# UpGreen Analysis – Copenhagen's Green Infrastructure for Climate Resilience

Copenhagen is embracing a data-driven approach to urban resilience. Through the UpGreen analysis, the city mapped and assessed over 280,000 trees, uncovering vital insights for greener, cooler and more climate-ready neighbourhoods

Copenhagen is globally recognized for its commitment to sustainability and climate adaptation. A key part of that strategy is urban greenery. The city's trees, parks, and green spaces act as natural air conditioners, carbon sinks, and rainwater sponges, helping mitigate urban heat islands and flooding risk. Urban forestry experts often cite the "3-30-300 rule" as a benchmark for healthy green cities: every resident should see 3 trees from their home, each neighbourhood should have 30% tree canopy cover, and everyone should live within 300 metres of a green space (nbsi.eu). Achieving these targets is not just about planting trees, but ensuring the right trees thrive in the right places. This is where data-driven analysis becomes crucial.

## UpGreen

UpGreen is an innovative analysis framework that supports cities in measuring and managing urban greenery for climate resilience. By combining satellite imagery, AI algorithms, and ecological indicators, UpGreen provides a "health check" for every tree and green area across an entire city. It evaluates how well the urban forest is performing, from canopy coverage to tree health, cooling effect and more, so city planners can make informed decisions. In essence, UpGreen turns raw data into actionable insights: which districts need more trees or parks, which trees are under stress, and how much ecosystem service (like cooling and carbon sequestration) the greenery is providing.

Copenhagen served as a demonstration site to apply the UpGreen analysis. This case study outlines how the UpGreen analysis was conducted for Copenhagen, the challenges it addressed, and the key findings that are guiding the city's greener future.

## Challenge

Like many cities in Europe, Copenhagen faces intensifying climate challenges. It is already experiencing hotter summers, drier spells, and heavier rainstorms due to global warming. Projections indicate average temperatures could rise over 3°C by end of century under high-emission scenarios, bringing more frequent heatwaves above 25°C and longer summer droughts. At the same time, extreme rainfall events are expected to increase, raising the risk of localised flooding in the city's low-lying neighborhoods. Green infrastructure is one of Copenhagen's strongest lines of defense against these climate risks. Trees and parks help cool the city, provideshade during heatwaves, absorb stormwater, and generally improve urban comfort.

However, the city needed better data on the quality and resilience of its trees. Traditional tree inventories might count how many trees are planted, but they don't reveal which trees are thriving versus which are struggling or dying. Prolonged heat and drought can weaken trees over time, reducing their canopy (and thus their benefits) and making them more vulnerable to pests or disease. In a worst-case scenario, entire stands of trees could fail, undermining Copenhagen's climate adaptation goals. City officials identified several critical questions: How healthy and productive are Copenhagen's trees? Which areas have trees under stress from heat, drought or pollution? Where are the gaps in canopy cover

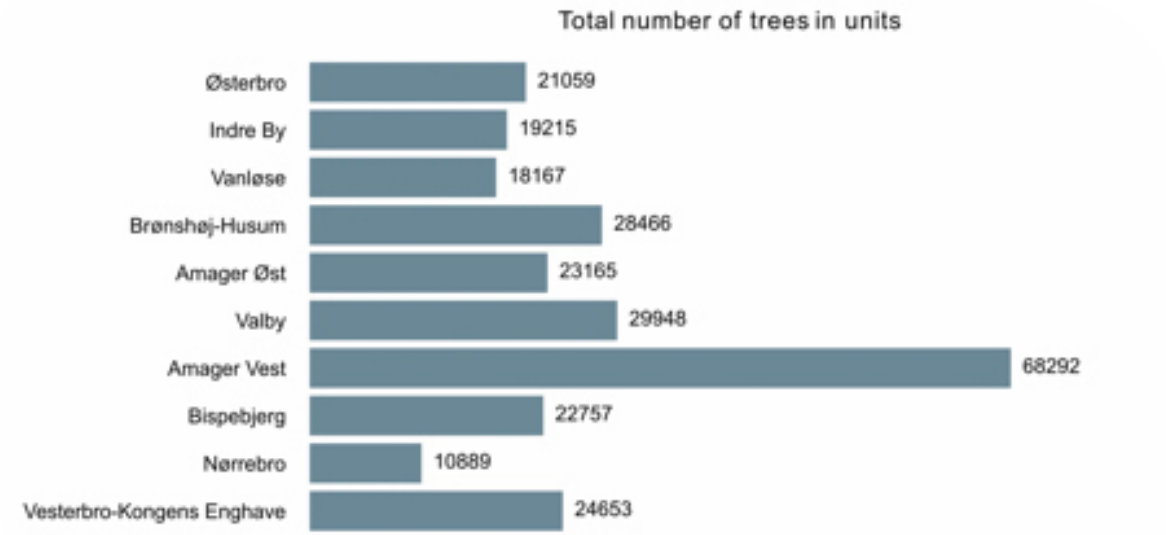
relative to the 3-30-300 targets?

# Solution

To tackle this challenge, Copenhagen partnered with ASITIS to conduct a comprehensive UpGreen analysis – a data-driven "greenery audit" of the entire city. The solution combined high-resolution satellite imagery, advanced machine learning, and ecological analytics into a powerful methodology:

## Satellite-based Tree Mapping:

Satellite-based Tree Mapping: Using recent aerial and satellite images, ASITIS identified and mapped every tree across Copenhagen. A deep learning model (U-Net convolutional neural network) was applied to infrared imagery to automatically detect tree crowns based on their chlorophyll signature. This automated segmentation found even the trees tucked away in courtyards or along streets. To ensure accuracy, only sizable crowns (larger than 30 m²) were counted as trees, and very small shrubs or hedges were filtered out.

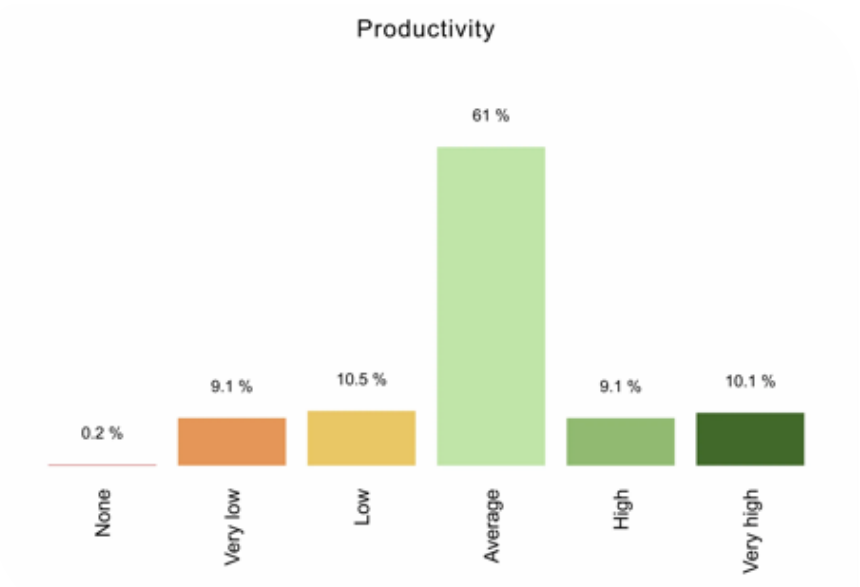



**280 000 trees**

The result was a precise digital map of Copenhagen's urban forest, over 280,000 trees in total, spanning parks, streets, and backyards alike.

# Enhanced Vegetation Index (EVI) – Tree Productivity:

**Beyond mapping tree locations, the UpGreen analysis evaluated the health and productivity of each tree. Satellite data was used to calculate the Enhanced Vegetation Index for every identified tree crown over the growing season. EVI is a spectral index that indicates how 'green' and photosynthetically active a plant is. By integrating EVI over time and normalising by tree size, ASITIS could gauge each tree's chlorophyll content and vigor relative to others. In simple terms, this measures how well a tree is performing its job of photosynthesis and growth. Trees with high productivity have dense, healthy foliage (lots of chlorophyll) and are likely providing strong ecosystem services (cooling, carbon capture). Trees with low or no productivity have sparse or unhealthy foliage,serving as a warning sign that these trees may be in poor health or not growing effectively. Very low productivity can mean a tree is either old, diseased, recently pruned, or otherwise struggling, which in turn means it sequesters less carbon and provides less cooling. By classifying trees into productivity bands (from "Very high" to "None"), the analysis pinpointed which areas have lots of lush green trees and which have many underperforming ones**




***The distribution of trees across the different productivity categories***

# Tree Stress Assessment:

Productivity alone doesn't tell the whole story, so UpGreen also assessed **environmental stress factors** for each tree. ASITIS developed a composite stress index considering three main criteria: **long-term drought, heat exposure**, and **proximity to roads (pollution and disturbance)**, each weighted equally.

This index tapped into climate data and urban form:

**Drought stress:** using metrics like vapour-pressure deficit and rainfall records to see if a tree's location faced frequent dry conditions (e.g. periods of 2+ weeks with minimal rain).

**Heat stress:** using land surface temperature data to flag areas where summer ground temperatures exceeded 40°C for extended days, an indicator of urban heat island hotspots that strain trees.

**Other urban stressors:** using distance from roads and the level of traffic, soil compaction, salt, and limited root space. These factors combined can shorten a tree's lifespan significantly.

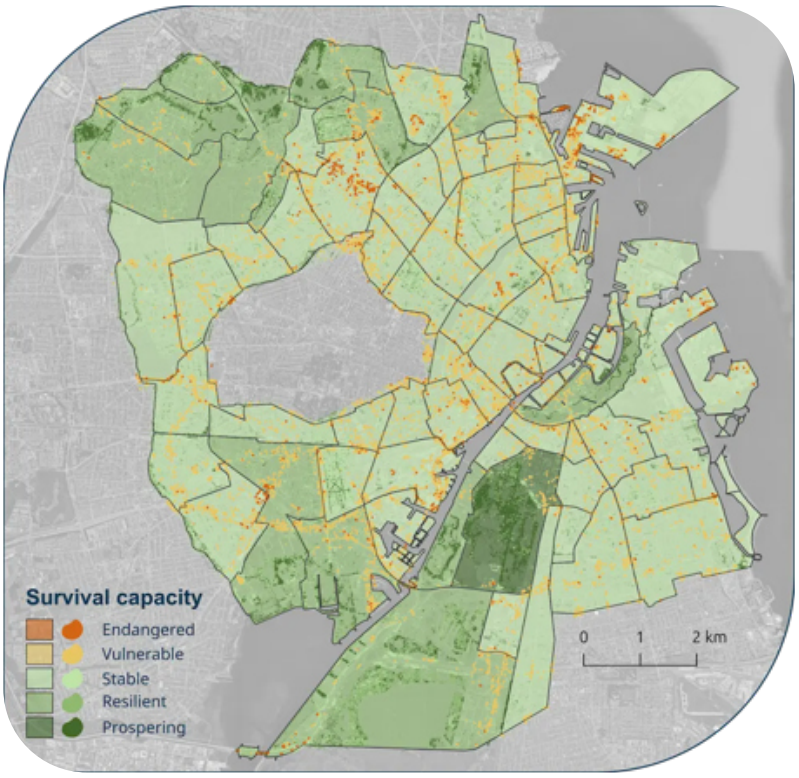

> Each tree in Copenhagen was scored and categorized into stress levels (None, Low, Moderate, High, Extreme) based on this index. Only a small fraction fell into the higher stress categories, which is a testament to Copenhagen's generally healthy environment – but those that did were mostly in known tough environments like busy intersections or industrial areas.

Lenka Foltýnová, Ph.D

ASITIS's lead environmental analyst and Climate Resilience Specialist

# Survival Capacity Analysis:

By examining productivity trends and stress levels together, the UpGreen method estimates each tree's survival capacity – essentially the tree's ability to thrive in the long term if conditions remain unchanged. Trees were classified as Prospering, Resilient, Stable, Vulnerable, or Endangered, reflecting their current vitality and future outlook. For example, an old oak with very low productivity and high stress might be tagged "Endangered" (likely to decline soon without intervention), whereas a young street tree with average productivity and low stress would be "Resilient" or "Stable." This forward-looking metric is crucial for planning renewal: areas with many Vulnerable or Endangered trees will need replanting or extra care in coming years.




Average survival capacity categories within administration units.

# Ecosystem Services – Cooling & Carbon:

Finally, ASITIS quantified two of the most valuable ecosystem services provided by Copenhagen's trees: their cooling effect on urban microclimate and their carbon sequestration. Using the productivity data and tree size, the team estimated how much each district's trees contribute to cooling through shade and evapotranspiration (in °C of temperature reduction), and how much $CO_2$ they collectively store (in tonnes). These estimates were aggregated by neighbourhood (Copenhagen's administrative "Bydel" units) for a strategic overview. The analysis effectively put numbers to nature's benefits, something city economists and planners can factor into budgets and climate accounts.

| Bydel | Cooling (°C) | Sequestration (t $CO_2$) | Trees in u |
|---|---|---|---|
| Østerbro | 0.03 | 1055 | 21059 |
| Indre By | 0.04 | 1029 | 19215 |
| Vanløse | 0.09 | 866 | 18167 |
| Brønshøj-Husum | 0.13 | 2061 | 28466 |
| Amager Øst | 0.05 | 754 | 23165 |
| Valby | 0.14 | 1640 | 29948 |
| Amager Vest | 0.19 | 4498 | 68292 |
| Bispebjerg | 0.15 | 1428 | 22757 |
| Nørrebro | 0.10 | 562 | 10889 |
| sterbro-Kongens Enghave | 0.11 | 1122 | 24653 |

Cooling effect and carbon sequestration of trees in Bydel units, Copenhagen.

The inclusion of the 3-30-300 principle as a guiding framework ensured that the analysis remained focused on actionable outcomes (like increasing canopy where it's below 30%, or identifying spots that lack access to green space within 300 m).

# Key Findings and Numbers

The UpGreen analysis yielded a wealth of data, painting the most detailed picture ever of Copenhagen's urban greenery. **Key findings include:**

- Citywide Tree Count: A total of 280,192 individual trees were mapped and analysed across Copenhagen.

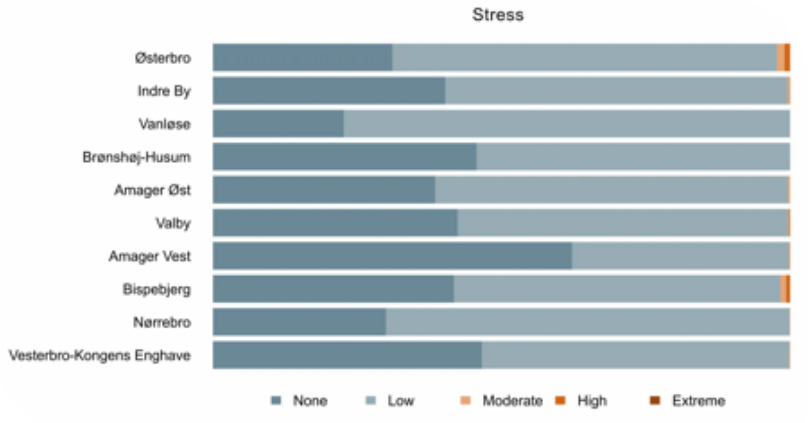
20%

Approximately **20%** of Copenhagen's trees were found to have **below-average productivity**, meaning they have relatively little chlorophyll (and thus are growing poorly) for their size. Within this group, roughly half (about **10% of all trees**) showed **very low or essentially no productivity**, indicating severe underperformance. These low-vitality trees provide only limited ecosystem services and are at risk of **premature mortality under stress.**

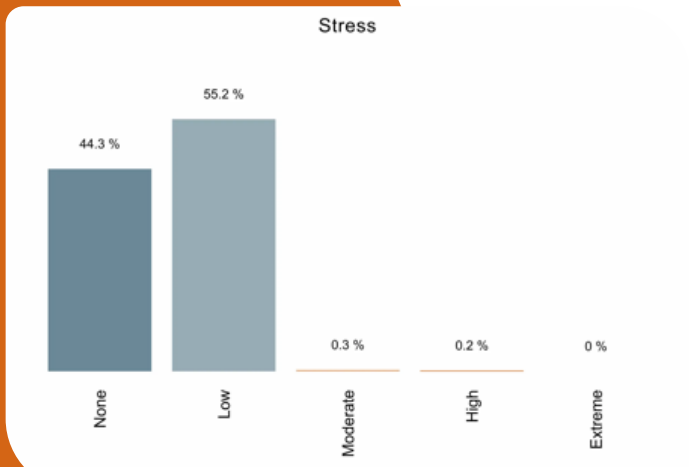
- Around **40%** of trees were classified as highly **prospering or resilient**, with strong growth and good health. The remaining trees were "stable" or moderate in productivity. This mixed profile suggests that while the majority of Copenhagen's urban forest is doing well, a significant minority is struggling, often older trees or those in poor conditions. In areas with clusters of low-productivity trees, the city may need to invest in measures like targeted feeding, mulching, or **irrigation during dry spells** to boost tree vitality.

## Stress Levels

Encouragingly, the data showed that **severe environmental stress is relatively rare** for Copenhagen's trees. Only **0.48%** of all mapped trees, roughly 1 in 200, are growing in locations with **elevated stress levels** (high or extreme composite stress). That amounts to just over **1,300 trees** citywide facing the toughest conditions, such as hot, dry microclimates or heavy pollution. Of those, about 36% (around 480 trees) are in the **high or extreme stress** category, meaning they likely experience multiple compounding stressors. These tend to be concentrated in a few known hotspots, for example, parts **of Bispebjerg (Nordvest)** and **Østerbro (Nordhavn)** were identified as having the highest levels of tree stress.




Relative distribution of stress categories within administration units

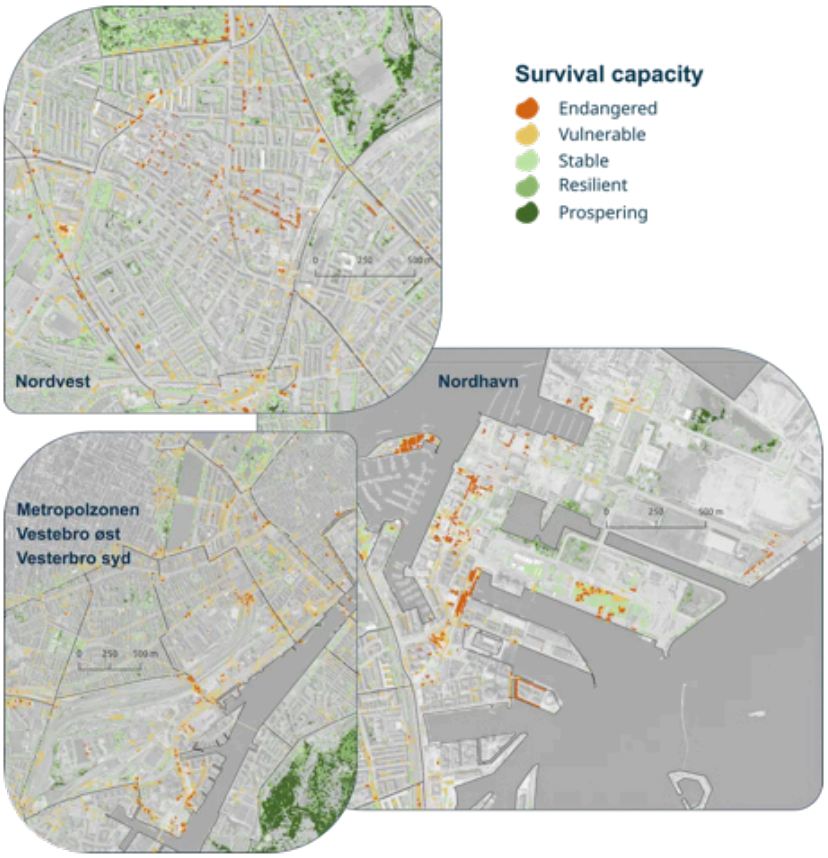


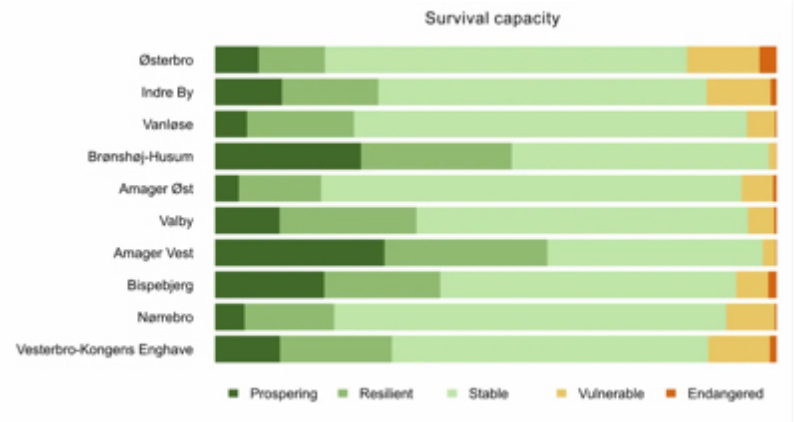

The distribution of trees across the different stress categories

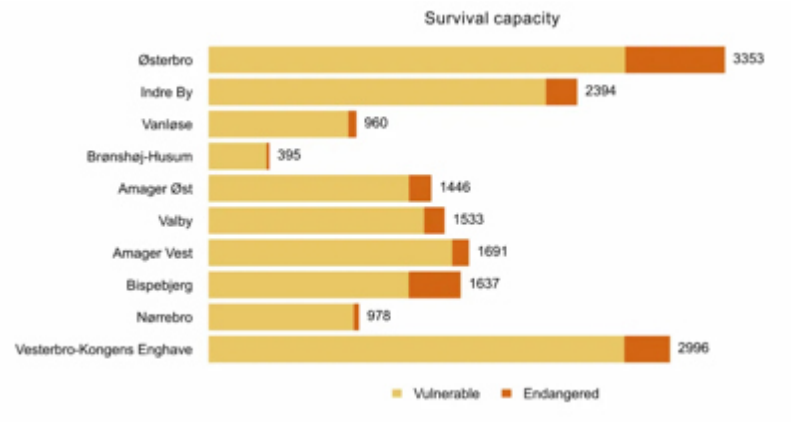
The vast majority of trees, however, are in **low-stress environments,** thanks to Copenhagen's ample parks and generally clean air. This finding highlights areas of success (most of the city provides good conditions for trees) while flagging the specific neighbourhoods where tree stress mitigation (like improved watering or soil measures) should be prioritized.

# Vulnerable and Endangered Trees:

By combining the productivity and stress insights, ASITIS identified 18,563 trees (6.6% of the total) that are in "Vulnerable" or "Endangered" status. These are the trees likely to struggle or decline in coming years if nothing is done. In contrast, about 39% of trees (over 108,000) were rated as doing well (Prospering/Resilient) and likely to survive without intervention. The remaining ~54% were in a middle "Stable" category. The spatial distribution of vulnerable trees was uneven: some districts have many more at-risk trees than others. Østerbro and Indre By (the Inner City) emerged as critical zones in this respect. Each of these central districts has over 2,000 trees classified as vulnerable or endangered, representing more than 10% of their trees, the highest shares in the city. Another district, Vesterbro–Kongens Enghave, also fell into this category of concern with a similarly high proportion of struggling trees. It's notable that these areas are all dense urban environments with limited green space; Østerbro and Indre By also have the lowest tree densities (trees per hectare) in Copenhagen. In Østerbro, in particular, many existing trees are both few and stressed, meaning their lifespans are likely shortened, making Østerbro arguably the most problematic area for urban greenery in the city.

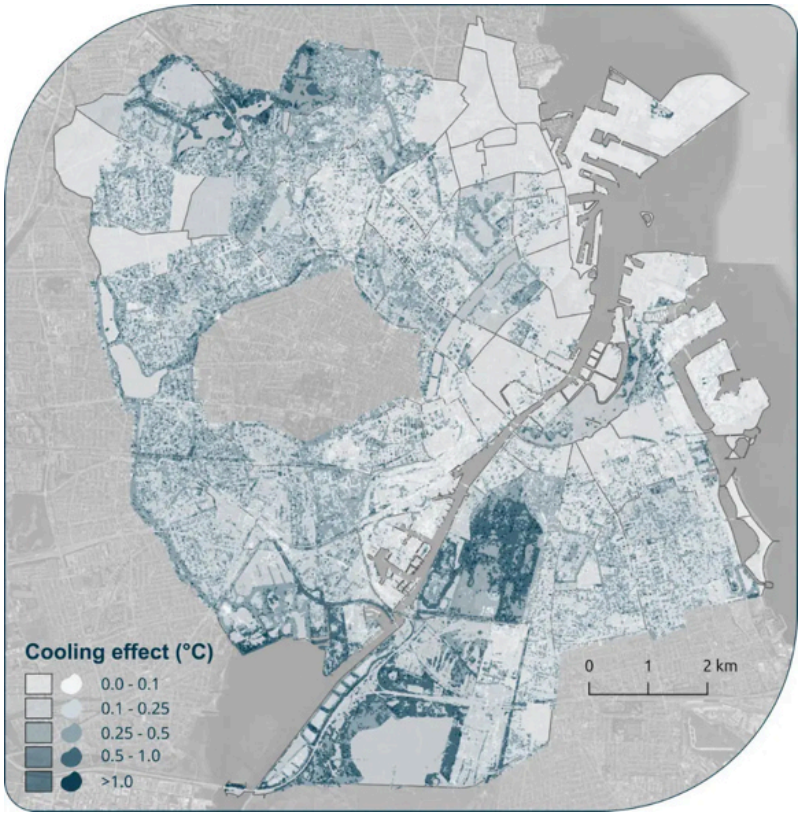





**Survival capacity in areas with the highest number and concentration of trees in "Vulnerable" and "Endangered" categories.**

# Cooling Effect of Trees:




**The UpGreen analysis put numbers to the urban cooling provided by Copenhagen's trees. Citywide, the collective transpiration and shading from trees can lower summer air temperatures, but the effect varies greatly by district. For example, in leafier residential districts like Amager Vest, the trees were estimated to provide up to 0.19°C of cooling on average. Amager Vest also has the largest number of trees (~68,000) contributing to this effect. By contrast, central, less-green districts like Østerbro and Indre By showed only about 0.03–0.04°C of average cooling from their trees. In essence, there simply aren't enough trees in those areas to materially cool the environment, which aligns with residents' experiences of hotter streets in the city core. Although these temperature differences may seem small, they are significant in human terms. A one-degree reduction in air temperature can translate to a perceived cooling of up to ten degrees in felt temperature. The analysis also pinpointed several sub-district "hot spots" with virtually no cooling benefit, for example parts of outer Østerbro like Nordhavn showed less than 0.01°C tree cooling.**

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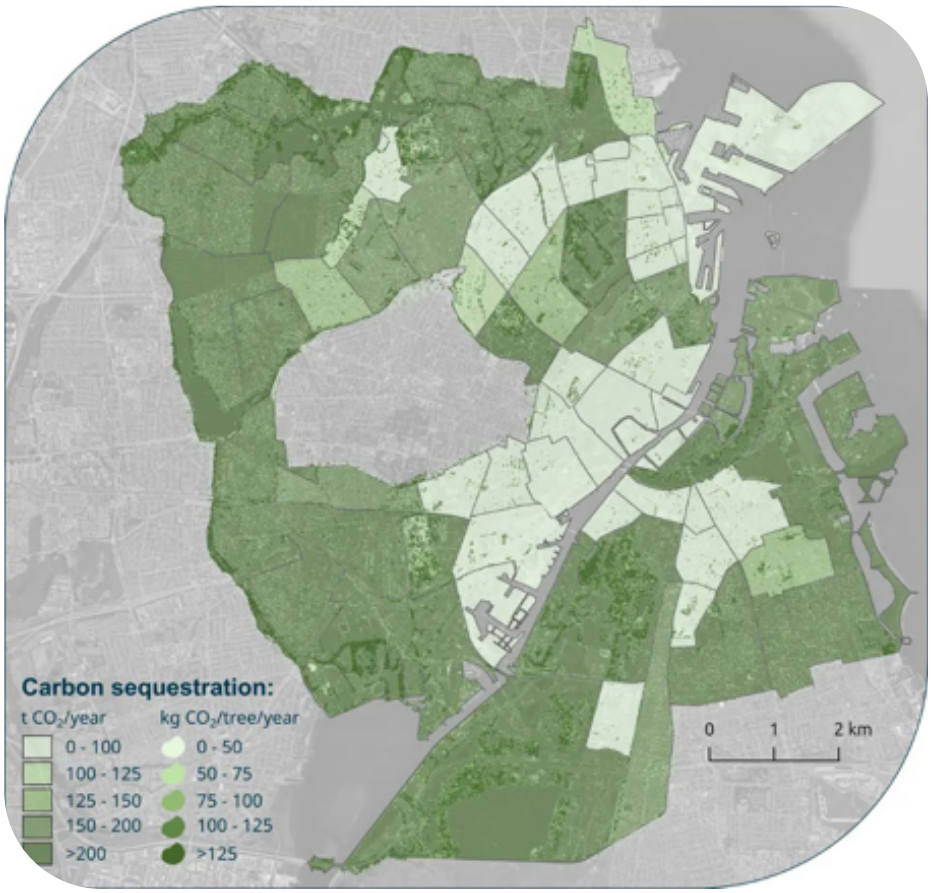


Hand in hand with cooling, the **carbon storage and sequestration** by Copenhagen's urban forest was quantified. Healthy trees absorb $CO_2$ as they grow, helping offset emissions. The analysis found that districts with more or bigger trees unsurprisingly store more carbon. For instance, the trees in Amager Vest (which include some large parks) can store roughly **4,500 tonnes of $CO_2$,** the highest of any district. Meanwhile, Østerbro's smaller urban forest holds only about **1,055 tonnes** – reflecting both fewer trees and likely smaller average tree sizes there. Citywide, the thousands of trees contribute substantially to carbon management, but again the central and northern neighbourhoods lag behind in this ecosystem service. The **city centre's low carbon sequestration capacity** is a direct consequence of having fewer and weaker trees. This finding provides a quantitative rationale for planting more trees in Copenhagen's dense areas: not only would it beautify and cool the city, it would increase carbon capture in line with climate goals.

## Overall results

**Most trees are healthy, stress is generally low, and tangible cooling and carbon benefits are being delivered.** Yet the analysis also uncovered clear disparities: certain districts (especially historic and inner-city zones) have a double deficit of quantity and quality in their urban forest. Fewer trees, and a higher fraction of those trees in poor condition, means these areas are more vulnerable to heat, floods, and the loss of ecosystem services. **Østerbro** exemplifies this, having both the sparsest tree cover and the most trees likely to die off soon.

# Impact and Recommendations

**The impact of the UpGreen analysis for Copenhagen is two-fold: it provides an immediate evidence base for action in Copenhagen, and it serves as a model for other European cities aiming for greener, more resilient futures.**

## Using Results to Renew Green Infrastructure

**Copenhagen can now strategically use these findings to renew and enhance its green infrastructure. With a map of all 18,563 vulnerable trees, urban foresters know exactly where the next tree losses are likely to occur if nothing is done. The city can plan ahead to replace those trees (or nurse them back to health if possible) before the hottest summers hit.**

**For example, Østerbro's high-risk trees could be pre-emptively supplemented with new plantings, focusing on drought-tolerant, heat-resilient species as recommended in the analysis.**

**Likewise, Indre By's low canopy cover could be improved by planting in every possible spot, even if space is tight, measures like pocket parks, curbside tree boxes, or green roofs and facades can add incremental greenery.**

Crucially, the data on **cooling effect and tree density** helps prioritize neighborhoods for greening investments. Copenhagen can see that boosting canopy in Østerbro, Indre By, and certain northwest districts would yield the greatest marginal gains in cooling (since those currently have the least). Planting shade trees along streets and open squares in those areas will help reduce urban heat islands. Similarly, increasing tree cover in low-canopy districts moves the city closer to the "30% canopy" goal of the 3-30-300 rule, which in turn improves citizens' well-being. The city can set specific targets, like "add 5,000 new trees in Østerbro by 2030" or "achieve 20% canopy cover in Indre By," and track progress using the UpGreen data as a baseline.

The **carbon sequestration insights** also strengthen the case for urban forestry as part of Copenhagen's climate mitigation strategy. While the city is focused on cutting emissions through energy and transport initiatives, preserving and expanding the urban forest is a complementary strategy – essentially a nature-based carbon sink. By quantifying $CO_2$ uptake, the analysis allows planners to factor trees into the city's carbon accounting and climate commitments.

## Protecting and Optimising Ecosystem Services:

Beyond planting, the UpGreen findings guide better maintenance and protection of existing green assets. Trees identified with low productivity but not high stress might be suffering from issues like nutrient deficiency or mild disease; these can often be remedied with improved tree care (fertilisation, pruning, pest control). The city's park management can allocate more resources to such trees to boost their productivity and extend their lifespans. For trees in high-stress spots (like those 1,300 in heat/pollution hotspots), measures such as installing tree pits that capture more rainwater, reducing nearby pavement, or adding shade for young saplings could alleviate some stress. Copenhagen is already known for innovative water management (e.g. its "sponge city" approach to cloudbursts); integrating tree health into those plans – for instance, ensuring street trees get enough water during droughts via rainwater harvesting –

Furthermore, the analysis underscores the importance of species selection and diversity for future plantings. Not all trees handle urban stressors equally. The data can be cross-referenced (if the species are known) to see which types of trees in Copenhagen tended to have higher stress or lower productivity. This could inform a shift towards species that performed well. As climate conditions shift, Copenhagen may introduce more southern European species that tolerate heat, or hardy native species known for resilience. A diverse urban forest also supports biodiversity, providing habitat for birds and insects, which aligns with Copenhagen's broader environmental goals.

# Conclusion

Copenhagen's UpGreen analysis is a prime example of moving "from analysis to action." By thoroughly understanding the state of its urban greenery, the city is now equipped to make smart, targeted decisions to enhance climate resilience. The 3-30-300 rule provided a clear vision, and the data provided the roadmap to achieve it. From this point forward, every new tree planted, every park upgraded, and every policy made for urban nature can be backed by evidence. Copenhagen can monitor its progress – are fewer trees "vulnerable" next year? Is canopy cover increasing? Are more citizens within 300 m of a park?

Our message to cities everywhere: we must act now to prepare for the climate of tomorrow, and with the right data, we are ready. The Copenhagen case study shows that even in a leading green city, there is always room to improve and that improvement starts with understanding the current situation in detail.