).

The initial step involved calculating the current TCC in percent per district (current TCC, % = (current area of TCC / total area) * 100). Subsequently, estimations were made to determine the required TCC to achieve a 2 %pts increase (TCC goal = ((current TCC, % + 2) / 100) * total area), as well as to reach a 30 % TCC (TCC goal = (30 / 100) * total area). Following this, the necessary increase (desired increase = area of TCC, goal – current area of TCC) as well as the corresponding number of trees needed to achieve such an increase (number of trees = desired increase / m^2 per tree canopy) was determined. An average tree canopy diameter of 8 m (~50.3 m^2) was adopted for our calculations to provide a visual representation of the projected outcome. The GIS software *ArcMap* was used to propose locations for the additional trees. Dots with 8 m in diameters, representing trees, were inserted in orthophotos of the areas.

The criteria employed for selecting tree planting locations were as follows: in the scenario aiming for a 2 %pts increase, half of the trees were situated on public land, and the remaining half on private properties. Additionally, in line with the 3-goal (part of the 3–30–300 rule)

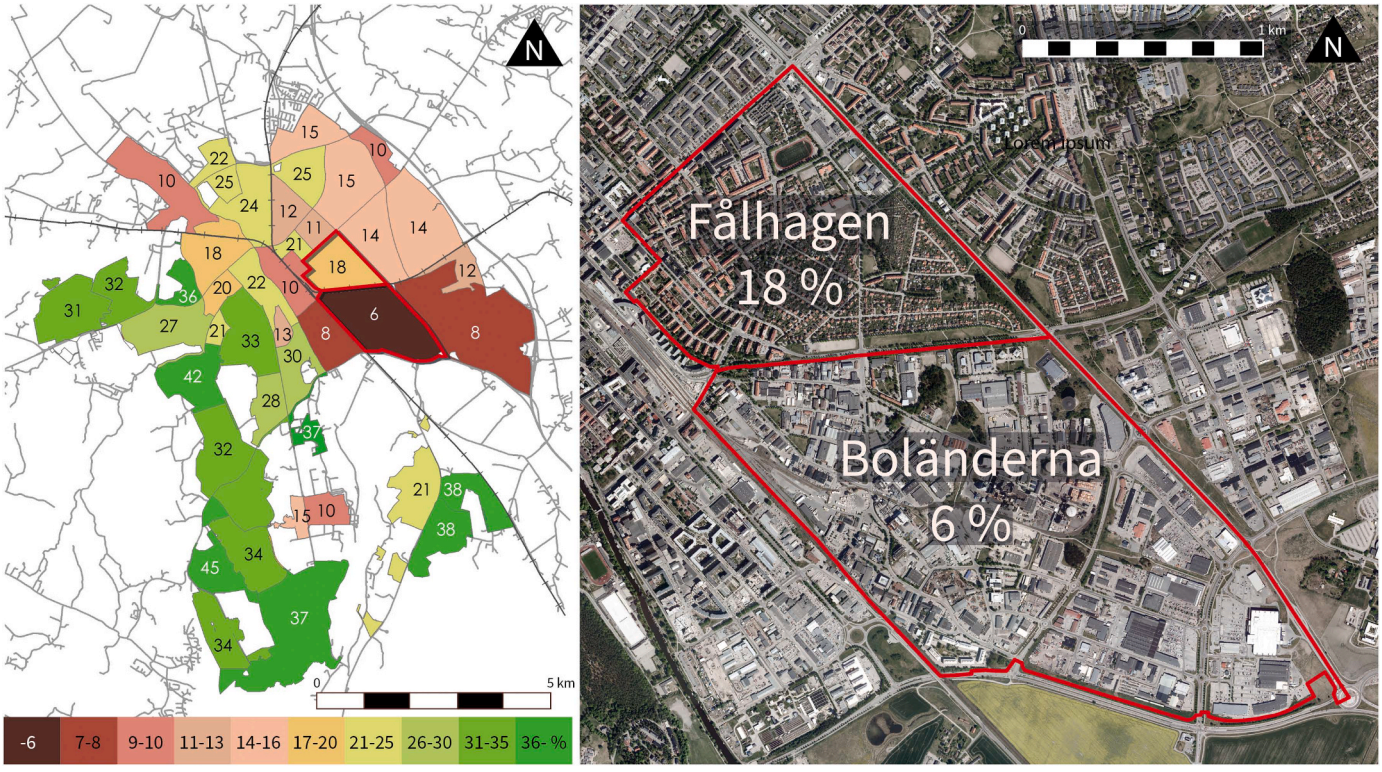

Fig. 1. Current situation in Uppsala. Left: Uppsala's TCC as of 2022, data from Uppsala Municipality (2022a). The two study areas are marked with red borders. Right: the districts chosen as study areas, Fålhagen and Boländerna. Basemap: ©*Lantmäteriet*.

trees were positioned strategically to ensure that, in conjunction with existing ones, every building was surrounded by a minimum of three trees, without other buildings blocking the view. Regarding the 300-goal, existing green spaces were identified and 300 m buffer zones were created around them. To guarantee access to urban greenery within 300 m, priority was given to areas beyond these buffer zones for the addition of new trees. Furthermore, trees were also added along roads and on parking lots, without seemingly interrupting current functions. Additional trees were placed in locations already designated as green spaces but with the intention to enable continued leisure activities demanding a degree of open space.

We set out to apply the similar set of criteria for the 30 % TCC scenario. However, we early on recognized the necessity for exceptions due to the substantial space required for accommodating the large number of additional trees. Instead, the majority of the accessible public areas had to be designated for tree planting. In Boländerna, we also had to suggest some changes in land use. The results of the scenario approach are presented as Figs. 2 and 3 in the *Results* section.

We wish to emphasize that the proposed locations for additional trees in this pilot study serve solely as illustrative examples intended to enhance the reader's comprehension of the requirements for achieving the increases in TCC. No comprehensive site assessments or ground analyses were conducted to ascertain the feasibility of placing the new trees.

4. Results

In Fålhagen, the current TCC is approximately 18 %. An increase of 2 %pts would result in a TCC of 20 %. To achieve 30 %, an increase of 12 %pts is necessary. Fig. 2 shows the current situation in Fålhagen, as well as the number of trees needed to achieve the desired increases.

The top map in Fig. 2 shows the result of proposing the positions of 493 additional trees within the limits of Fålhagen, thus increasing its TCC by 2 %pts. Following the criteria for selecting the tree planting locations, half of these trees (247) have been suggested on private property, including residential yards, schoolyards, and parking lots adjacent to shops and other companies. Fålhagen consists of several smaller residential properties, and one additional tree on a little less than half of the private properties in the area is sufficient to reach 247 trees. The other half, 246 trees, have been placed on public land, which generally means in parks and alongside roads. In Fålhagen, 30 % of the land is public. The southern border of the district is part of a green belt the municipality has expressed an interest in strengthening (Uppsala Municipality, 2016), and several of the trees have therefore been placed along that border. Almost all properties in Fålhagen have a green area within 300 m, and most residential yards contain three or more trees already. Therefore, neither the '3' nor the '300' goal has altered the placing of new trees in any major way.

The bottom map in Fig. 2 shows the 30 % scenario, in which an additional 2864 trees have been added. To fulfil the scenario, several green spaces have been turned into forest patches, and tree rows have been suggested alongside most vehicle roads. An area which is today an open schoolyard with almost no shade has also partially been turned into a forest patch. The same has been done with some of the parking lots in the area.

The current TCC in Boländerna at 6 % is the lowest in all of Uppsala. A 2 %pts increase would bring its TCC up to 8 %. To reach 30 %, which is five times the current TCC, an increase by 24 %pts is needed. Fig. 3 presents the numbers showing Boländerna's current situation, as well as the necessary increases to reach the 2 %pts goal and the 30 % goal, respectively.

In Boländerna, which is nearly twice the size of Fålhagen, 962 trees are needed to achieve a 2 %pts increase. Half the trees have been suggested for public land and the other half for private land. Since the amount of public space is relatively low here (20 %), there are only a few spots available to suggest new trees on public land, with most of the 481 trees being placed alongside roads. The number of private properties is much lower here than in Fålhagen, and the average size of the properties is much larger, and they are hosting companies instead of residential buildings as in Fålhagen. If three additional trees were planted in every private property in Boländerna, 481 trees on private land would be achieved.

As shown in the bottom map of Fig. 3, 11,433 trees are needed to achieve 30 % TCC, and a considerable change in land use is needed for that to become a reality. If trees were to be planted on every lawn, along every road and on every parking lot, it would still not be enough. If several of the estates would be turned from industry sites or shopping centres into forest, there is a possibility that 30 % TCC could be realised. Even if this may not be a realistic situation, we decided to visualise it to show the magnitude of the number of trees needed. Therefore, eight properties were changed into forest. Boundaries for these properties are shown in Fig. 3. The properties were chosen because they have the appropriate size to fit all the trees needed.

5. Discussion

In this pilot study our aim was to calculate and illustrate the number of trees needed to fulfil the goals of Konijnendijk's and SEPA's guidelines. The findings indicate that comprehensive alterations in land use are needed to fulfil the goals. For instance, substantial modifications, such as the conversion of expansive parking lots in Boländerna, along with certain roadways, into parks or forest patches, could be considered if vehicular usage were to decrease.

Boländerna appears to be an especially challenging area in which to achieve the goals, because of its low TCC-starting point and high proportion of private properties. While one might argue that industrial and commercial areas like Boländerna may not require an urgent increase in greenery as residential areas do, it is important to recognize that Boländerna serves as a workplace for a significant number of individuals who spend a considerable portion of their waking hours there. Thus, providing them with opportunities to take a break from work in the greenery, seeing trees outside their window, or encounter trees along their daily commutes to work, seems reasonable. Moreover, there is a risk that such areas could disrupt the essential green connectivity needed to facilitate movement and provide habitat for various species within urban environments.

The 14,297 additional trees needed to achieve 30 % TCC in Fålhagen and Boländerna can be compared to the approximately 500 trees planted each year in the entire municipality. Every new tree does not have to be an expensive specimen from a nursery though. Increased TCC could also be achieved by helping nature grow on its own. For example, micro-forests could be created by using the Miyawaki method, in which seeds or small specimens of native species are planted close together and then allowed to grow as something that in many ways resembles a primeval forest, with many of the accompanying ecological functions (Lewis, 2022). Since this is considered a very fast way of accomplishing large volumes of vegetation, the chances of achieving a 2 %pts increase in only ten years (which is part of SEPA's guideline) are greater, compared to more traditional ways of planting trees in urban settings. It is crucial to find various measures for how to increase the number of trees and therewith fulfil the guidelines. However, such exploration lies beyond the scope of our pilot study; thus, we refer to existing research (e.g. Eisenman et al. 2024). What this pilot study initiates is instead a discussion of to what extent the guidelines are feasible on a local, neighbourhood level. Moreover, it underscores the necessity of collaboration with private property owners.

In Uppsala, private property owners together own a clear majority of the land. It is crucial that citizens are engaged to become aware of the difference their backyards could make when it comes to contributing ecosystem services and increasing biodiversity and green connectivity (Beumer and Martens, 2015). Studies show that people in general have an interest in making environmental improvements but might not know

Fig. 2. Results, Fålhagen. Top: scenario showing a 2-%pts increase, for which 493 trees are needed. Bottom: scenario showing an increase by 12 %pts in order to achieve the 30 % goal. For this scenario 2864 trees have been added. Basemaps: ©*Lantmäteriet*.

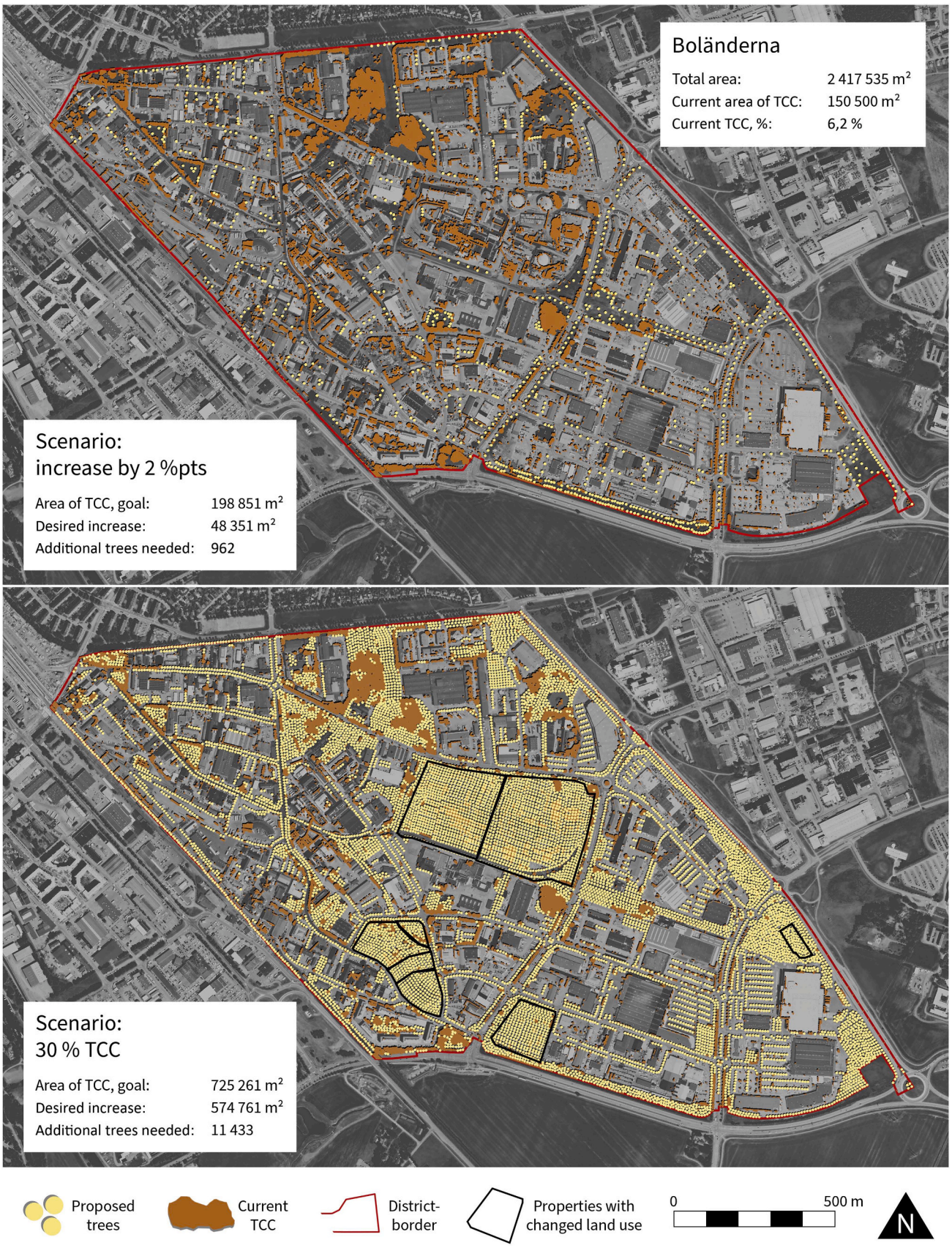

Fig. 3. Results, Boländerna. Top: shows the scenario in which 962 trees have been added, leading to a 2-%pts increase. Bottom: a total of 11,433 trees have been proposed, which would result in an increase by 24 %pts and a TCC of 30 %. Basemaps: ©*Lantmäteriet*.

how to accomplish these (Kollmuss and Agyeman, 2002; Shaw, 2014). Municipalities could encourage private property owners to increase TCC on private land through initiatives such as tree planting campaigns. However, current legislation poses challenges in regulating TCC within private properties, with opportunities mainly existing during the initial stages of planning and design for new developments. This underpins the importance of safeguarding public spaces during the development of new residential and commercial areas. It also stresses the importance of imposing requirements on developers. As demonstrated in this pilot study, once an area has been developed, finding available space for planting new trees becomes notably challenging.

Establishing distinct policies on how to achieve the goals could be an efficient way for a municipality to make a difference, not only in Uppsala but worldwide. Several aspects would have to be defined, including what the goal is, by when it should be achieved, and how it should be measured. These goals risk colliding with other aims, including densification plans, but policies with a holistic awareness can help municipalities to steer clear of such collisions. Even though adaptation for the city in question seems necessary, the results indicate that both Konijnendijk's and SEPA's guidelines could effectively be used as starting points for policies aimed at regreening our cities. Achieving the 30 % goal may seem far away in many places, but taking it 2 %pts at a time is a good way to initiate progress.

CRediT authorship contribution statement

Eric Lund: Writing – original draft, Visualization, Validation, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Helena Nordh:** Writing – review & editing, Supervision, Methodology, Conceptualization.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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