Interreg CENTRAL EUROPE

Co-funded by the European Union

CONE

Heat stress mitigation

CONE – 2nd Workshop - Training of trainers

ONLINE | 11 of April 2025

Presenter: Marzena Suchocka

https://www.architectureanddesign.com.au/news/how-trees-can-mitigate-heat-in-urban-ecosystems#

https://ehs.research.uiowa.edu/occupational/heat-stress

Heat stress

„Heat stress occurs when the body cannot get rid of excess heat. When this happens, the body's core temperature rises, and the heart rate increases. As the body continues to store heat, the person begins to lose concentration and has difficulty focusing on a task, may become irritable or sick, and often loses the desire to drink. The next stage is most often fainting and even death if the person is not cooled down."

Heat stress- TYPES

HEAT RASH

Symptoms

- Clusters of red bumps on skin
- Clusters of red bumps (often appears) on neck, upper chest, folds of skin

First Aid

- Work in a cooler, less humid enviroment
- Keep the affected area dry

https://ehs.research.uiowa.edu/occupational/heat-stress

Heat stress- TYPES

HEAT CRAMPS

Symptoms

- Muscle spasms
- Pain
- Cramps occur during or after working hours

First Aid

- Rest in shady, cool area
- Drink cool water
- Wait a few hours before you return to strenous work

https://ehs.research.uiowa.edu/occupational/heat-stress

Heat stress- TYPES

Symptoms

- Cool, moist skin, heavy sweating
- Headache, dizziness, weakness
- Nausea or vomiting
- Irritability, fast heart beat

First Aid

- Rest in shady, cool area
- Drink cool water
- Cool with cold compresses
- Don’t return to work

https://ehs.research.uiowa.edu/occupational/heat-stress

HEAT EXHAUSTION

Heat stress- TYPES

Symptoms

- Confusion
- Fainting, very high body temperature
- Excessive sweating or red, hot, dry skin

First Aid

- Rest in shady, cool area
- Drink cool water
- Cool with cold compresses
- Don’t return to work

HEAT STROKE

https://ehs.research.uiowa.edu/occupational/heat-stress

Heat stress- workers

- German research (WWF/KIW) shows that office workers still function to their **full capabilities at 23°C**. At 30°C, they only function at **70%**. It is an established fact that at 30°C typing speeds drop by half compared with 20°C. For physical labour, a **50%** drop in performance is given for temperatures of more than 30°C.

- Trees and vegetation have a cooling effect on the climate of the town or city: the shade they provide means that less sunlight hits the ground and the moisture evaporating from their leaves absorbs heat. In the shade of a tree, only **10-30%** (depending on the species of tree) of the sunlight reaches the ground in the summer. Various studies conducted in the United States have also measured that **walls** standing in the shade of trees heat up by an average of **20°C less**.

https://www.urbangreenbluegrids.com/heat/#heading-7

https://www.sustainability-times.com/clean-cities/lots-of-trees-can-help-keep-cities-cooler-in-summer/

Heat stress- hot nights

- Climate change increases hot days by a similar amount for both urban and rural situations. **However, rural and urban increases differ significantly for the frequency of hot nights**. While Beijing as a rural surface has **14** additional hot nights, the urban surface has **26** additional hot nights and a further 15 hot nights, resulting in a total of 42 hot nights in Beijing for the future climate.

- In Lagos hot nights reach **153** per year compared to **81** for the rural situation.

https://theconversation.com/can-trees-really-cool-our-cities-down-44099

https://www.researchgate.net/publication/228458273_Climate_Change_in_Cities_Due_to_Global_Warming_and_Urban_Effects

What is

the significance of green infrastructure, especially trees,

for the heat island mitigation and water management,

as well as improving the living conditions and the health of the city dwellers?

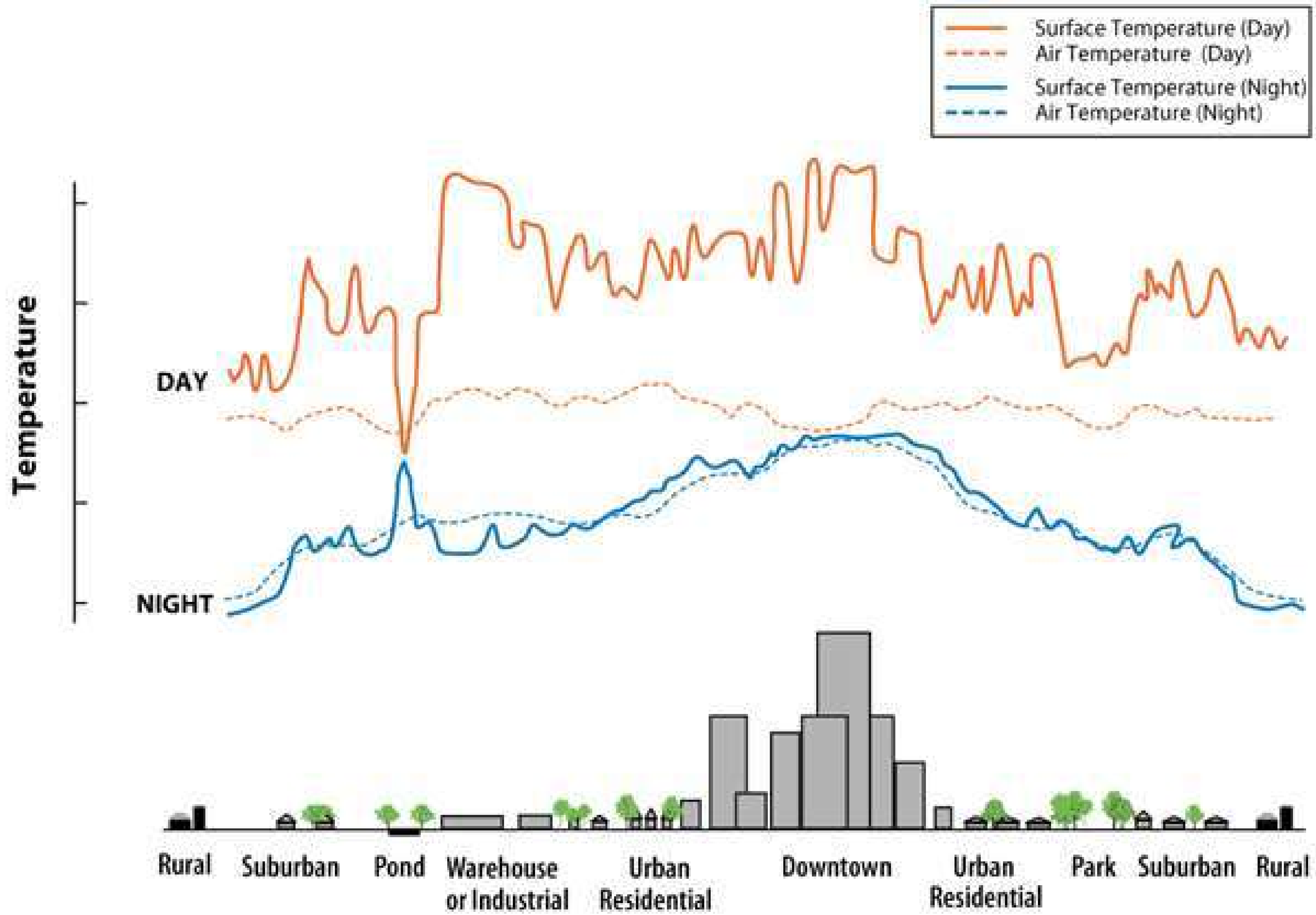
Did you know that:

In Atlanta, by planting 5,000 larger trees (trunk diameter 30 cm)

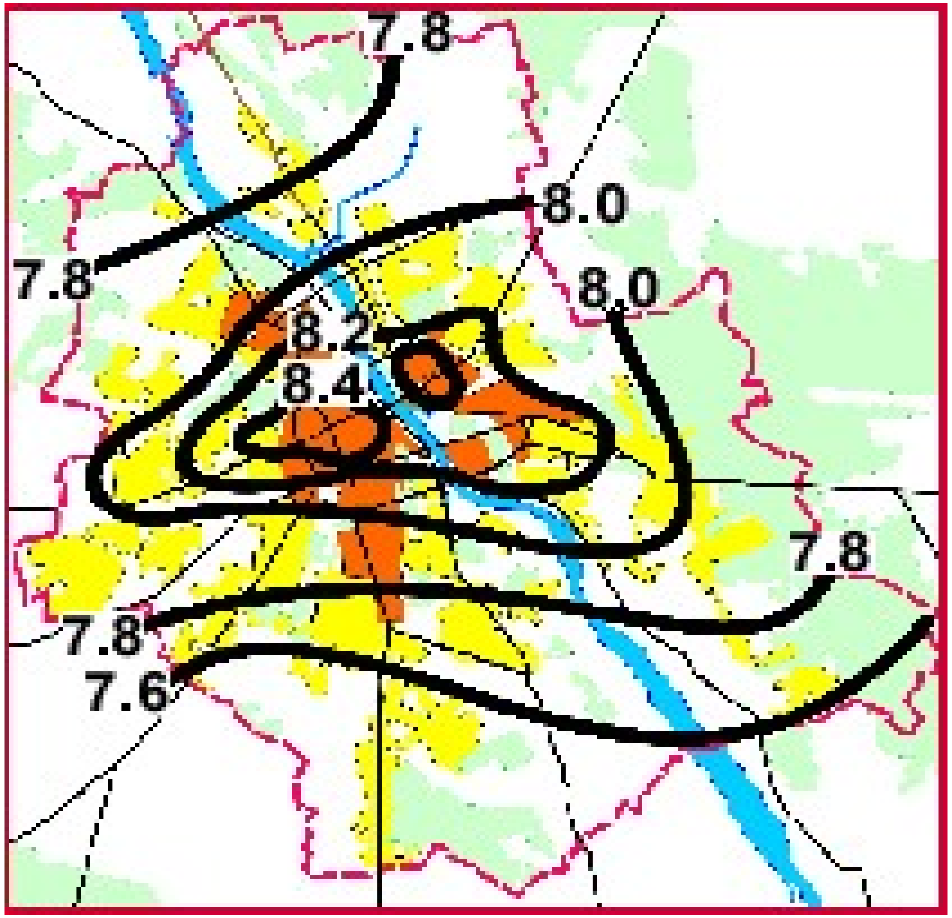
and 60,000 smaller ones (trunk diameter 7 cm),

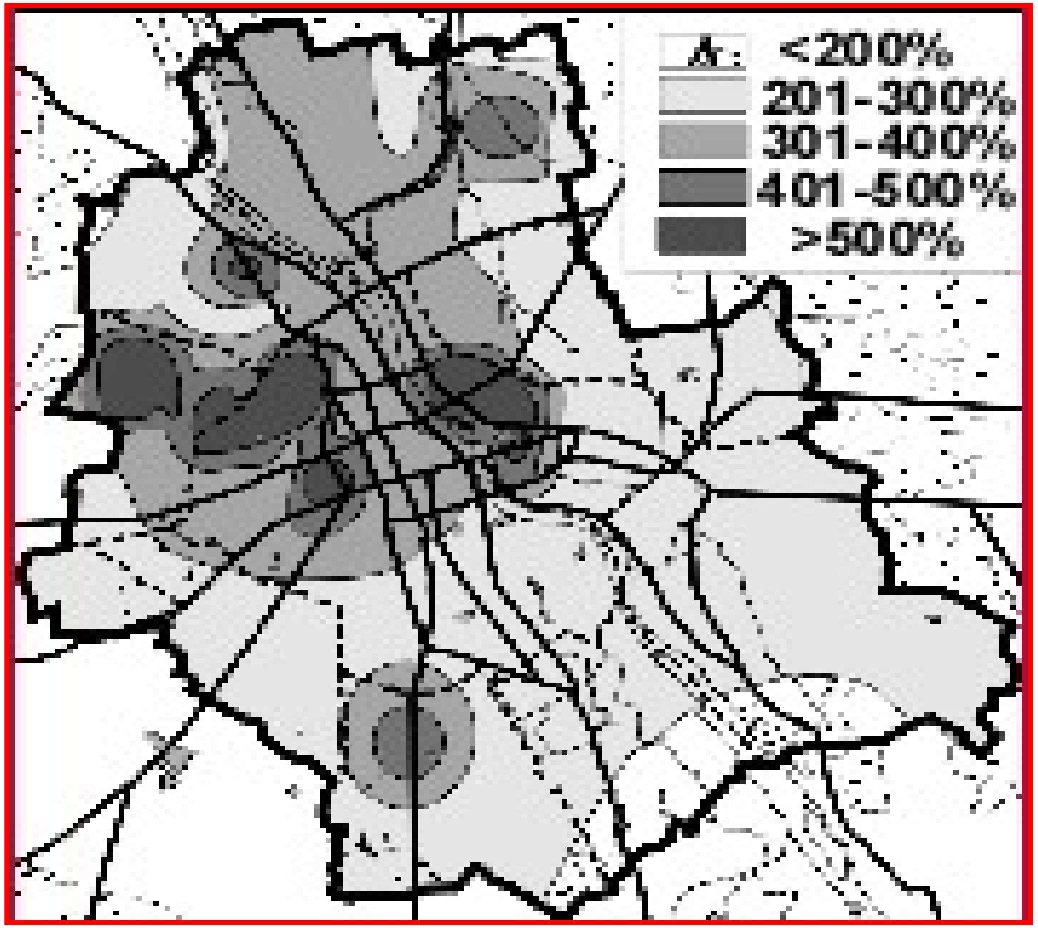
reduced heat islands by 1/3, which translated into significant economic effects in terms of energy savings for space cooling.

The trees mitigates the air temperature


Surface Temperature (Day)
Air Temperature (Day)
Surface Temperature (Night)
Air Temperature (Night)
Temperature
DAY
NIGHT
Rural
Suburban
Pond
Warehouse or Industrial
Urban Residential
Downtown
Urban Residential
Park
Suburban
Rural

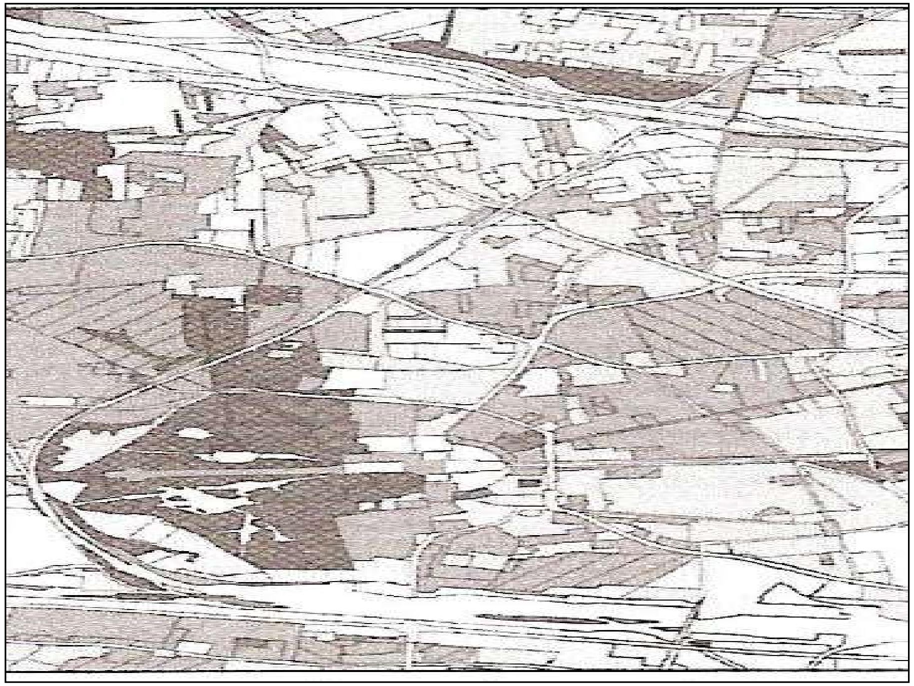
Urban Heat Island i Warszaw





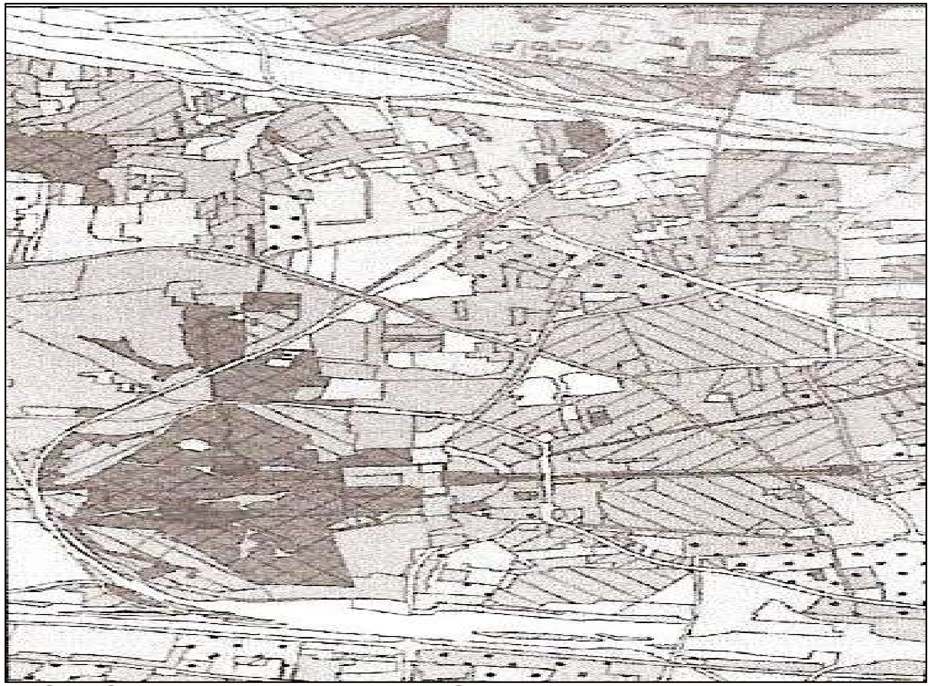
There is a close relationship between the increase in temperature and the amount of atmospheric air pollution increases by 10% for every 5% increase in temperature over 24 oC (Botkin et al. 1997).

Relationship between canopy cover and surface temperaturedata from Munich (Tyrvainen,2005 za Pauleit i Duhme)



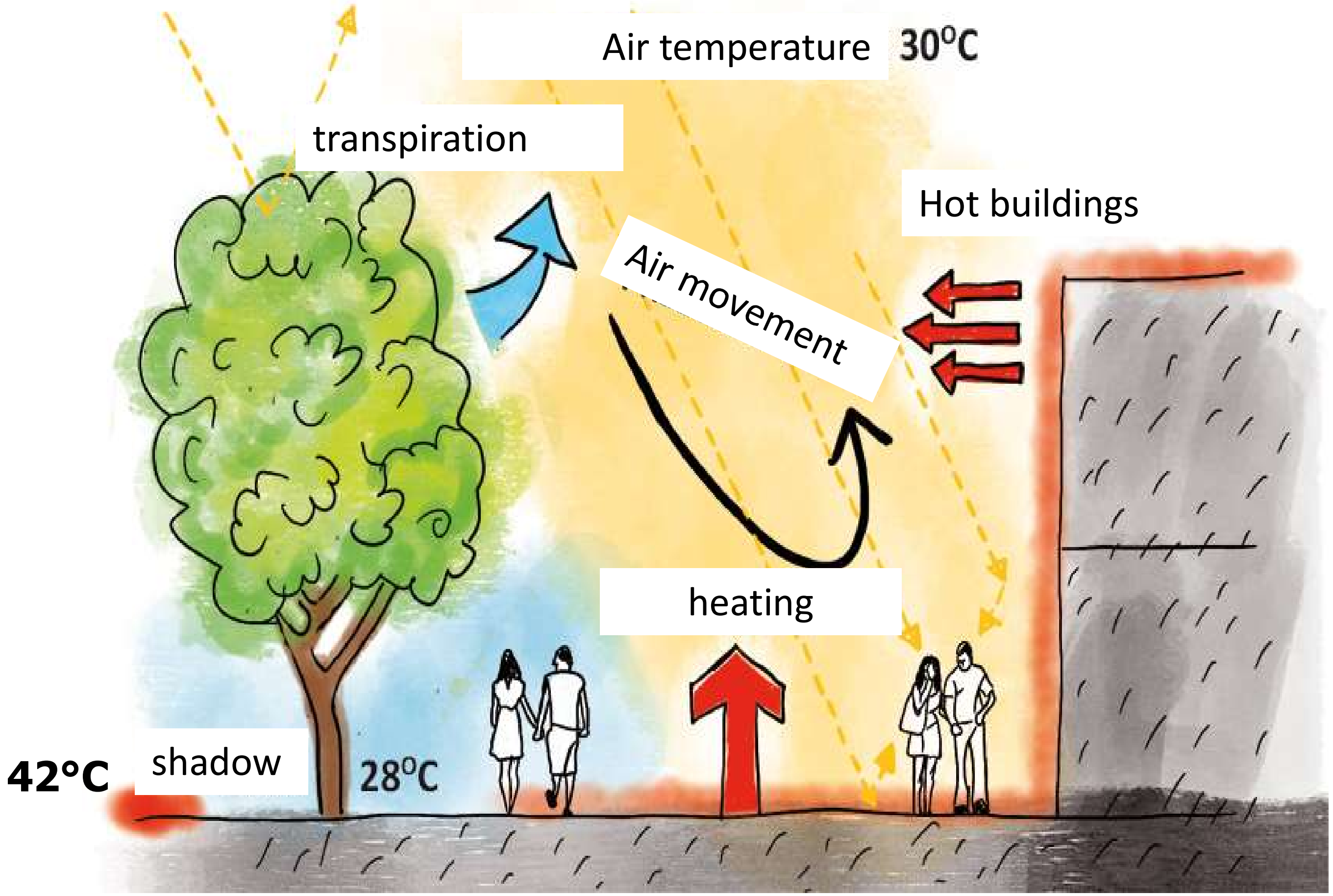
Tree canopy cover%

- ² 5 %
- > 5 - 10 %
- > 10 - 20 %
- > 20 - 30 %
- > 30 - 40 %
- > 40 -50 %
- > 50 - 75 %
- > 75 %



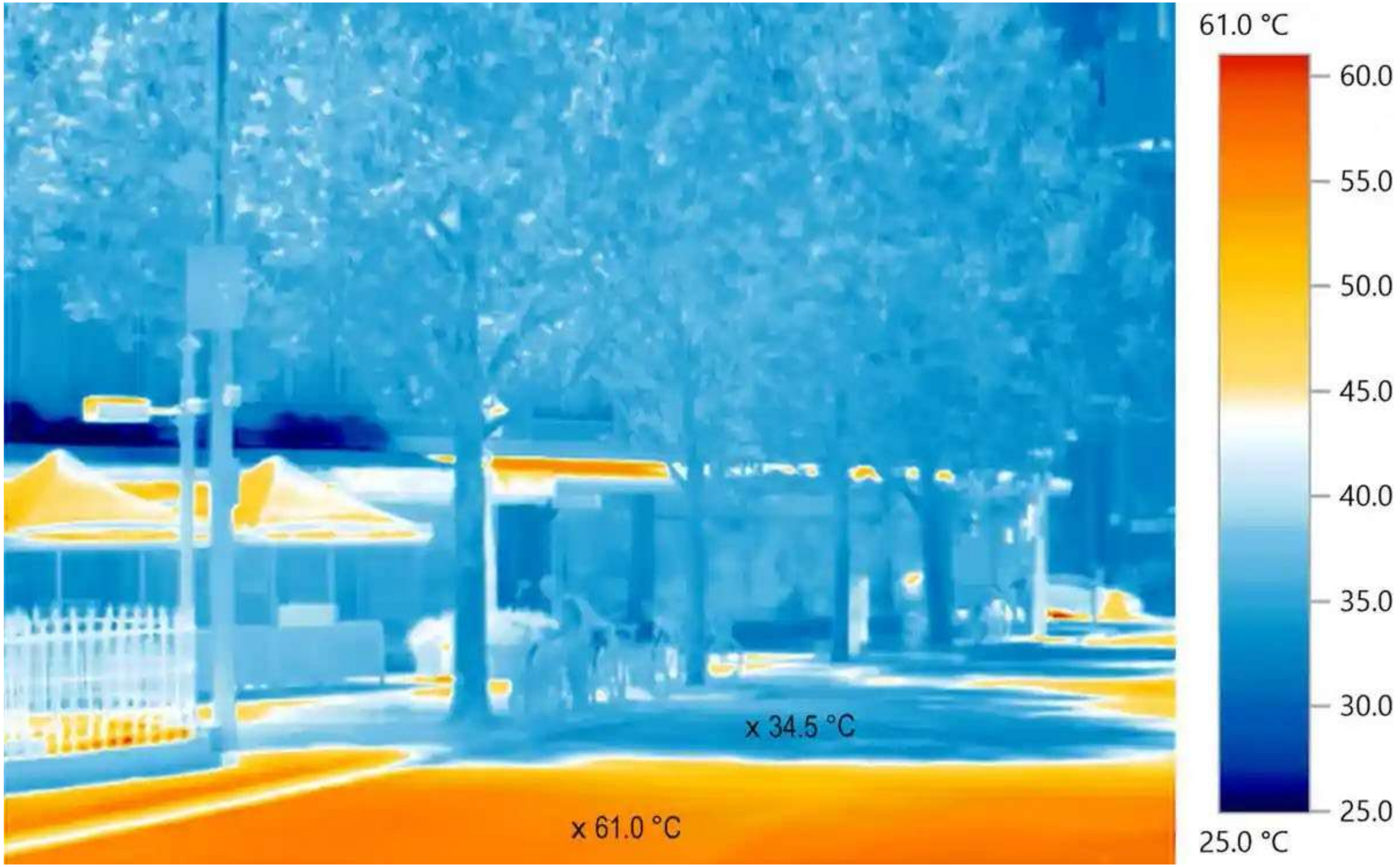
Surface temerature o C

- ² 22
- > 22 - 25
- > 25 - 28
- > 28 - 31
- > 31 - 34
- > 34 - 37
- > 37 - 40
- > 40



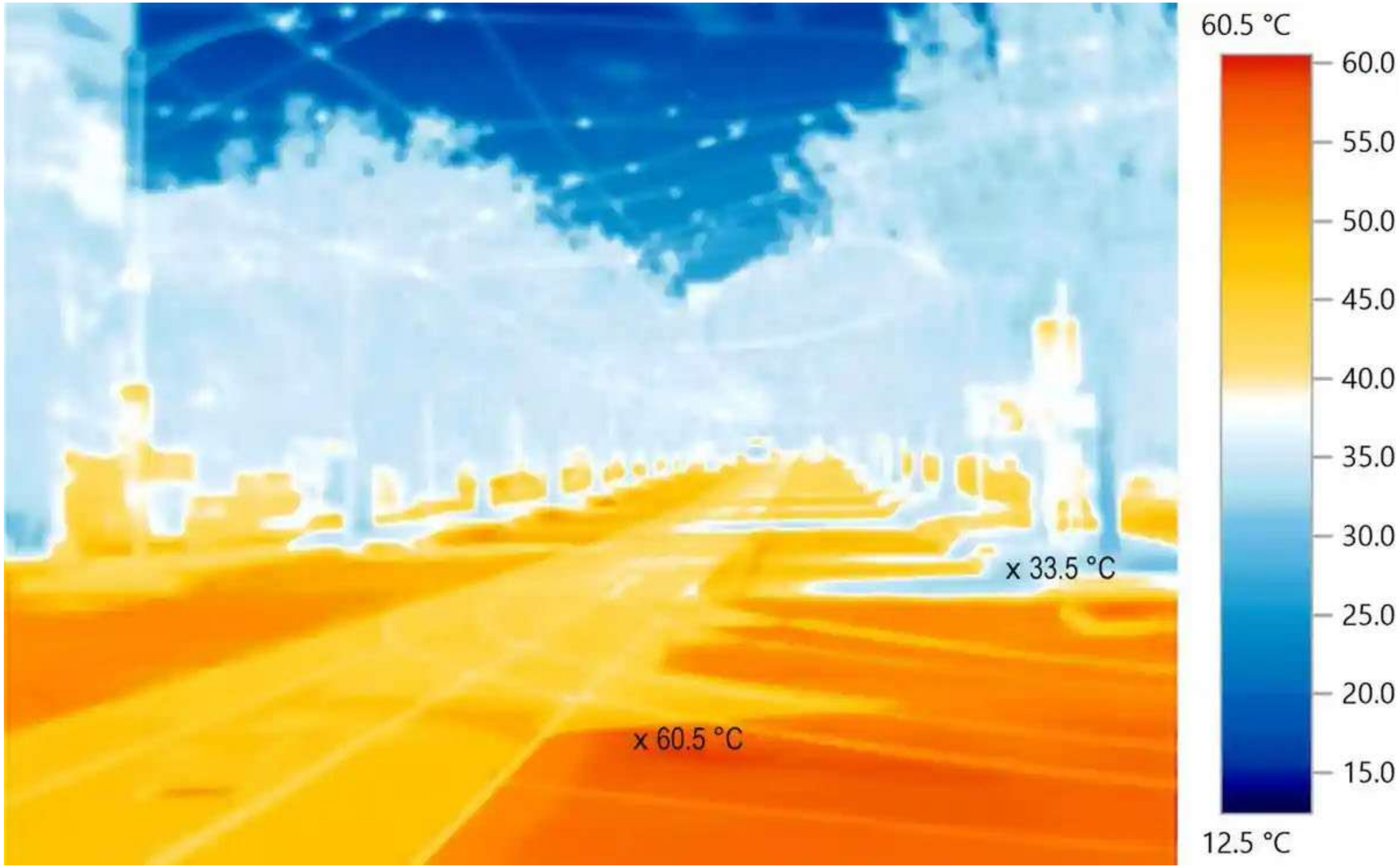
During a hot summer day at 32°C, when the pavement slabs are heated to 42°C, there is a temperature of 28°C under the crowns of nearby trees with irrigated pavement.

trees can lower the air temperature of the streets during hot, sunny, summer days by up to 11 degrees Celsius



Elizabeth Street heat camera opposite Queen Victoria Market. Photograph: City of Melbourne

Source: https://www.theguardian.com/sustainable-business/2017/feb/21/urban-heat-islands-cooling-things-down-with-trees-green-roads-and-fewer-cars



Elizabeth Street heat camera opposite Queen Victoria Market. Photograph: City of Melbourne

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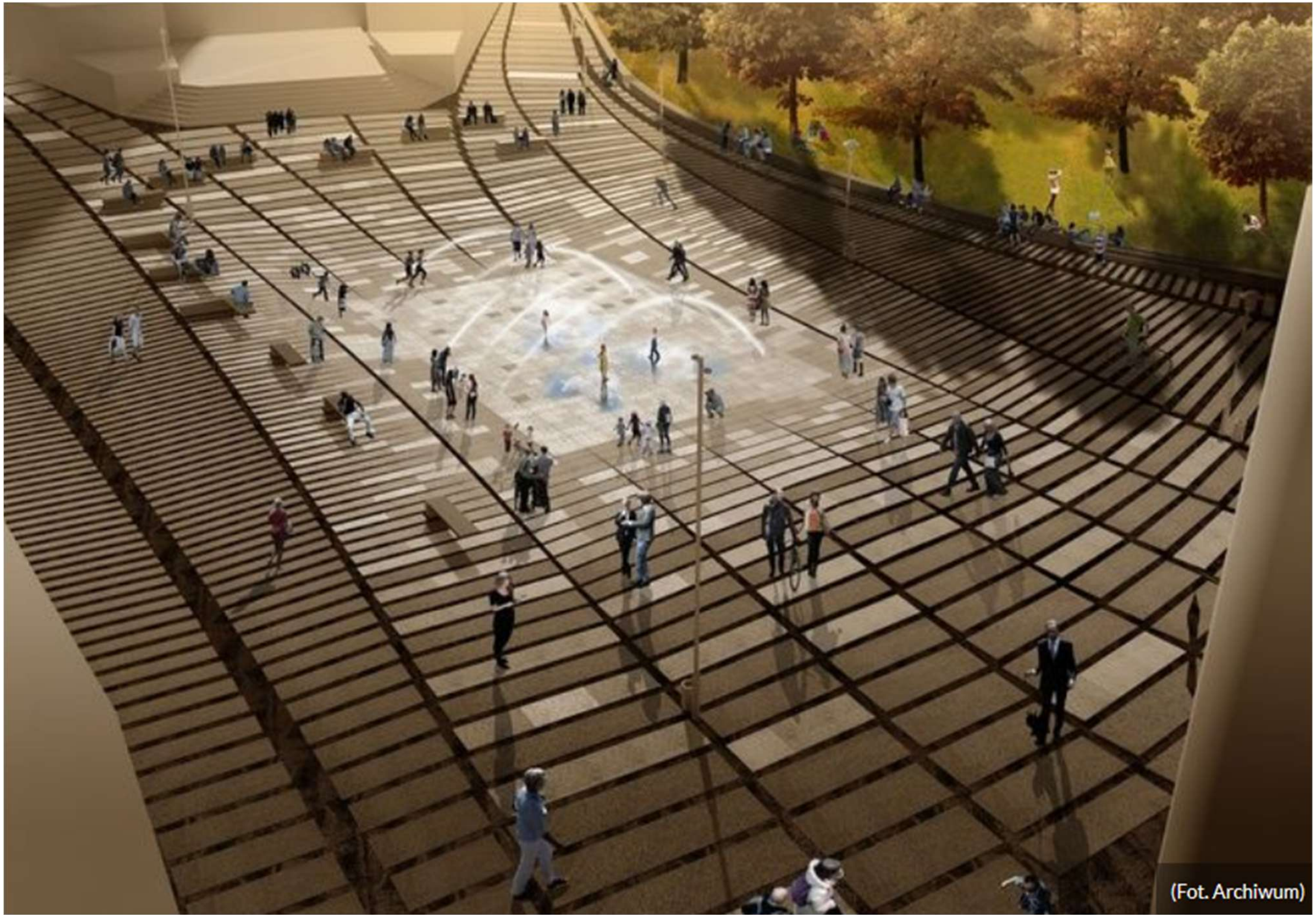
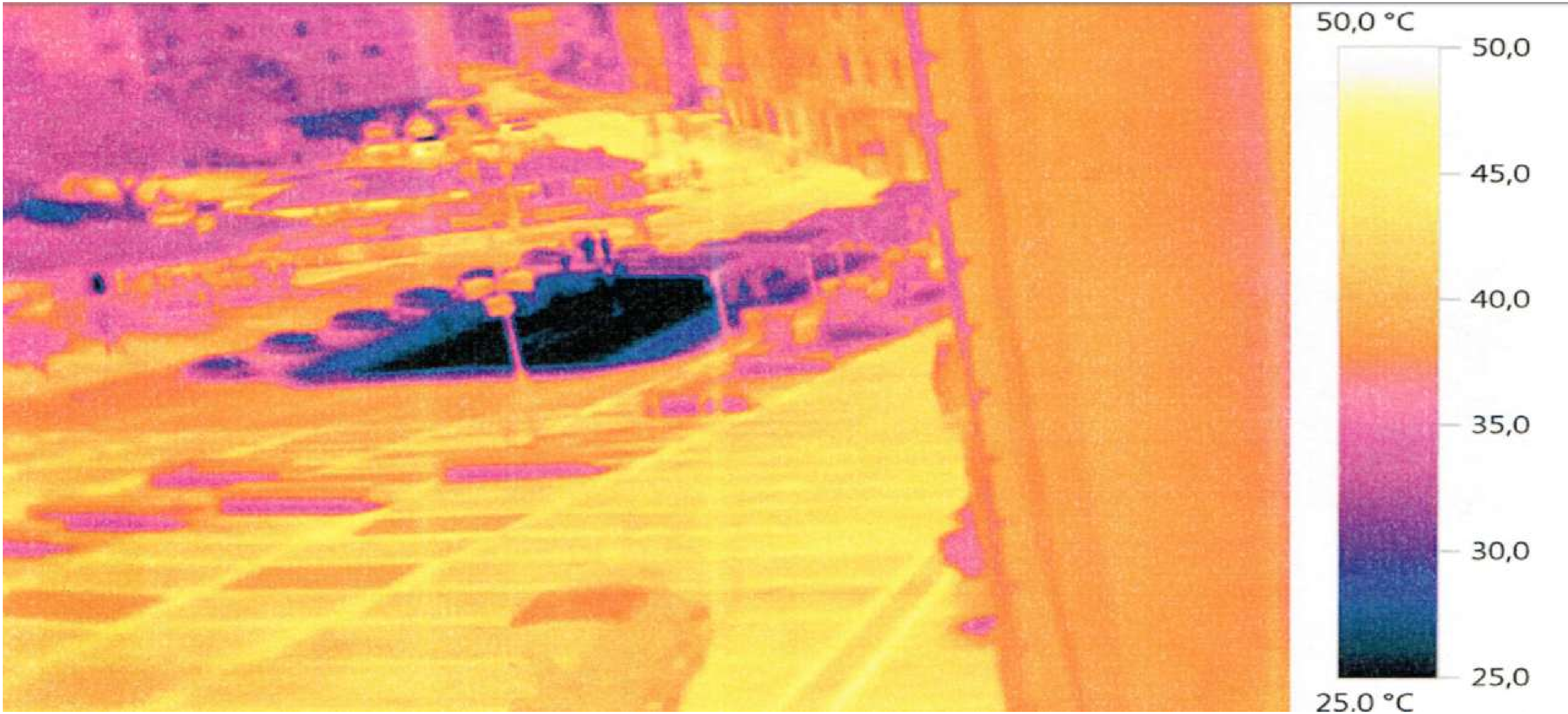
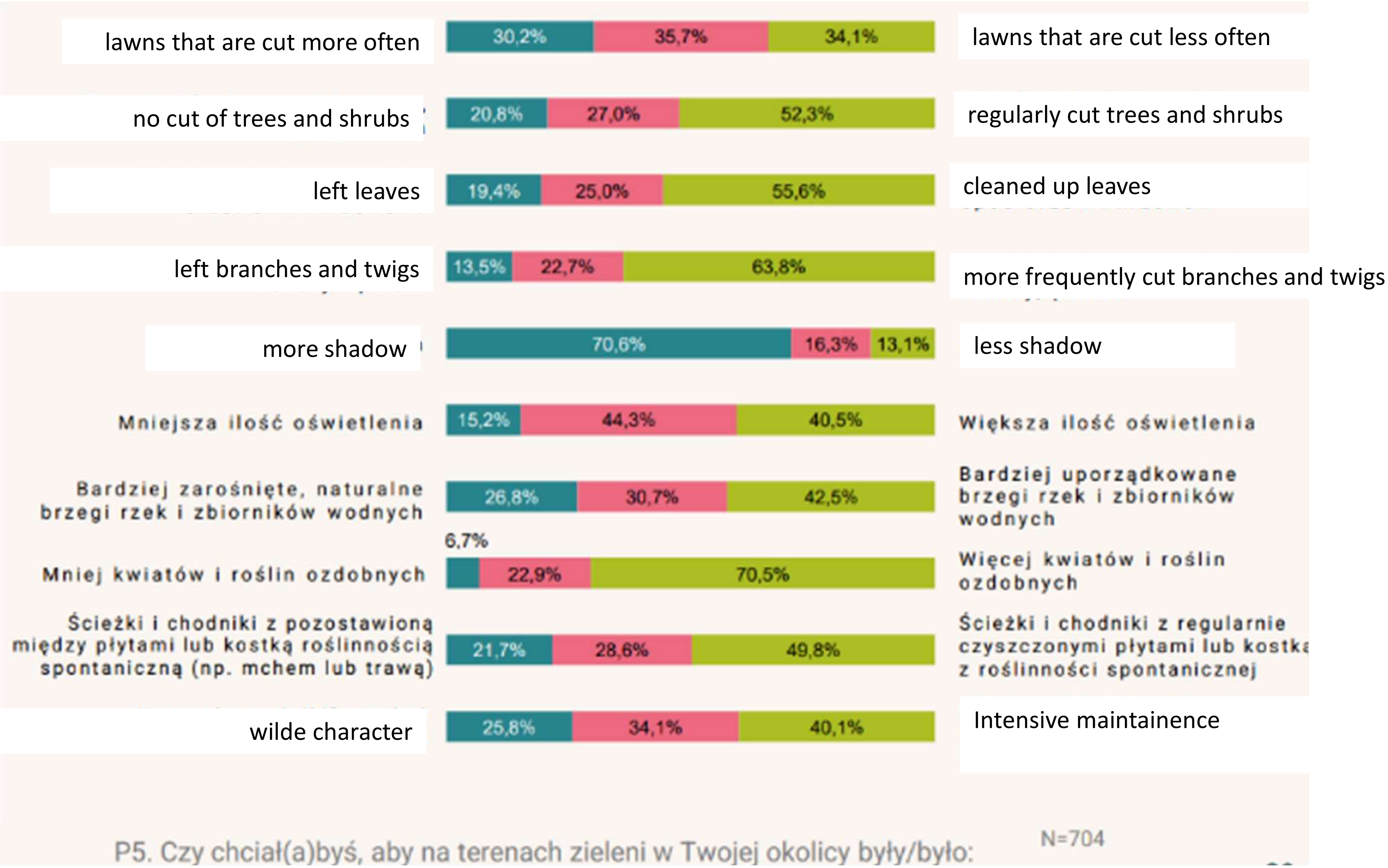

(Fot. Archiwum)


50,0 °C
50,0
45,0
40,0
35,0
30,0
25,0
25,0 °C

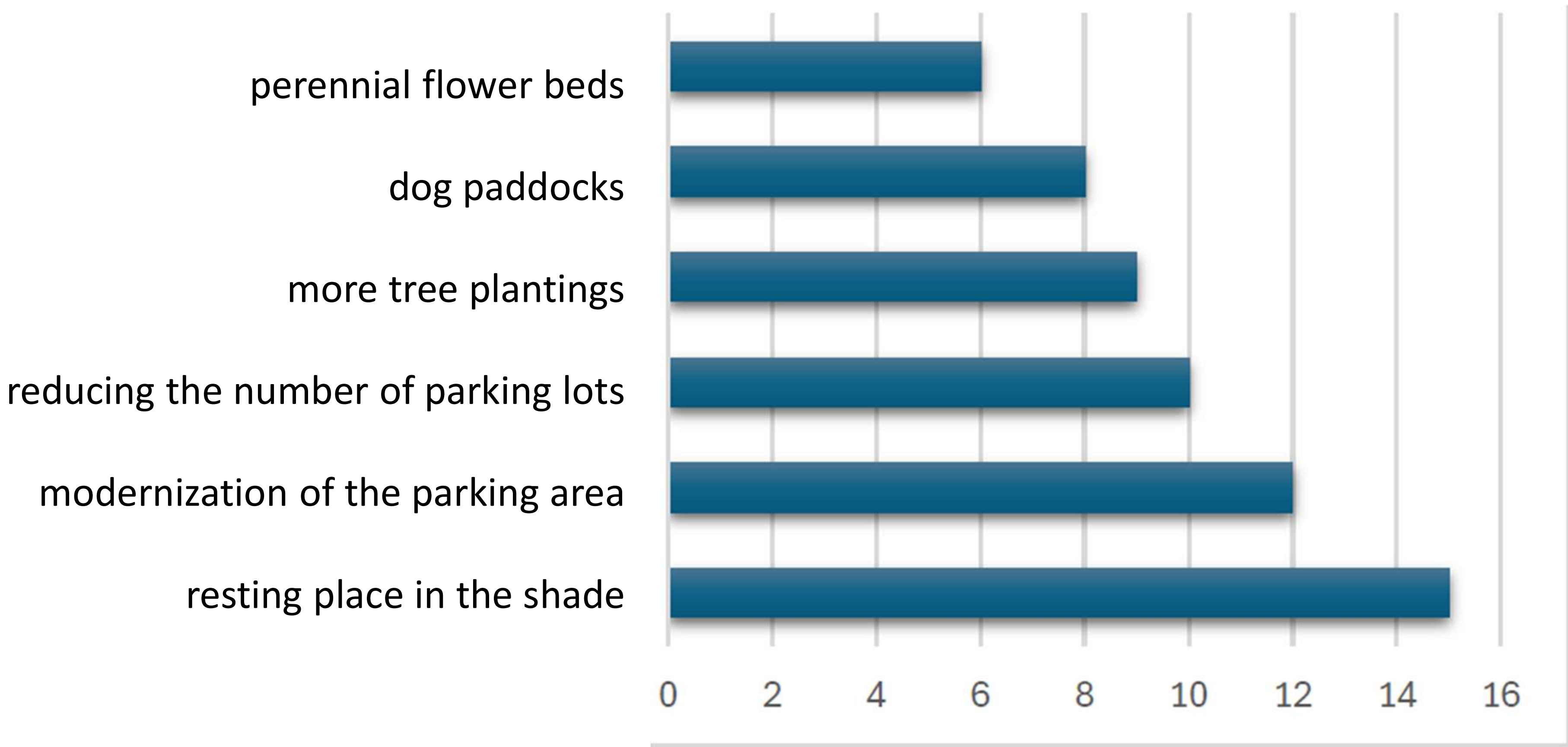
pavement foundation modification – structural soil *(improuvment of site conditions and retention capacity)*


PRZY BAZYLICE

expectations of how to maintain urban greenery



what the pocket park concept should include?



‘Cool Walks’ App Finds Shady Walking Routes to Avoid Extreme Heat in Barcelona

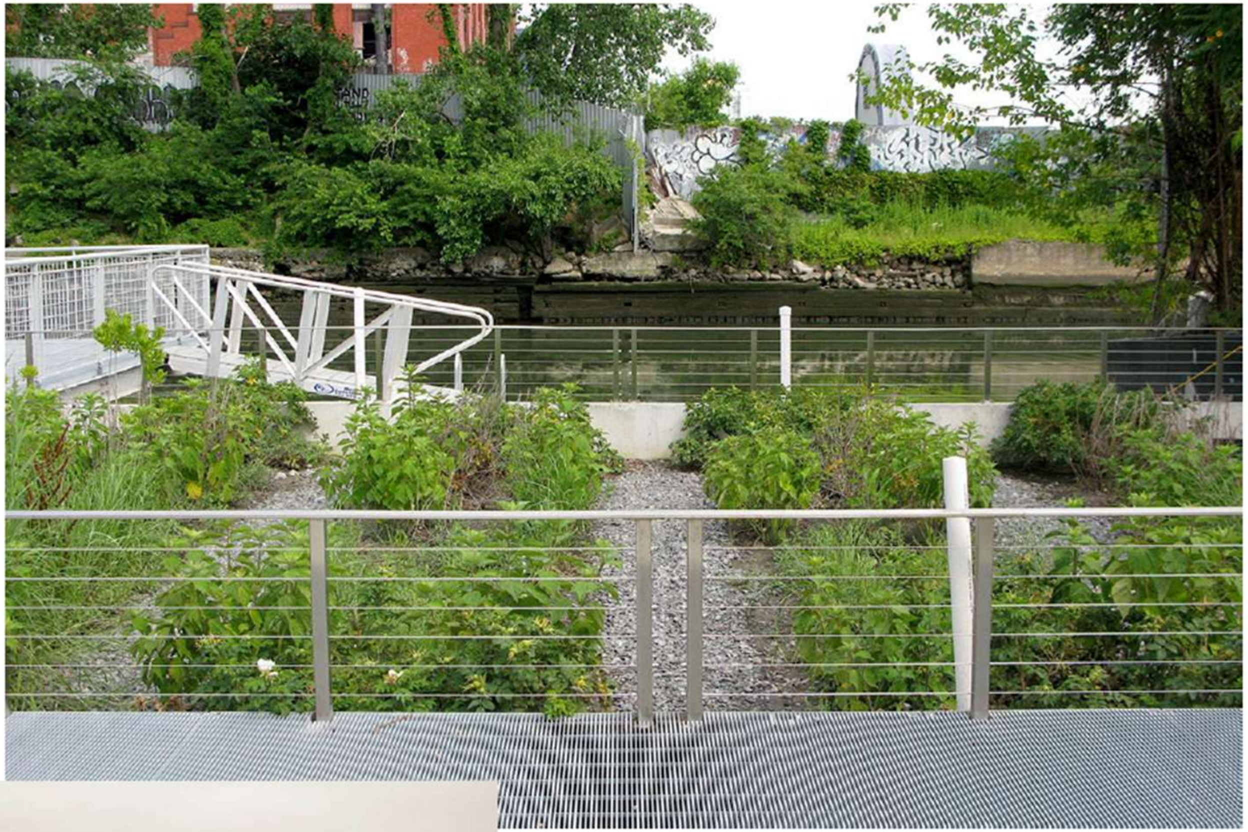
By Audrey Nakagawa | Jun 24, 2021 3:27AM EDT

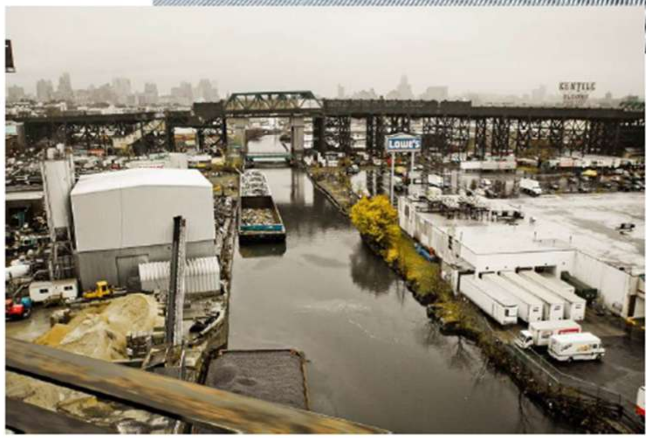
CULTURE

An app called “Cool walks” has been developed in Barcelona that shows how to get from one point to another by walking as much as possible in the shade. “

The app offers three options: the shortest route, a route optimized for shade, and a vampire route that avoids the sun altogether.”

Blue-green infrastructure
what does it mean today?





sponge park

Brooklyn, Gowanus Canal Sponge Park™ DLANDstudio

https://dlandstudio.com/Gowanus-Canal-Sponge-Park-Pilot

Fot. A. Cieszewska

temporary garden

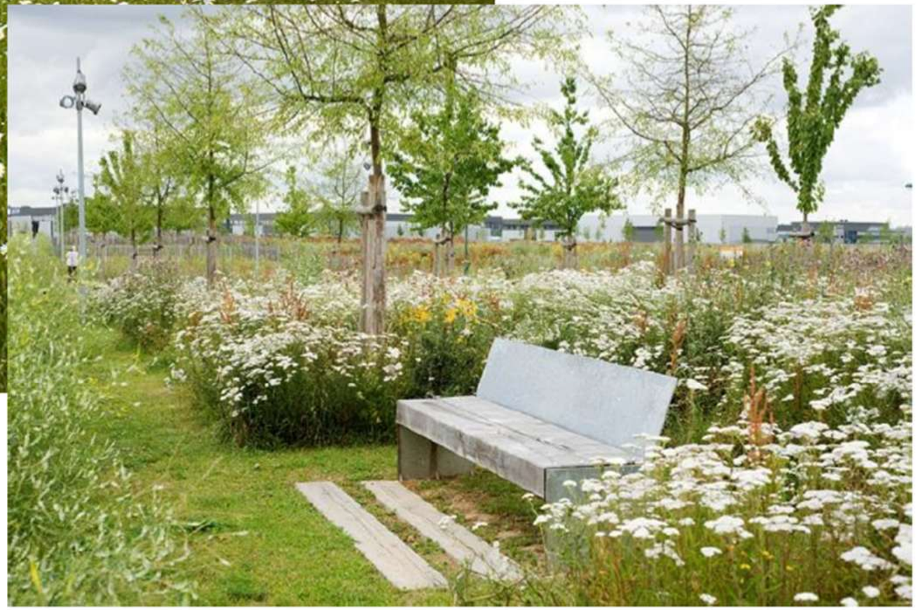
Lozanna

habitat gardens - **prairie garden**

ecosystem design - meadows

flower meadow

leaving leaves



Park Montevrain Urbicus, Francja

low-budget parks, wastelands

Pozostałości ekosystemów Hoobsa (ang. *remnant vegetation*).
Studies show ecosystem benefits, including human health
(Thompson, Kao-Kniffin 2016, Watkins et al. 2020)

https://tobrze.wordpress.com/2016/03/02/montevrain-park-urbicus/

Potters Fiekd, Londyn

Eco-dzielnica Bottière Chenaie
Nantes, Francja
ww.landezine.com/index.php/2012/09/bottiere-chenaie-eco-district-by-atelier-des-paysagem bruel-delmar/

urban agriculture

pocket forest

Miyawaki forests grow in two to three years and are self-sustaining. Density is the key, with the inclusion of a wide variety of pioneer native species of trees and shrubs.

Five years ago the Bosque da Batata ("Potato Grove") was an abandoned urban gas station; now it is a swatch of Atlantic Forest, bringing shade and shelter for a range of urban species — humans included.

https://blorrainesmith.medium.com/pocket-forests-full-of-more-change-347af955e616

Once the forest has grown enough to cast shade and offer air circulation, gardeners can start to add ground cover native to the area (wild sarsaparilla, Canada mayflower and spinulose wood fern are common throughout much of Canada).

The combination of species chosen is important because various species have evolved together and thrive in the same or similar environments. A great way to determine species collections is to inventory nearby natural areas. This illustration shows a selection from the Mixedwood Plains Ecozone that extends from southwestern Ontario through southern Quebec along the St. Lawrence River.

Trees must be native to the area to support native insects, birds, mammals, reptiles and amphibians.

Planting species that make up each of the four forest levels mimics productive natural forest systems and maximizes potential biomass and biodiversity in the space.

Dense planting encourages rapid upward growth and suppresses weeds.

CANOPY
- A American beech
- B Eastern hemlock

SUB-CANOPY
- C Black cherry
- D Yellow birch

UNDERSTOREY
- E Ironwood
- F Chokecherry

GROUND COVER
- G Prickly gooseberry
- H Northern bush honeysuckle
- I Maple-leaved viburnum

The soil is rejuvenated before planting by adding compost and covering it with mulch and leaf litter. Mycorrhizae and other microorganisms can be added via a "compost tea"of wild soil and water..

The community is connected via fungal networks, which allow for sharing nutrients and resources.

In the first few years, it's important to weed and mulch to ensure the plot isn't overtaken by unwanted opportunistic plants.





Dbam o środowisko!
Instrukcja sadzenia roślin
FOREST MAKER
Na wyznaczonej sekcji (1 m²) posadź 3 rośliny różnych gatunków.
Wykop dołek – korzenie muszą się w nim swobodnie zmieścić – nie mogą być podwinięte ani skręcone!
Ugnieć ziemię ręką lub butem dookoła sadzonki.
MikroLasy sadzone metodą Miyawaki rosną
bioróżnorodne niż lasy gospodarcze. Odpow
rozpoczyna cyrkularny proces tworzenia odż
Już wkrótce w tym MikroLesie zamieszkają
Mikrolas
W 100% ZGODNIE Z METODĄ MIYAWAKI
FOREST MAKER
250 m² MIKROLASU POCHŁANIA 500kg CO₂/ROK
POCHŁANIA 750kg PYŁÓW PM10 Z OTOCZENIA ROCZNIE
UŻYLIŚMY DO POSADZENIA 0% TORFU Z TORFOWISK
JEST W 100% ORGANICZNY, ROŚNIE NA KOMPOŚCIE
45m³ TYLE JESIENNYCH LIŚCI Z OKOLICY MOŻEMY W NIM ŚCIÓŁKOWAĆ
MIEJSCE DO ŻYCIA DLA MINIMUM 500 GATUNKÓW
18x BARDZIEJ BIORÓŻNORODNY NIŻ LAS GOSPODARCZY
32% SZYBCIEJ WODĘ DESZCZOWĄ DO GLEBY
90%
-10dB
-10°C
2,5x
97%
Mikrolas to szybko rosnący, bioróżnorodny i samoregulujący się ekosystem.
Działa jak „glebarium", dzięki czemu możemy zasilać go co roku w jesienne liście i drewno z okolicy zgodnie z gospodarką obiegu zamkniętego. W mikrolesie specjalnie dobrane gatunki drzew i krzewów tworzą wielopiętrowy układ roślinności, naśladując procesy naturalnego odnowienia lasu.
Mikrolas na kampusie SGGW zajmuje powierzchnię 420 m² i został posadzony społecznie w dniu 2 października 2024 roku. Posadzono łącznie 750 drzew i krzewów z 37 gatunków rodzimych oraz 600 cebul i kłączy geofitów wiosennych. Przeszczepiono 30 m² leśnego runa z naturalnych stanowisk Leśnego Zakładu Doświadczalnego SGGW w Rogowie.
lipa drobnolistna
klon jawor
czarny bez
czereśnia ptasia
klon polny
wiąz szypułkowy
głóg jednoszyjkowy
klon pospolity
jarząb brekinia
topola osika
buk pospolity
grab pospolity
kalina koralowa
jabłoń dzika
kruszyna pospolita
UNIgreen
NAWA
FOREST MAKER

Źródło:https://twistedsifter.com/2011/06/high-line-park-new-york-city/

High Line Park
New York

pocket parks

park kieszonkowy *(pocket park)*

Autor: YuoTube
Jednym z pierwszych miejskich mini-parków, określonych jako park kies
jest Paley Park w Nowym Jorku na Manhattanie, który powstał w 1967
powierzchnię 390 m kw., słynie ze sztucznego wodospadu, który zagłus
miasta

wellbeing of city dwellers

lower energy bills

avoiding emissions

CO2 sequestration and absorption

higher local retention

slow down surface runoff

social ties

50% less crime

better physical and mental health of residents

….and many other benefits

Which can be expressed m3 of water retained in the crowns or in tons of CO2 absorbed

AND THEIR VALUE CAN BE CALCULATED MONETARY

green facades

A large five-leaf grapevine (*Partenocissus quinqefolia*), **occupying only about half a square meter of ground**, can produce about 2,600 m2 of foliage during the growing season (Table 1).

Such an area is about **the size of seven linden trees with a crown diameter of 10 meters**, and **much more than a 100-year-old beech which reaches a foliage area of about 1600 m2** (Borowski and Latocha 2014).

Tab. 1.

Partenocissus quinqefolia on 531 m2 of wall	
leaf area	2600 m^2
leaf mass	3000 kg
water transpiration	15000 *l/day*
transpiration cooling	37,5 *GJ/day*
oxygen production	250 kg *O2/year*
CO2 uptake	500 kg/rok *kg/year*

Benefits

Biological protection of the building
Extending the life of a façade

A green wall **provides protection** for a facade from external influences such as sun, rain, wind and temperature fluctuations, extending the life of a building's facade.

Vegetation on the walls also **reduces the ultraviolet (UV) radiation** reaching the building.

Green facade construction extends the life of the facade coating by 15 years

Benefits

Reduction of the level of noise in the environment, both outside and inside

The green wall works like a sound barrier in a building.

It **absorbs 41% more sound than a traditional facade**,
and this means that the environment both inside and outside is significantly quieter.

Noise reduction is up to 8 dB, which means it is reduced by half.

Benefits

Reduction of surrounding temperatures

Cooling benefits

green facade provides a thermal isolation effect that will help **reduce energy consumption**, protecting the building from the cold in winter and providing a **cooling effect in summer**

Plants absorb sunlight, **50% is absorbed and 30% is reflected**; so this helps create a cooler and more pleasant climate.

In terms of indoor conditions, this means that **air conditioning runs 33% less intensively**, which translates into energy savings.

The exterior green wall, also has a **positive effect on the heat island effect in the city**. In general, it is possible to **reduce the temperature in the urban area by 3°C**.

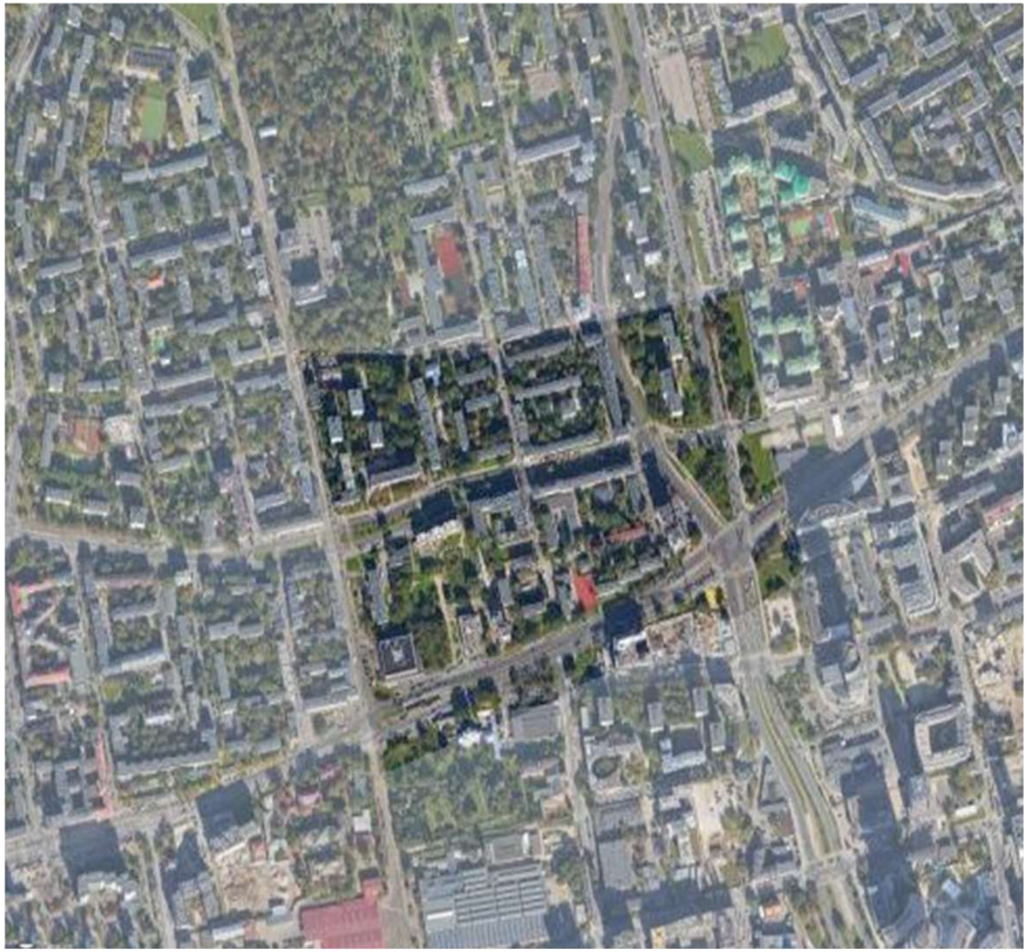
Does it pay off?

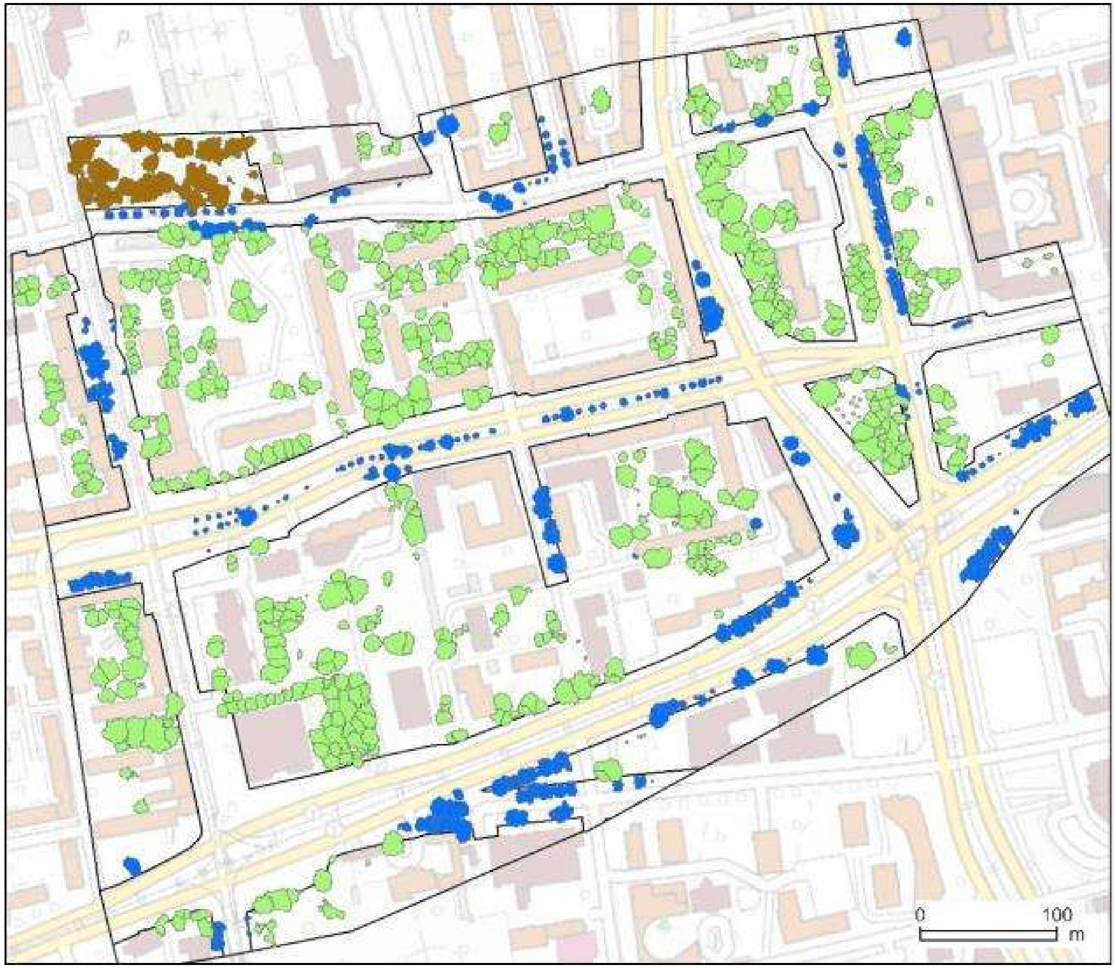
Urban forests in the United States can **reduce annual stormwater runoff by 2-7 percent**.

Green streets and tree planting are estimated to be **3-6 times more effective in managing stormwater per $1,000 investment than conventional methods**.

Nowak, D.J.; Crane, D.E.; Dwyer, J.F. 2002. Compensatory value of urban trees in the United States. Journal of Arboriculture. 28(4): 194-199.
Fazio, Dr. James R. How Trees Can Retain Stormwater Runoff. Tree City USA Bulletin 55. Arbor Day Foundation.
Foster, Josh, Ashley Lowe, and Steve Winkelman. The Value of Green Infrastructure for Urban Climate Adaptation. Rep. Center for Clean Air Policy, 2011.
McPherson G., Simpson J., Peper P., Gardner S., Vargas K., Maco S., Xiao Q.. Coastal Plain Community Tree Guide: Benefits, Costs, and Strategic Planting. USDA, Forest Service, 2006
Thaler J. The Environment, Financial and Health Benefits of Urban Forestry. Center for City Parks Excellence. The Trust for Public Land, 25 Mar. 2011

Value of tree





Valuation and assessment of ecosystem services provided by selected urban trees in Warsaw:

Assessment and valuation of the impact of trees on the
- concentration of carbon dioxide in the air,
- concentration of nitrogen dioxide, sulfur dioxide and particulate matter PM2.5 and PM10

- oxygen production by trees,

on the selected area of the Capital City of Warsaw

Ecosystem services calculation

NO2

105,2 KG NO_2/ROK

8414 PLN

1920,90 Euro

312,0 KG PM_{10}/ROK

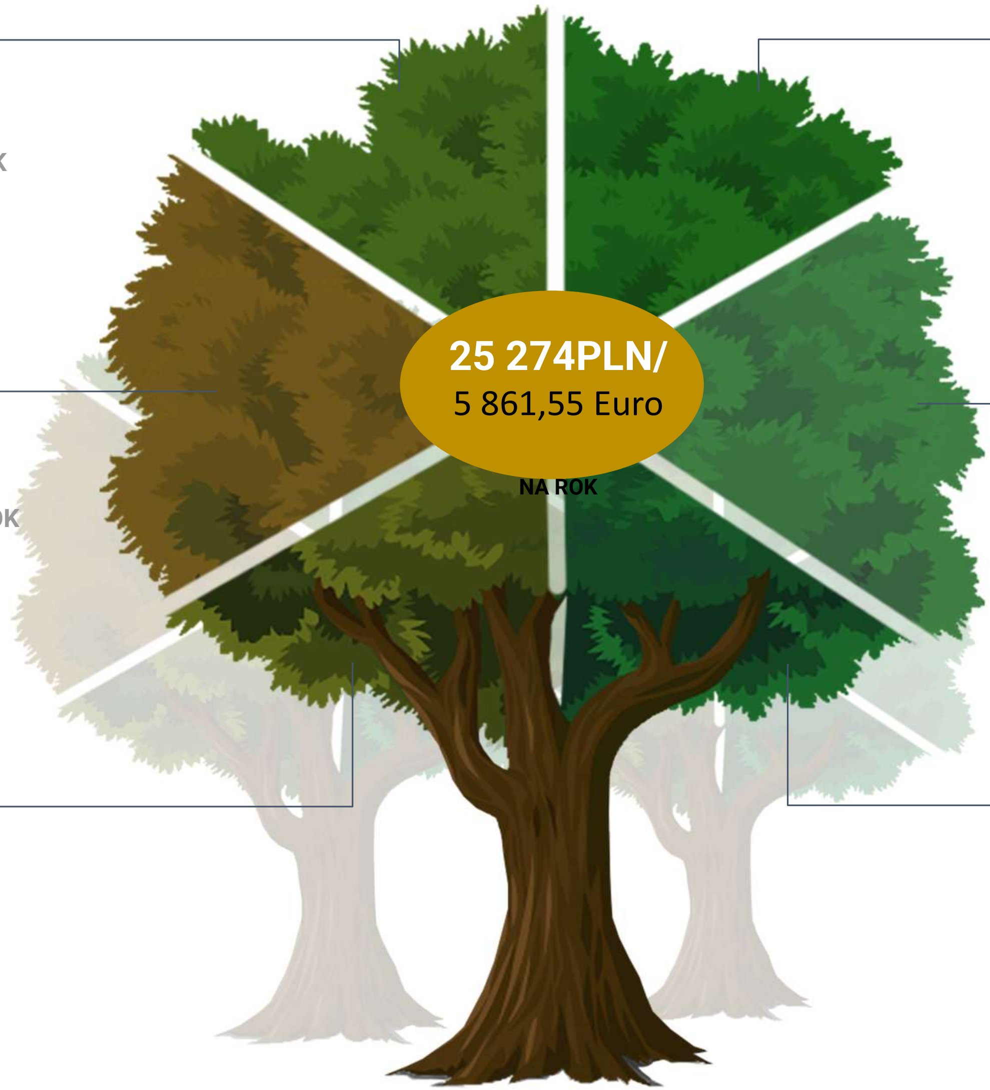
4681 PLN

960,05 Euro

9,3 KG $PM_{2,5}$/ROK

2333 PLN

483,95 Euro



SO2

15,9 KG SO_2/ROK

846 PLN

53 TON O_2/year

538 TON C/year storage

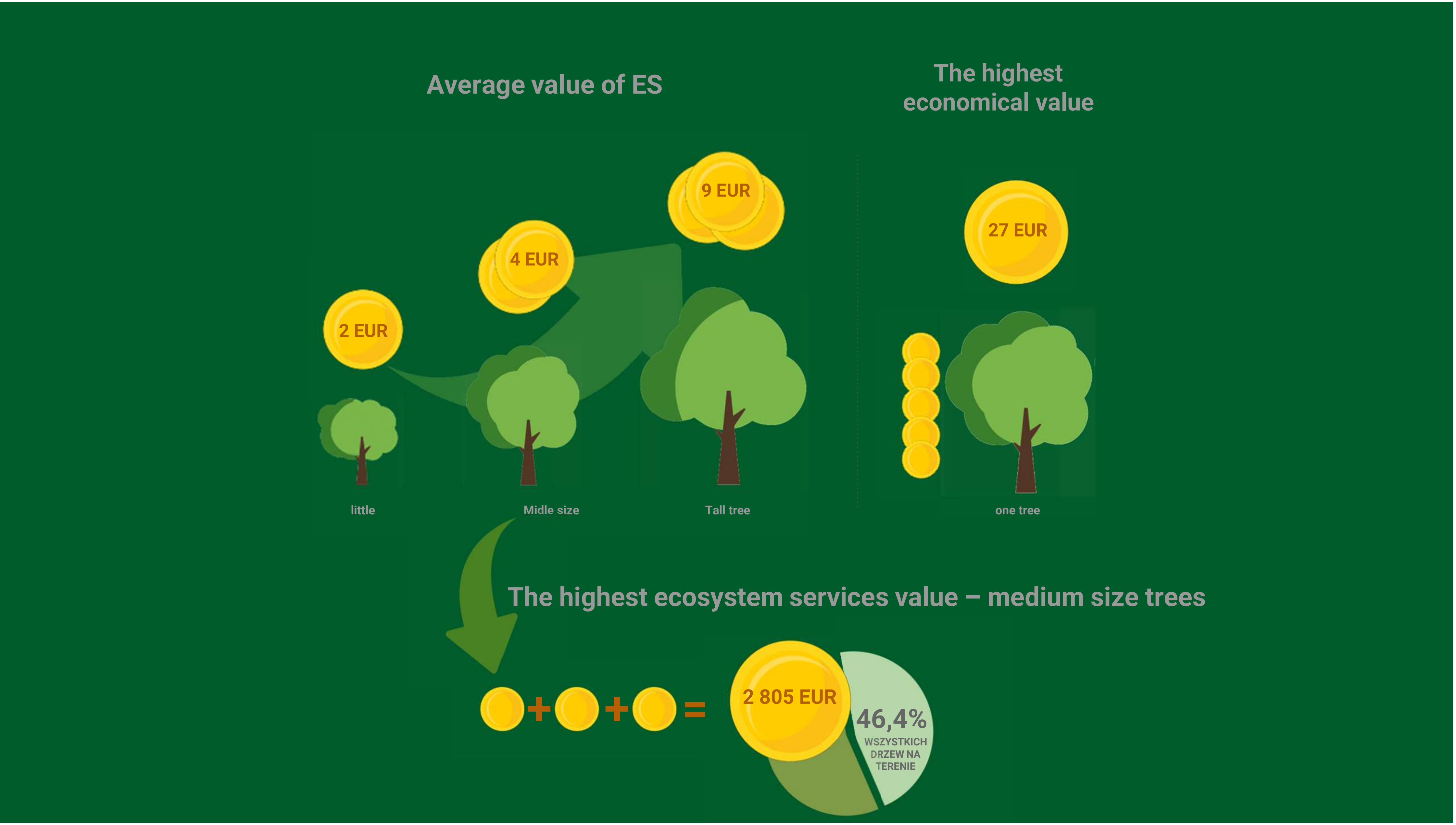
19,9 TON C/year

secwestration

9000 PLN

2 087,11 Euro

1336 trees



Average value of ES
The highest economical value
9 EUR
4 EUR
2 EUR
27 EUR
little
Midle size
Tall tree
one tree
The highest ecosystem services value – medium size trees
2 805 EUR
46,4%
WSZYSTKICH DRZEW NA TERENIE

The calculation of tree value including replacement value and value of ecosystem services is used worldwide as a basis for valuation of property valuers and refinement of methodology in this regard may also enable this direction in valuation practice in the City of Warsaw and the whole country.

The replacement value of trees was **9 806 968 PLN**. (2 274 686,11 Euro)

ecosystem services

tree No. 1118 were as follows:

NO2 removal: 3.16 KG/year;

SO2 removal: 21.2 KG/year;

PM2.5 removal: 37.3 KG/year;

PM10 removal: 2.68 KG/year;

C sequestration: 14.2 tons/year.

value of tree

The value of ecosystem services is: 71.5 PLN/year (16,58 Euro)

The replacement value of the tree is: 3 231,90 PLN (749,46 Euro)

The value of selected ecosystem services (air purification from NO_2, SO_2, PM2.5, PM10, oxygen production, carbon storage and sequestration),

1336 surveyed trees amounted to more than **25 000 PLN/year** (5 861,55 Euro)

The average value of ecosystem services of one tree in the study area was **23 PLN/year** (5,33 Euro)
(all benefits counted for Praski Park were **16 Euro/tree**)

The estimated value of the selected ecosystem services calculated by us for the City of Warsaw is over **174 million PLN per year** (40 340 160,00 Euro)

It is possible to include the value of other services (97 PLN per year per capita).
The replacement value of trees was **9 806 968 PLN** (2 274 686,11 Euro)

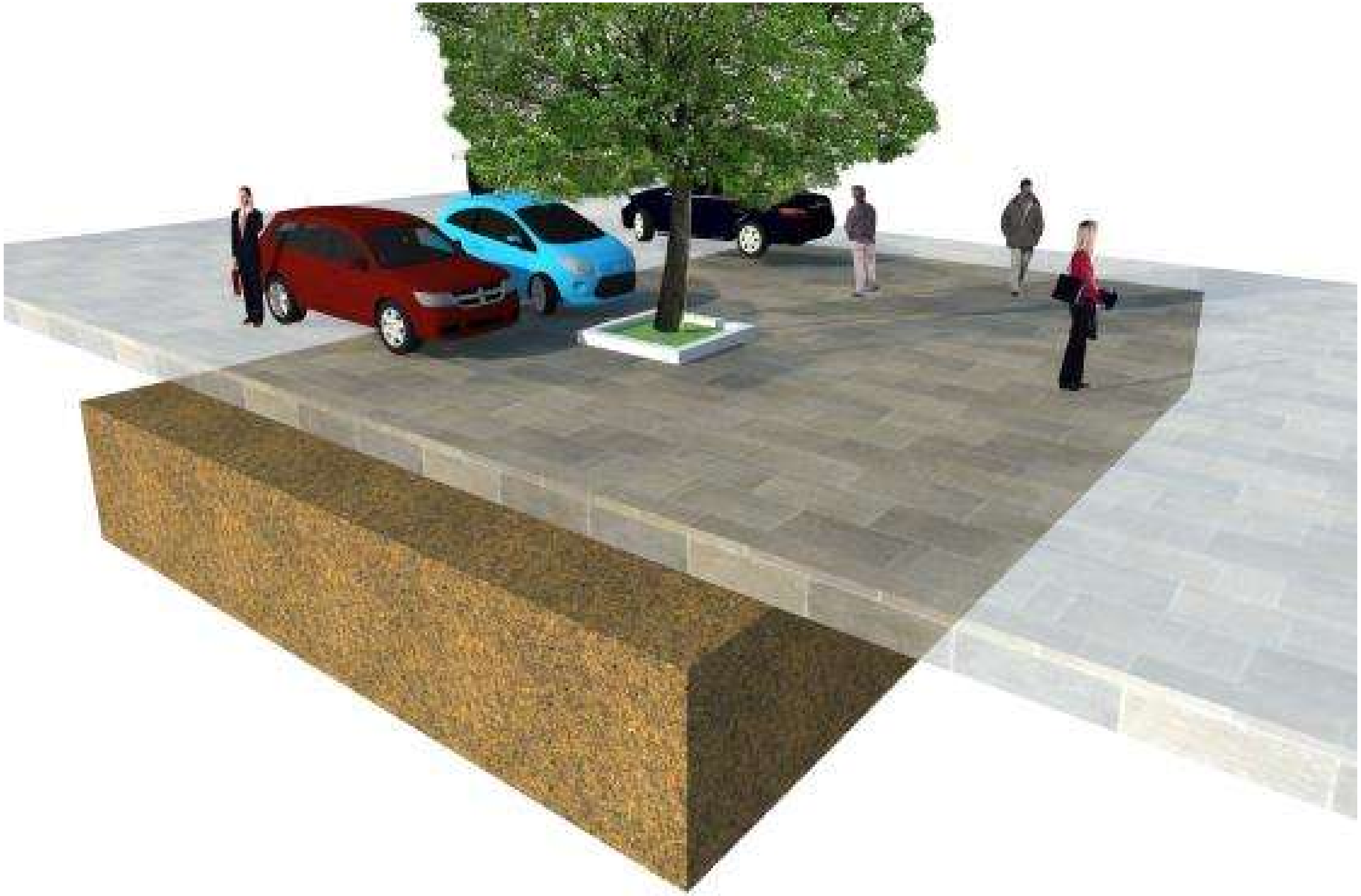
The collected database allows the conversion of further ecosystem services, for example, such as:

I) MITIGATION OF THE CITY HEAT ISLAND **based on m3 of water evaporated**,

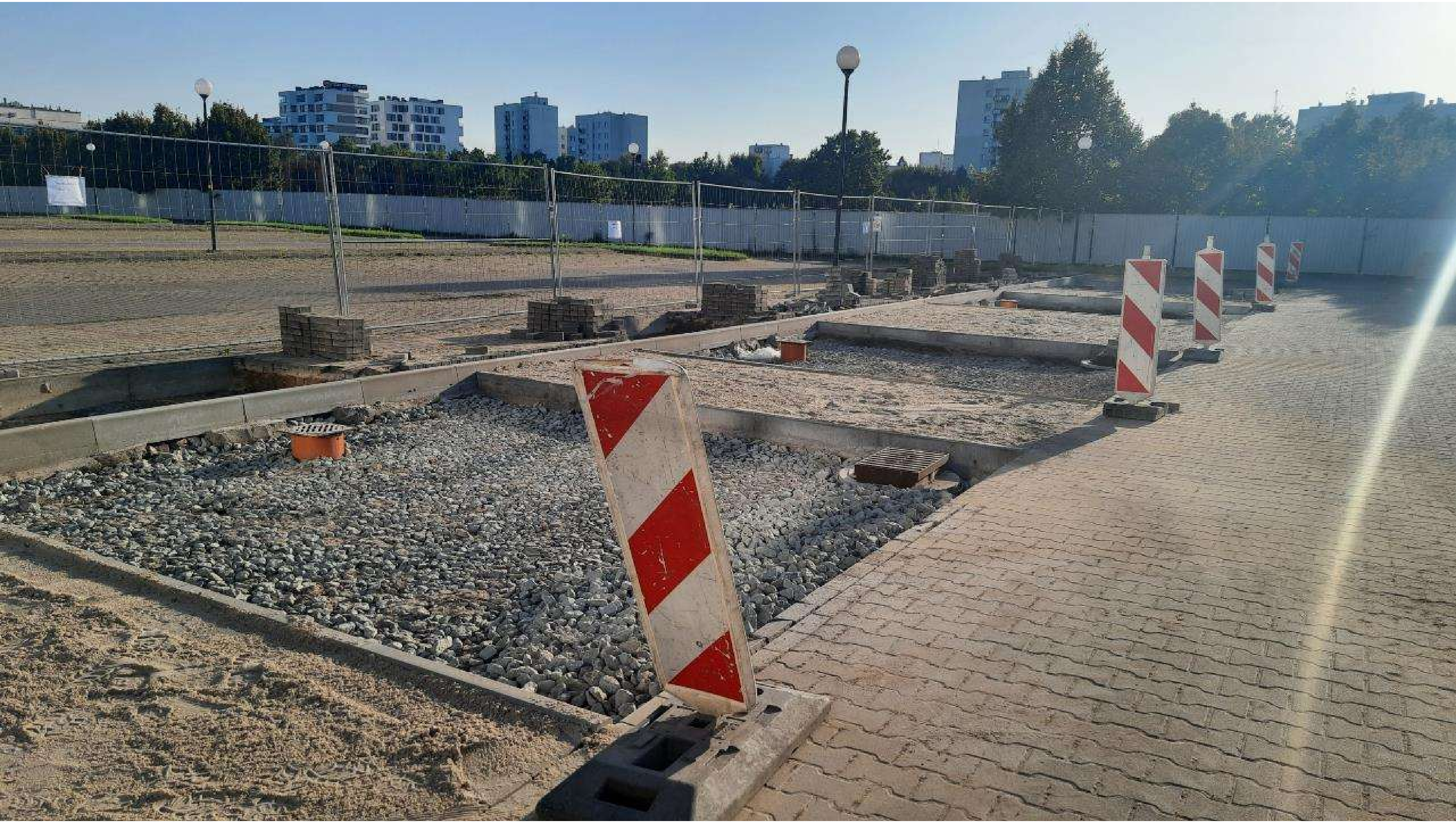
II) SURFACE RUN OFF LIMITATION **based on m3 of water**.

III) LESS ENERGY CONSUMPTION expressed in **reduction of energy costs** of buildings in Kwh per year, which generates savings

the maximization of the effect: work of green and gray infrastructure to increase the level of ecosystem services



structural soil vs. retention capacity



structural soil - a retention capacity of **0,17 do 0,31 m^3/m^2**

Parameters for trees planted on the SGGW experimental plot - common maples (*Acer platanoides*),

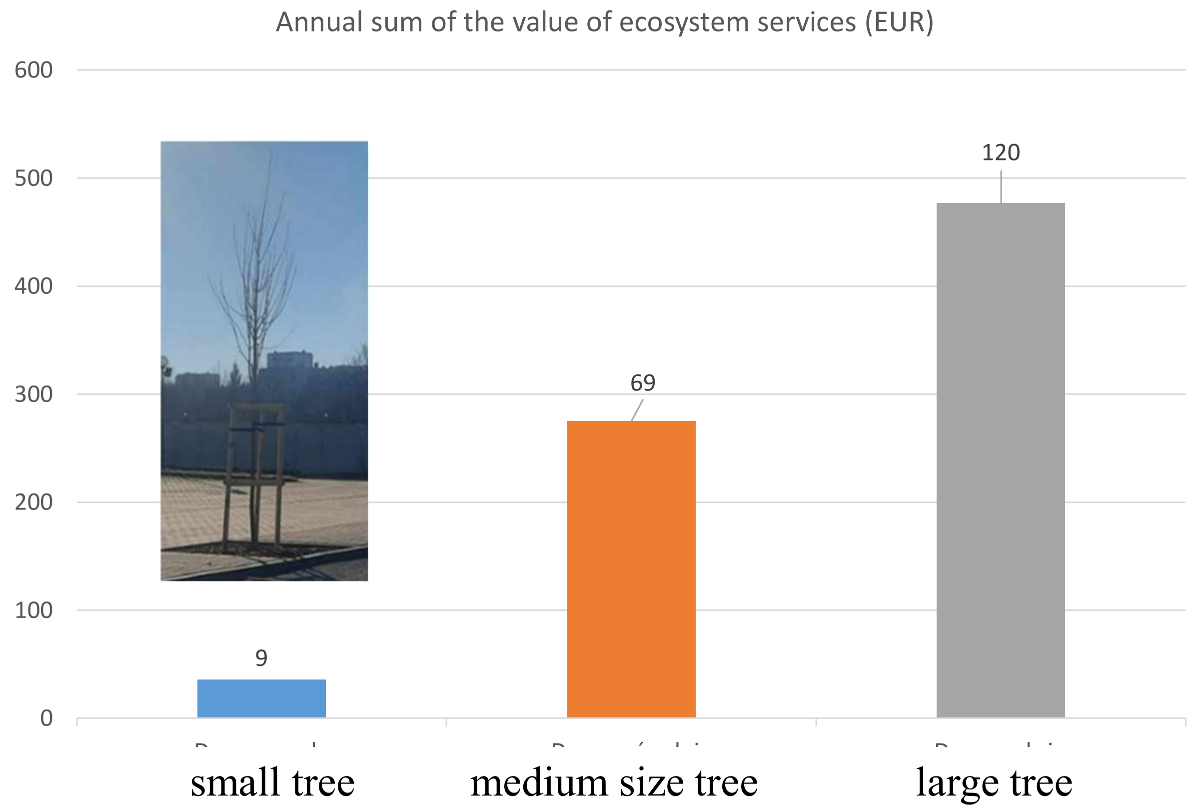
iTree Eco estimation of potential ecosystem services

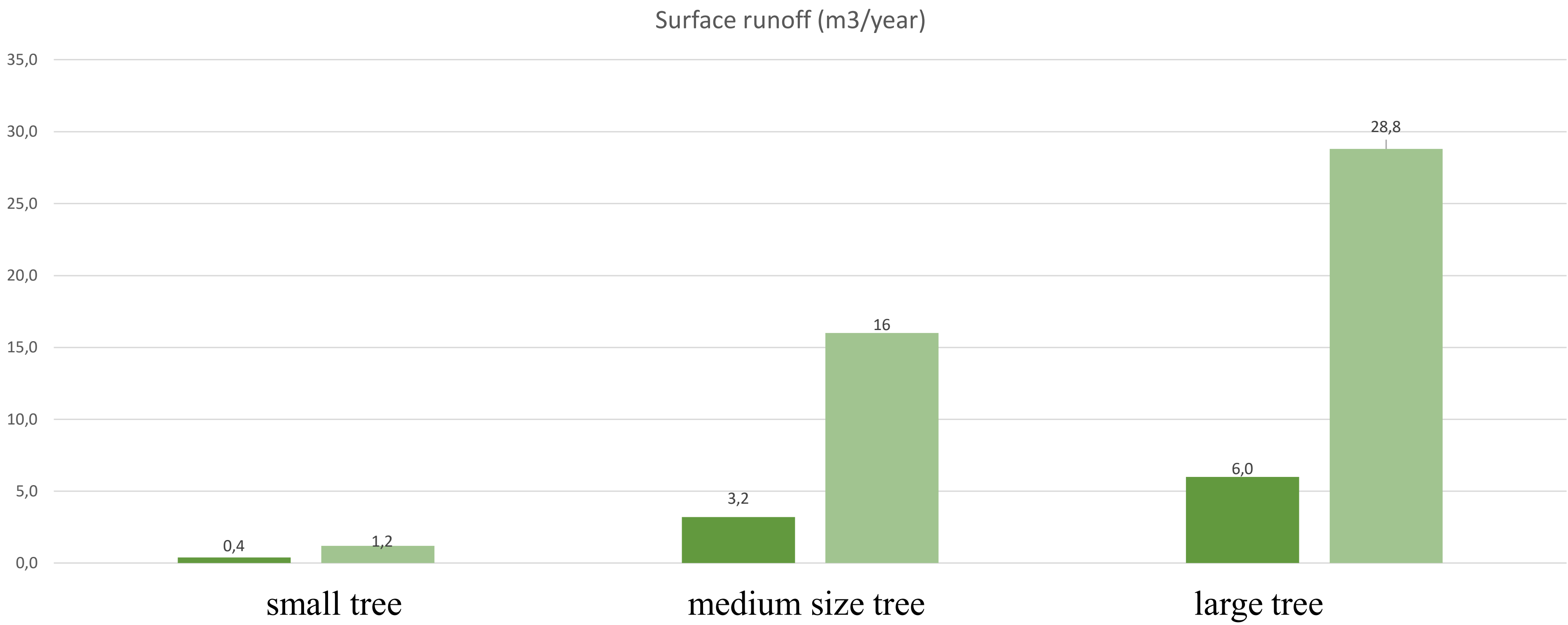
The following tree sizes were adopted:

small trees (20 years: tree height 5 m, breast height 13 cm),

medium trees (50 years: tree height 13 m, breast height 32 cm),

large trees (100 years: tree height 18 m, breast height 57 cm)





avoided runoff/water intercepted by trees


Stanowisko 4
Stanowisko 3
Stanowisko 2
Stanowisko 1

Ecosystem services studies are being conducted in the study area, including surface runoff, temperature (**urban heat island mitigation potential**).

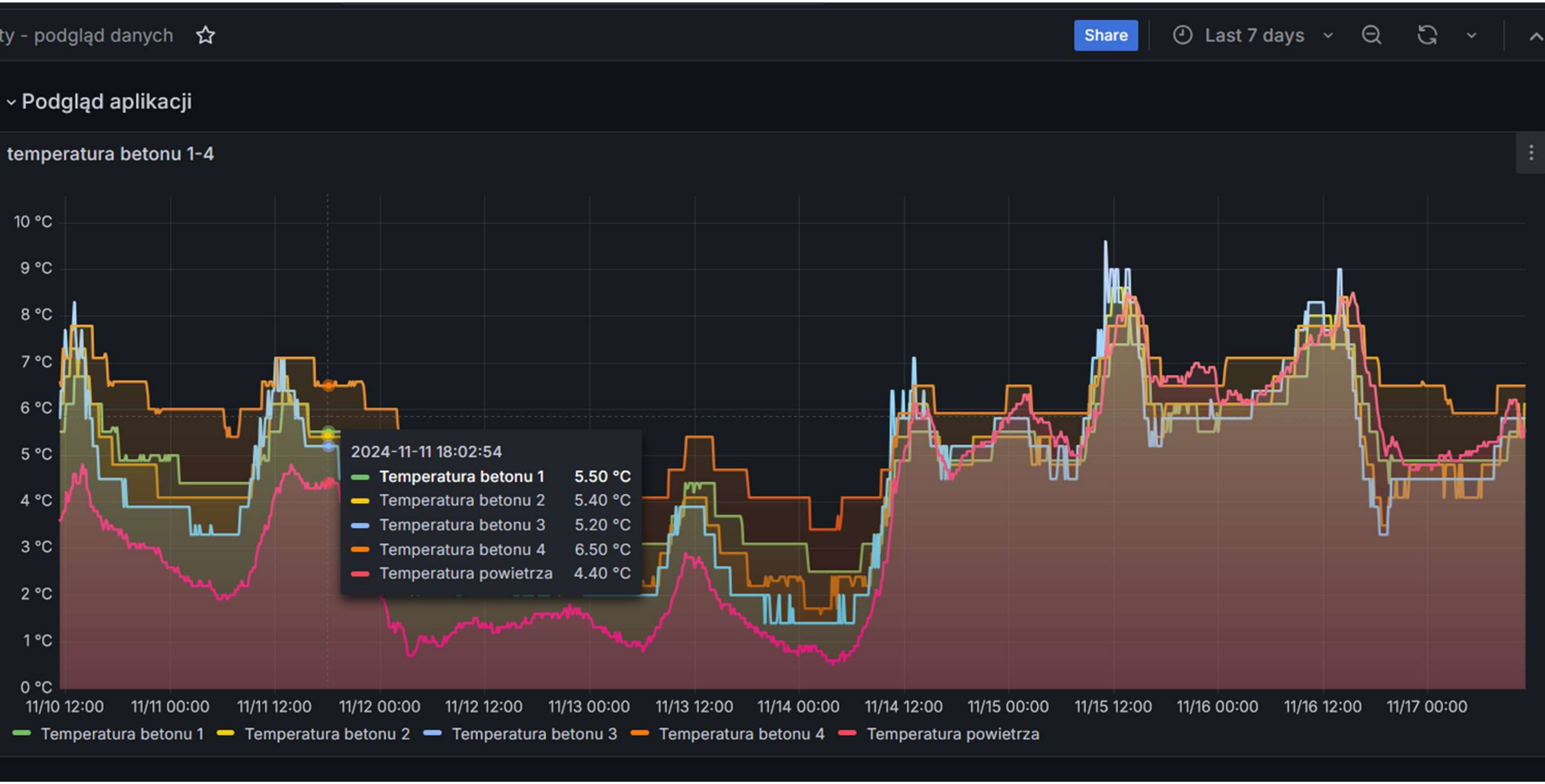
Monitoring will be carried out in the plots, including the following studies:

meteorological parameters such as air temperature,

precipitation amount, wind speed, relative humidity,

measurement of surface temperature, which will make it possible to determine any differences and reductions in the heating temperature of such surfaces in urban areas,

measurement of **surface runoff, measurement of humidity, temperature, salinity in the substrate near trees to determine water needs, measurement of CO_2**.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Last 7 days
Podgląd aplikacji
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Temperatura betonu 2 5.40 °C
Temperatura betonu 3 5.20 °C
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Temperatura betonu 4
Temperatura powietrza

To summarise:

The use of an structural soil SGGW pavements allows **planting and maintenance of trees in areas covered by pavements where previously this was not possible at all**, thus increasing green spaces in cities with high levels of ecosystem services or improving the functioning of existing spaces.

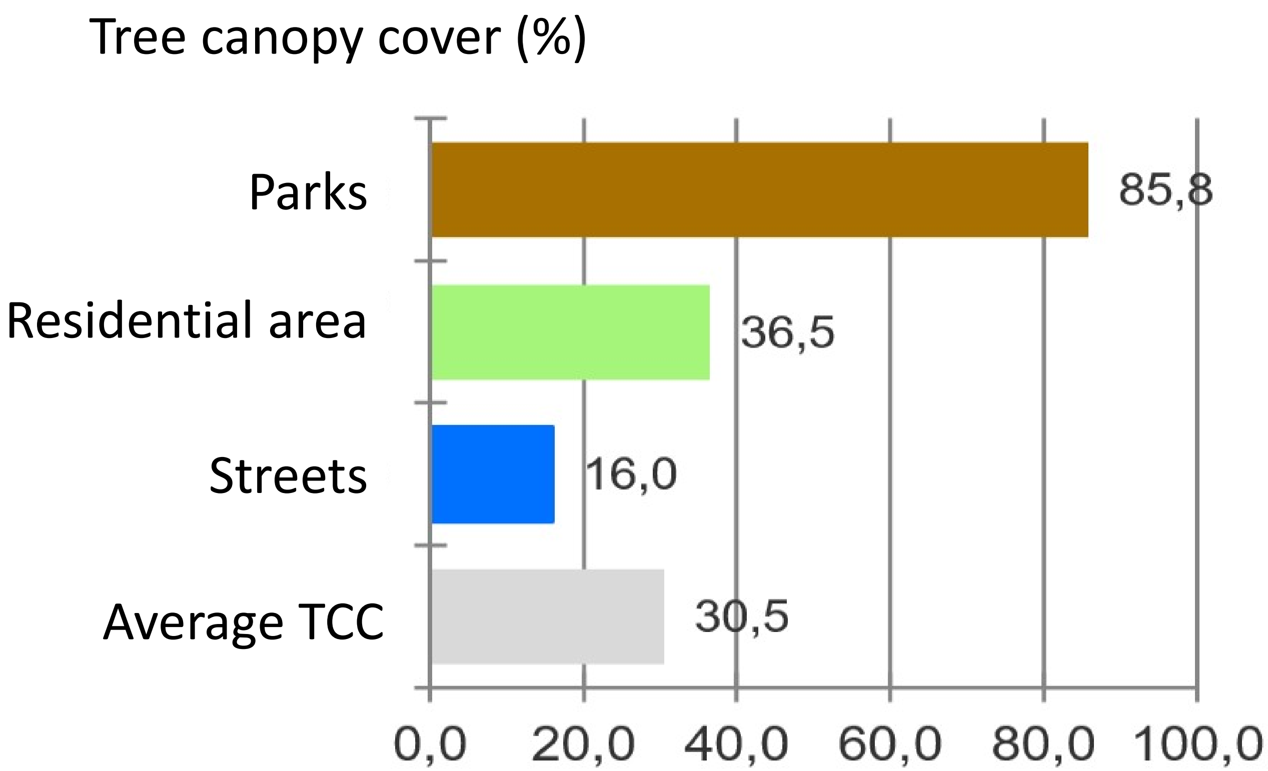
The structural soil SGGW ensures that the load-bearing capacity required for the road base E2>80 MPa (pedestrian and road traffic) is achieved .

Depending on the arrangement of layers, the tested variants of anti-compression substructure have a **retention capacity of 0.17 to 0.31 m3/m2**.

Crucial for the level of ecosystem services is that the trees reach **at least medium size**, i.e. an age of about 40-50 years (25 m3 to 35 m3 of retained water).

The application of the solutions described in this study allows improving the habitat conditions of **newly planted trees** in situations of space scarcity (open ground) and of **existing trees**, and has the potential to provide in highly urbanized urban conditions the possibility of long-term tree growth until natural aging.

HOW TO MANAGE URBAN FOREST?



What factor is optimal?

Allows for the establishment of targets necessary to achieve the optimal proportion of green space (e.g., 30% canopy cover) (Barron et al., 2016).

The tree canopy cover of the study area is 30.5%.

More than 33% canopy cover significantly reduces stress, anxiety and depression.

The 3-30-300 rule is an alternative for Dr. Frank Santamour's 10-20-30 rule for ensuring species diversity in urban areas. He outlined the importance of species diversity in urban forests to build resistance to pests and diseases. He argued, that a city's urban forest composition should not have more than **10%** of the same tree species, no more than **20%** of a single tree genus and should not exceed 30% of the same family.

PLANING FACTOR

However, the 10-20-30 rule, does not have a specific focus on the benefits provided by urban forests. From the perspective of challenges we have to face nowadays such as climate and public health urgencies, the 3-30-300 rule seems more useful to introduce a guiding principle for urban forest programmes, and city greening across the world, that ensure that all residents have access to trees and green areas – and the benefits these provide.

3 TREES FROM EVERY HOME

The first element of the rule is that every citizen should be able to see at least three trees (of a decent size) from their home. Studies have shown that fewer large-sized trees impacted resident mental health more positively than a larger number of smaller ones (Chi et al. 2022). The three trees can be seen as indicator for visible green space. Seeing green from our windows helps us keep in touch with beauty of the nature. It provides important breaks from our work and can inspire us and make us more creative. The specific number '3' is not supported by scientific evidence but was chosen to connect with the numbers 30 and 300 from a communication and 'stickiness' perspective.

30 PERCENT TREE CANOPY COVER IN EVERY NEIGHBOURHOOD

Second element of the rule is about the percentage of tree canopy cover in resident's neighbourhood. The multi-level research of Dr. Thomas Astell-Burt from University of Sydney in Australia has repeatedly found that 30% is an important threshold – a minimum canopy cover percentage which ensures residents benefit in terms of their health and wellbeing. A number of studies have shown significant association between tree canopy and cooling, better microclimate, mental and physical health and reduction of air pollution and noise. Many of the most ambitious cities in the world in terms of greening, including Bristol, Canberra, Seattle and Vancouver have set a target of achieving 30% canopy cover. At the neighbourhood level, 30 percent should be a minimum, and cities should strive for even higher canopy cover when possible.

300 METRES FROM THE NEAREST PARK OR GREEN SPACES

The World Health Organization recommends a maximum distance of 300 metres to the nearest green area of at least 1 hectare. The size of green space is important because larger parks and other bigger green spaces have been associated with more recreational opportunities including functioning as social meeting places, and offering opportunities for children's play. There's also higher levels of biodiversity. Unfortunately this is not always possible to achieve but a decent size of 0.5 ha should be a minimum. In addition it's important to pay attention to the context of the area and housing density. Either way as a designers we have to provide the access to high-quality urban green areas.

THE EVALUATION OF THE 3-30-300 GREEN SPACE RULE AND MENTAL HEALTH

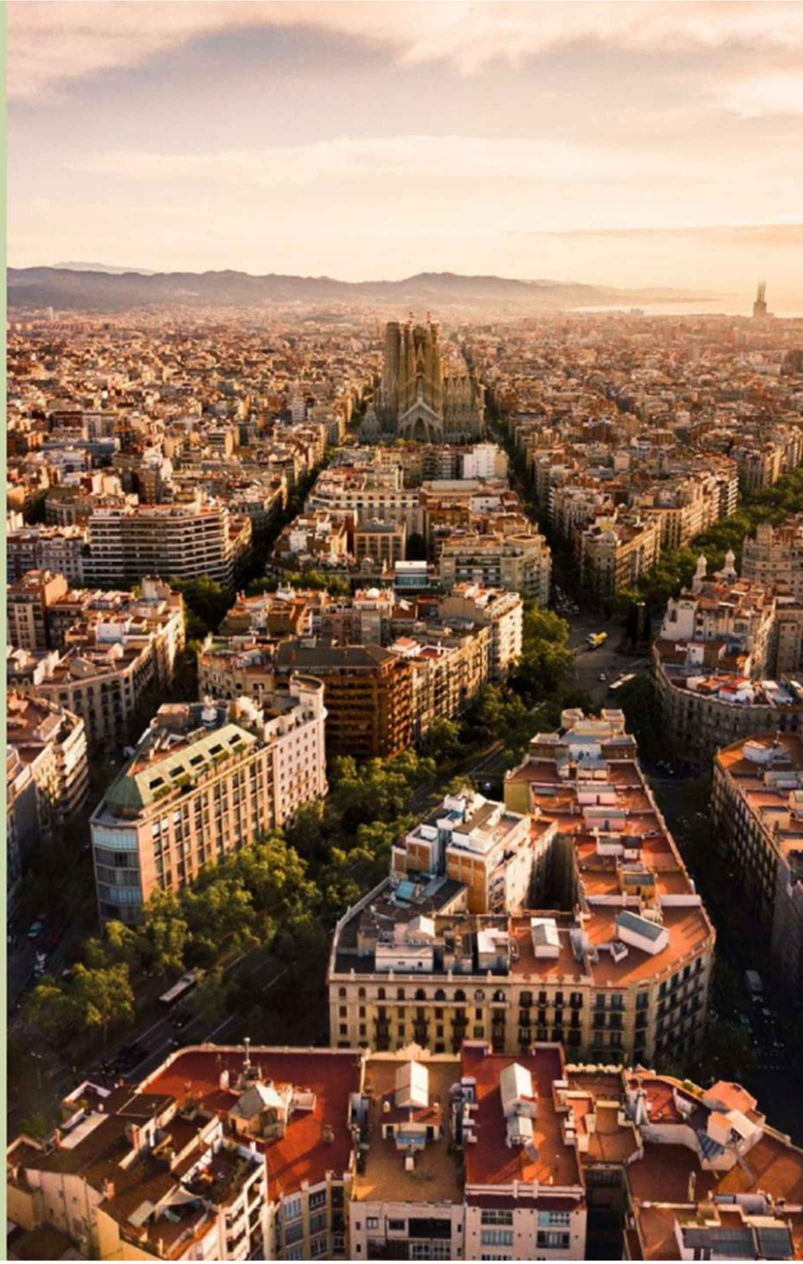
Mark J. Nieuwenhuijsen, Payam Dadvand

AIM

The aim of this study was to evaluate the relationship between the 3-30-300 rule and its components in relation to mental health.

METHODS

Researchers conducted a cross-sectional study based on a population-based sample of 3145 individuals aged 15-97 years from Barcelona. They created 3-30-300 green space indicators using questionnaire data, GIS, remote sensing and land cover maps. Mental health status was assessed with the 12-item General Health Questionnaire (GHQ-12) and also the use of medication such as tranquilizer/sedatives or antidepressants and psychiatrist or psychologist visits.

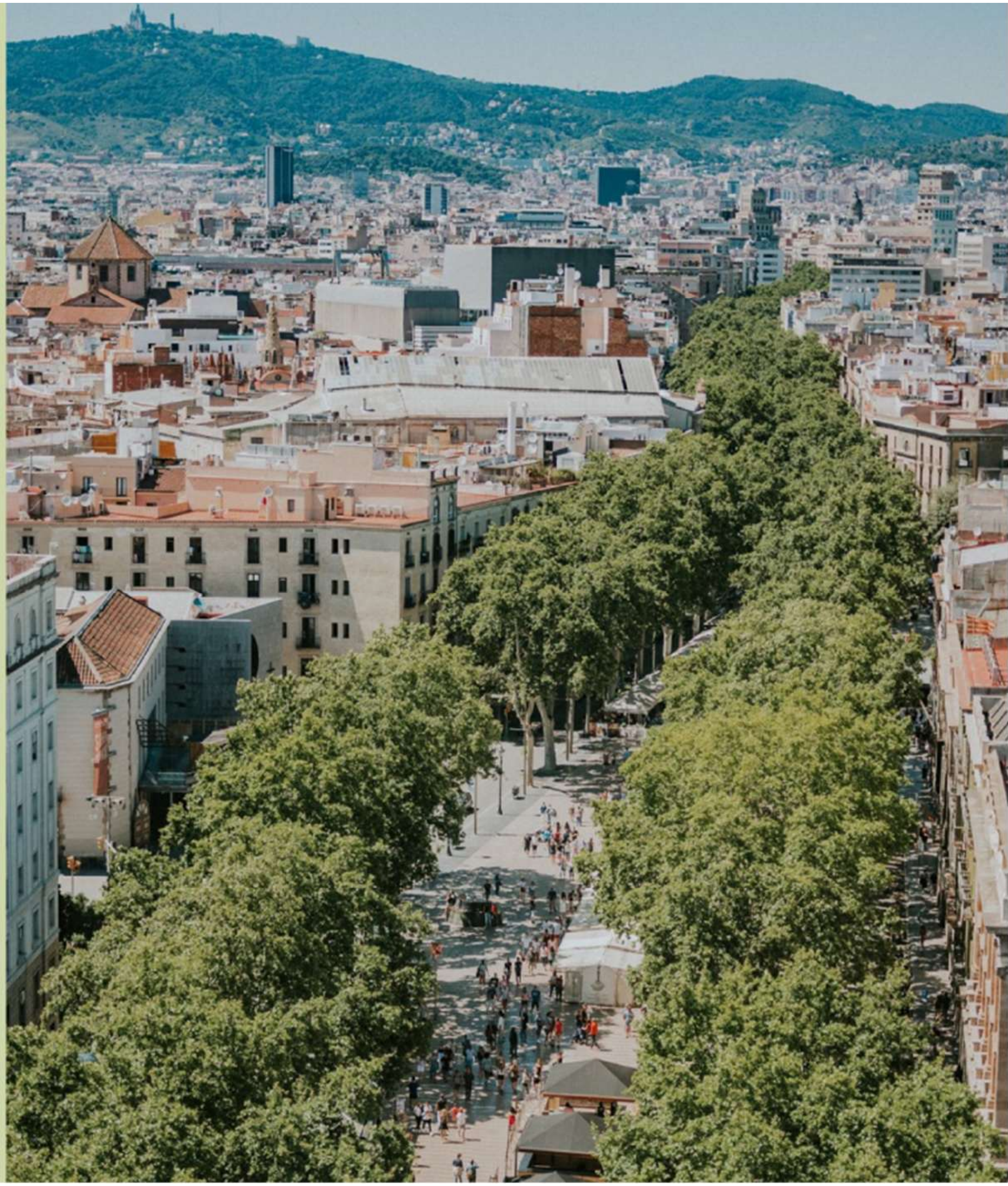


RESULTS

People in Barcelona have relatively little exposure to green spaces, whether through window view, living in an area with sufficient greenness, or access to a major green areas such as parks or forests Only 4.7% fulfilled the cryteria of 3-30-300 rule. Residential surrounding greenness, but not tree window view or access to major green space, was significantly associated with better mental health, less medication use, and fewer psychologist or psychiatrist visits compared to people who did not have an access to any of these elements.

CONCLUSION

Only a small group of people can fulfill the cryteria of 3-30-300 rule in Barcelona. Nevertheless they achieve the biggest health benefits.



A LOOK AT ACCESS TO GREEN SPACE IN TORONTO USING THE 3-30-300 RULE FOR GREENER CITIES

Kuntusangpo Ling

AIM

The aim of this study was determine the proportion of residences in Toronto and Mississauga that meet the 3-30-300 rule and to verify if there is a relationship between price of the residence and access to green space in these areas.

METHODS

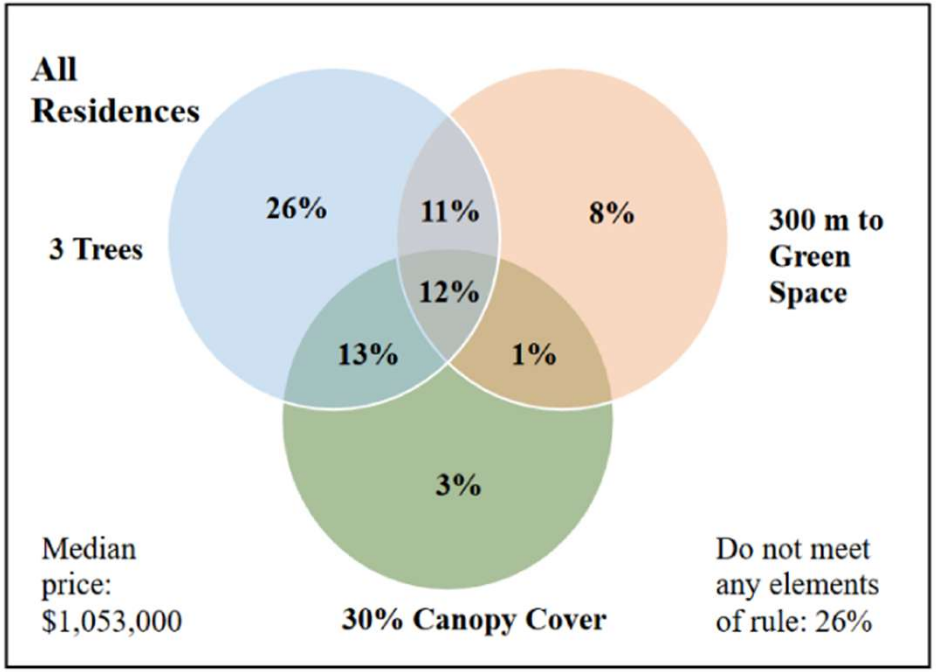
Researcher created a list constisting of 180 3-bedroom row houses and townhouses in different neighbourhoods in Toronto and Mississauga from an advertising website that were accessed in October and November 2021. Each residence was evaluated to see if it met each element of the 3-30-300 rule.

RESULTS

Of the 180 residences, 12% (22 residences) meet the entire 3-30-300 rule. Of note, 26% (47 residences) did not meet any element of the rule. The residences with the most expensive prices have a higher proportion than the other residences that meet the entire rule and each element of the rule. The residences with the most expensive prices also have the lowest proportion that do not meet any element of the rule.

CONCLUSION

The correlation between the listing price of a residence and all elements of the rule are statistically significant. The higher the listing price of a residence, the more accessible green space there is for that residence.



	Median Price ($)	Proportion that Meets Entire Rule (%)	Proportion that Meets 3-Tree Element (%)	Proportion that Meets 30% Canopy Cover Element (%)	Proportion that Meets 300 m Distance to Green Space Element (%)	Proportion that Does Not Meet Any Element (%)
Most Expensive	1,654,500	18	75	46	38	12
Midrange	1,053,000	8	55	22	21	40
Least Expensive	779,450	10	57	20	37	25

Table 1: Proportion of residences that meet the entire rule and elements of the rule, and that do not meet any element of the rule when divided into groups by listing price. The median price of each group is also listed.

How trees can mitigate heat in urban ecosystems[3]

Without a tree canopy, the heat from the sun directly hits the ground and gets trapped; it is subsequently released into the atmosphere, increasing the temperature.

Tree canopy cover can create 10-degree temperature differences.

http://lesjardiniersdeliledefrance.com/impact-environnemental/

[3]https://www.architectureanddesign.com.au/news/how-trees-can-mitigate-heat-in-urban-ecosystems#

How much greenery is enough?

increasing the city's **tree canopy cover to 30%** (from the 20% calculated in 2014) prevented 403 deaths per year (**3% of total mortality**), with the smaller increase still resulting in reduced mortality.

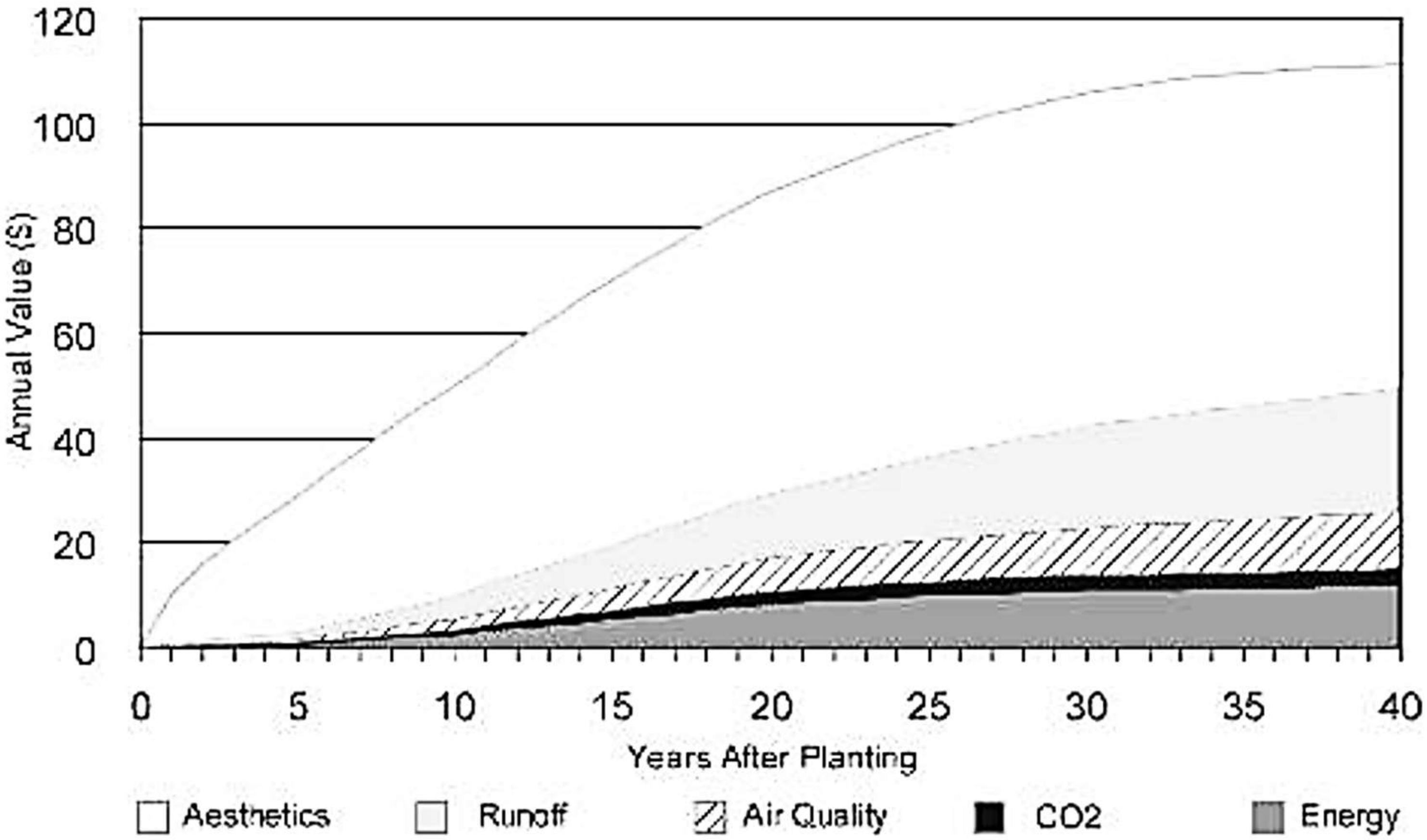
a 5% increase in tree canopy cover in areas where there are no trees could **result in 302 fewer deaths** per year citywide,

and an increase of **10%** could lead to a **reduction in mortality of 376 people**.

Residents of low socioeconomic status living in greenery-poor neighborhoods would benefit the most from an increase in tree canopy cover.

According to Kondo et al. (2020), an increase in tree canopy cover is an essential element of urban planning policy to promote social health and **environmental justice**.

annual benefits of ash trees



Arboriculture & Urban Forestry 33(1): January 2007

The calculations of the **replacement value of trees and ecosystem services** provide a basis for analysis of optimal tree satructure within the City.

Making replacement values and ecosystem services publicly available supports the management process by enabling **rational planning and benefit-cost analyses**.

Education is needed on the **relationships between organisms and conservation priorities**, such as protecting large and mature trees and green coridors.

Nowadays challanges are veryfing the priorities of urban forest management

Local land use plans and **city council standards** have a potential of playng the role of effective and important management tools.

Heat stress mitigation

Cooling with trees and vegetation

dr Marzena Suchocka

Landscape Architecture Department

Warsaw University of Life Sciences

Warsaw | 11 04 2025

Interreg CENTRAL EUROPE

Co-funded by the European Union

CONE

Interreg CENTRAL EUROPE

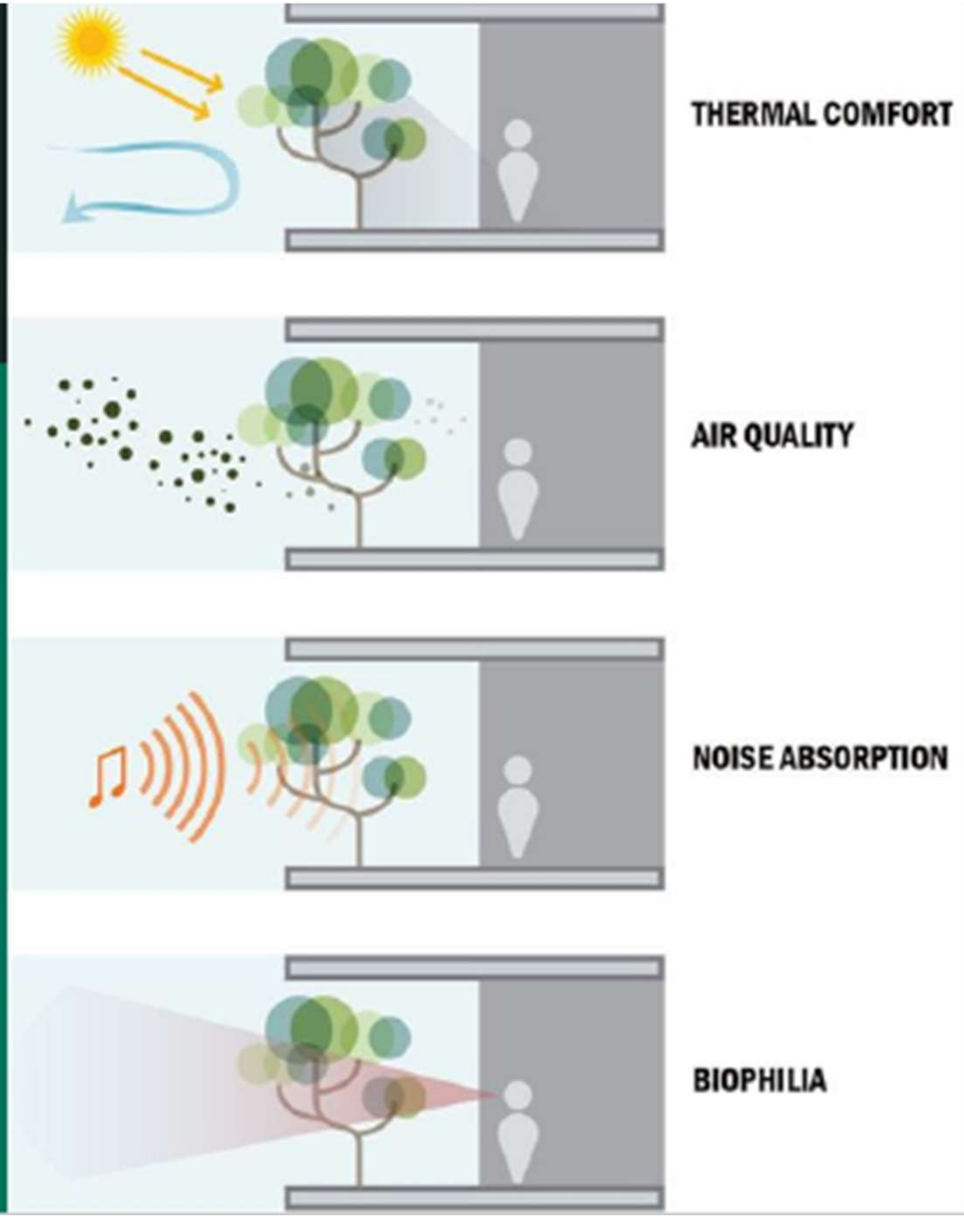
Co-funded by the European Union

CONE

- What impact do trees have on reducing the urban heat island (UHI)?
- Does plant species diversity have an impact on the reduction of heat stress in cities?
- What urban solutions increase the effectiveness of trees in combating heat stress?

WHAT BENEFITS DOES INTEGRATION OF TREES WITH BUILDINGS BRING US:

- Adding greenery to cities
- Cleaning the air
- Reducing urban heat
- Providing shade and shelter
- Making cities more beautiful
- Supporting wildlife
- Building sustainable cities

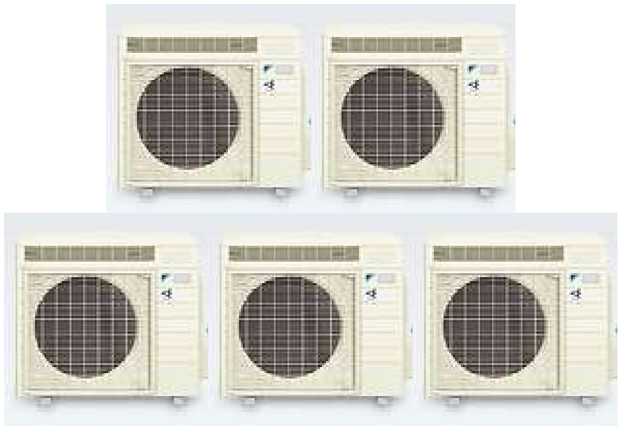


Heat stress- green solutions

To realize how great the cooling effect of one tree is, just imagine that a **large *Acer saccharinum*,** **can evaporate more than 265 liters of water per hour on a hot summer afternoon**.

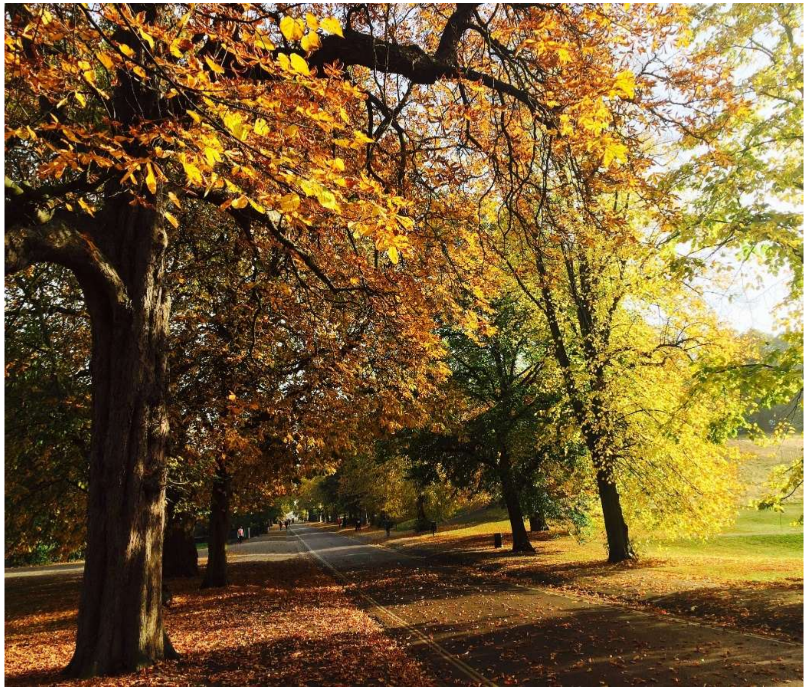
The effect of transpiration of such a large tree can be a cooling effect, which can be compared to the efficiency of **five average-sized air conditioners** (Leonard 1972).

=



Heat stress- Energy savings

- for London the best types for cooling the air are: Sessile Oak, Cherry Tree
- trees reduce 13% energy emissions in cities, saving £22 milion a year



http://anglistkazkrakowa.pl/jesien-w-londynie/

[2]https://www.energylivenews.com/2019/09/30/could-urban-trees-mean-we-can-leaf-air-conditioning-emissions-behind/

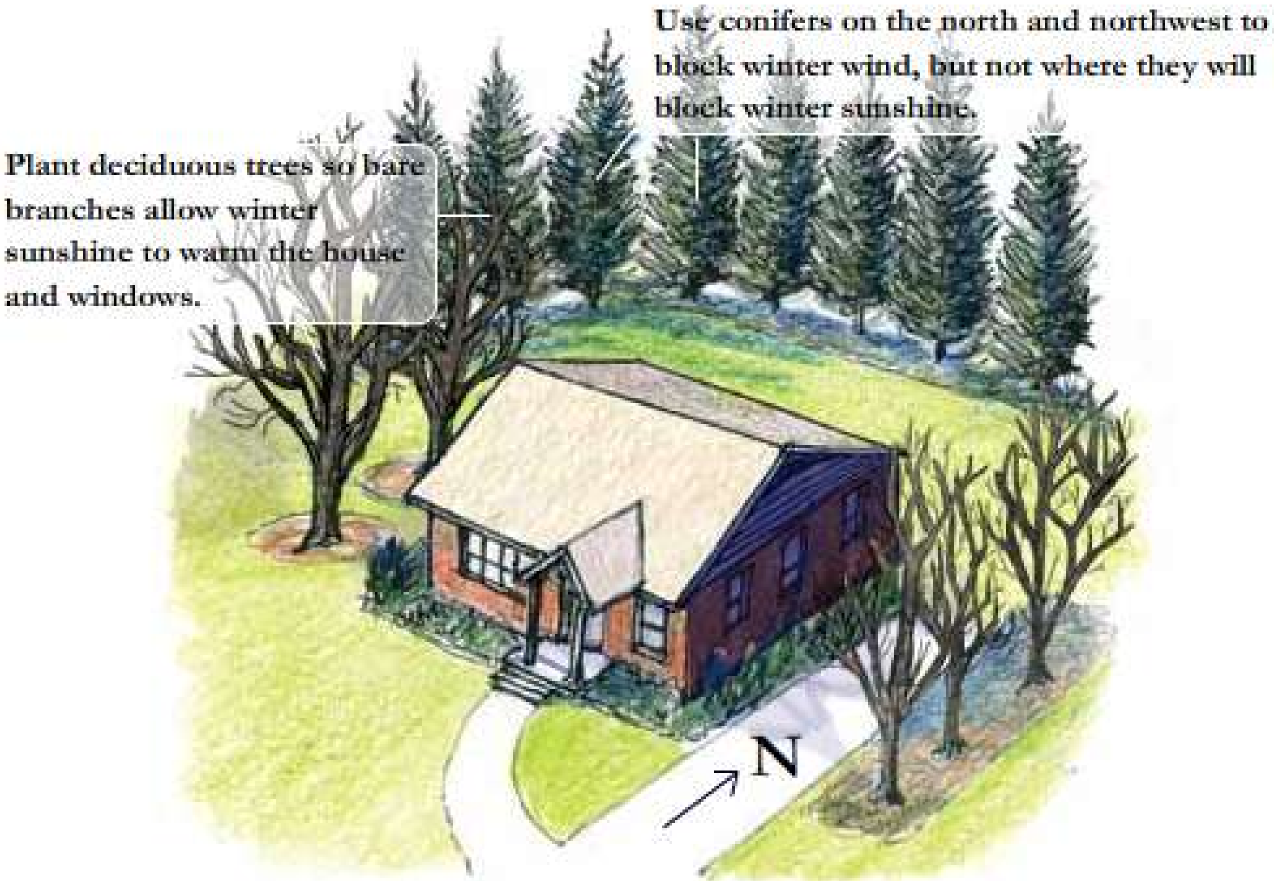
energy consumption for heating and cooling (Washington)

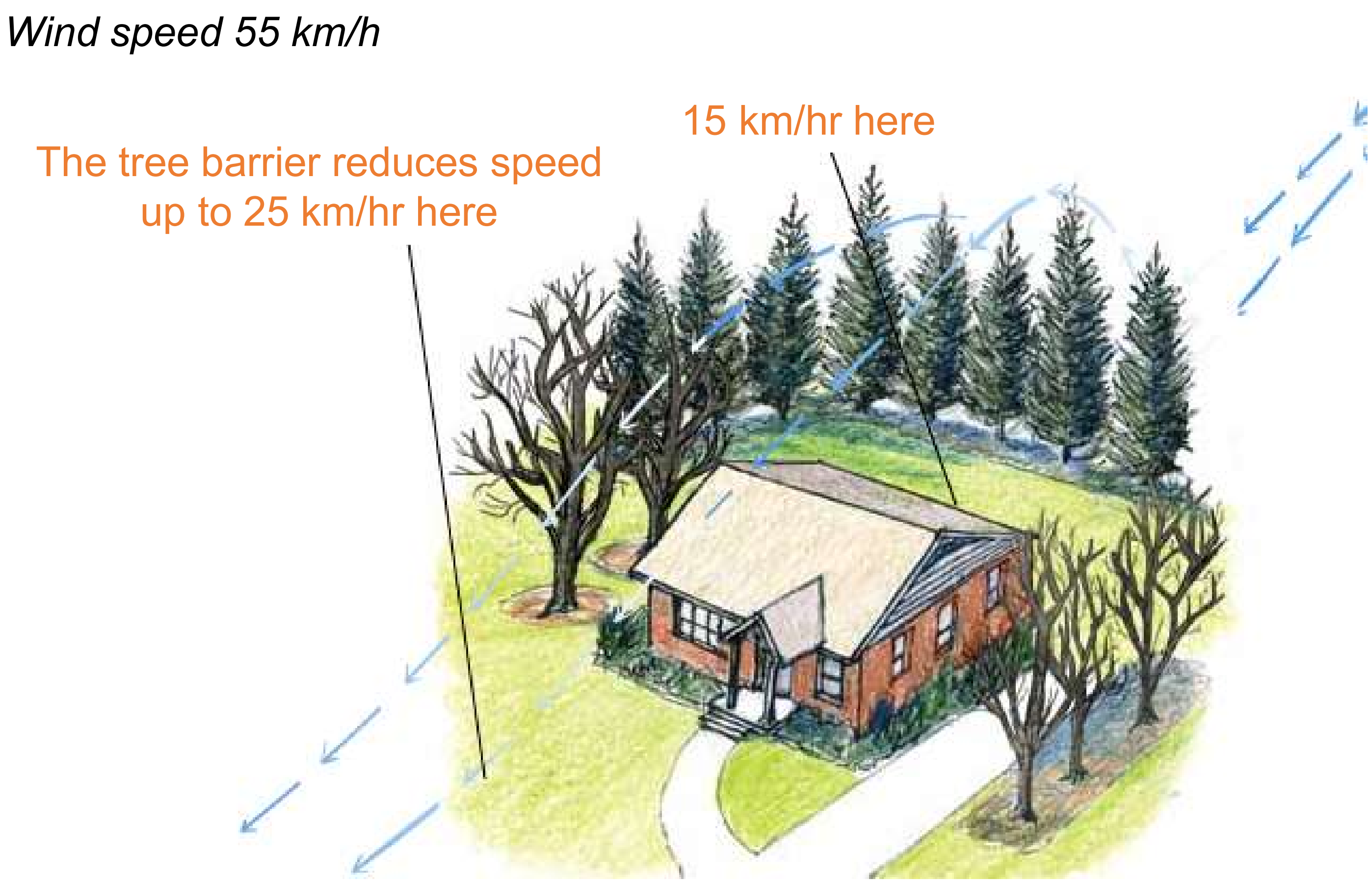
7 strategically placed trees reduce energy costs by $400 a year

24 dense conifers on the south side cause shade from the sun during winter, which increases energy costs by $300

Fig. 1. Typical tree planting guideline for energy-savings.

(wg. McPherson,1999)


Use conifers on the north and northwest to block winter wind, but not where they will block winter sunshine.
Plant deciduous trees so bare branches allow winter sunshine to warm the house and windows.
N



Planting a row of conifers on the north or north-western side of the building creates a wall to protect against cold winter winds ... **and reduces heating bills by up to 30%.**

Effect of tree shading on energy demand of two similar buildings

Effect of woody vegetation on cooling and energy savings in Acure city in Nigeria.

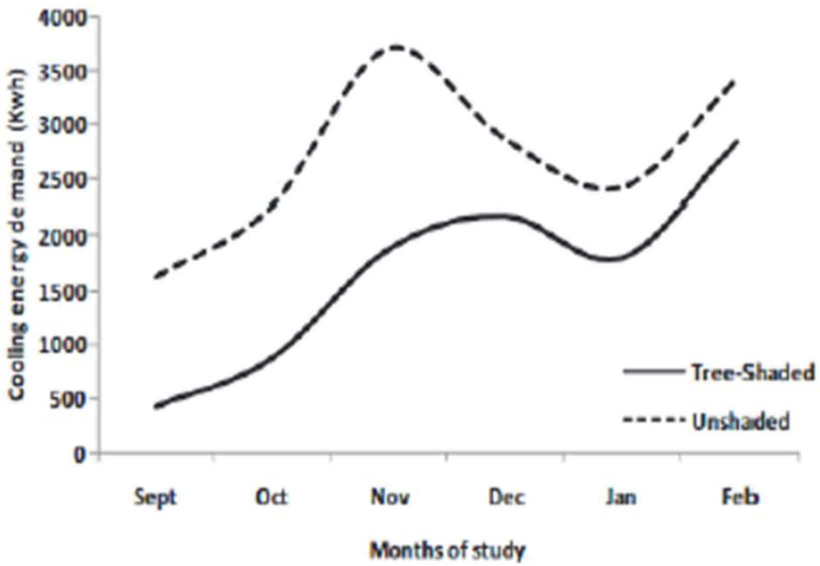
cooling effect of

un-shaded buildings compared to the tree-shaded one. Indoor warming and cooling rate show that the un-shaded building warms earlier and faster than the tree-shaded. Results indicate that tree-shading can save up to US$218 per month on energy costs.

Cooling devices and their energy demand in the building.

Cooling device	Quantity	Power consumption (per unit/W)	Total Power consumption (kWh)
AC	6	1353	8.118
Fan	4	147.5	0.59
Total	10	1500.5	8.708

Fig. 1. Outdoor environment showing the presence and absence of tree shades in both buildings.



A.A.Balogun, T. E.Morakinyo, O.B.Adegun

Effect of tree shading and transpiration on building cooling energy use

C.M.Hsieh, J.J.Li, L.Zhang, B.Schwegler

Effect of trees on cooling around the building – 4 scenarious of a typical summer day were simulated.

Nanjing city, China

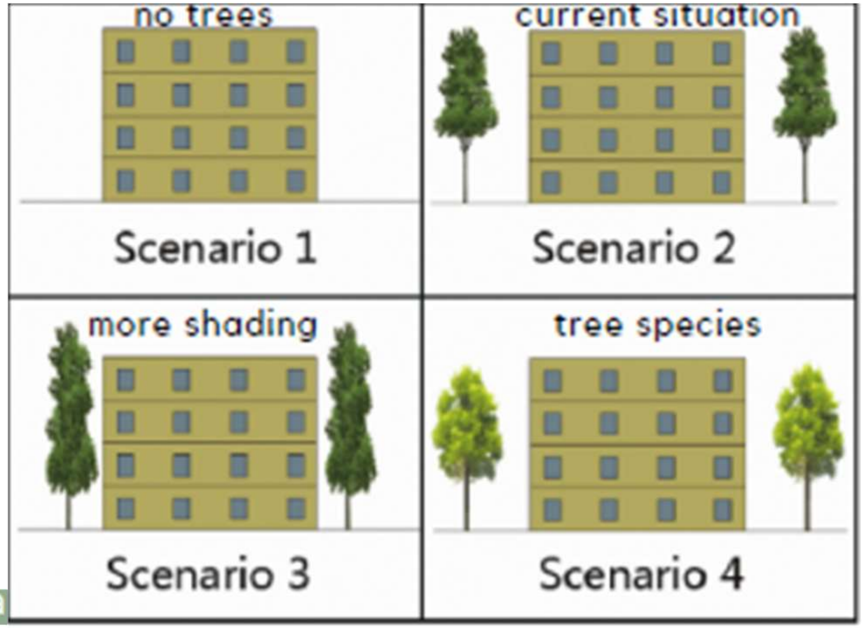


Fig. 4. Building and tree models of 4 scenarios in simulation.

The simulation results show that scenario 2 increased the cooling load of the building compared to scenario 1 by approximately 10 %. In scenario three, the cooling load was about 15.2% with maximum shading of the external building wall compared to scenario one. In scenario four, the existing tree species were replaced with species with higher transpiration rates, resulting in a reduction in the cooling load of the building of about 12% compared to scenario one

Effect of shelterbelt trees on reducing heating-energy consumption of office buildings in Scotland

Y. Liu, D.J. Harris

Effect of trees reduced significantly wind speed*, cousing reduction of external convection coeficient.*

It was observed ***energy savings by 18,1% of the total heat energy costs by placing sheltbelt trees*** *around a naturally ventilated office model with* ***glass fasades.***

Poorly designed seheltbelts can increase heating energy consumtion of building in winter.

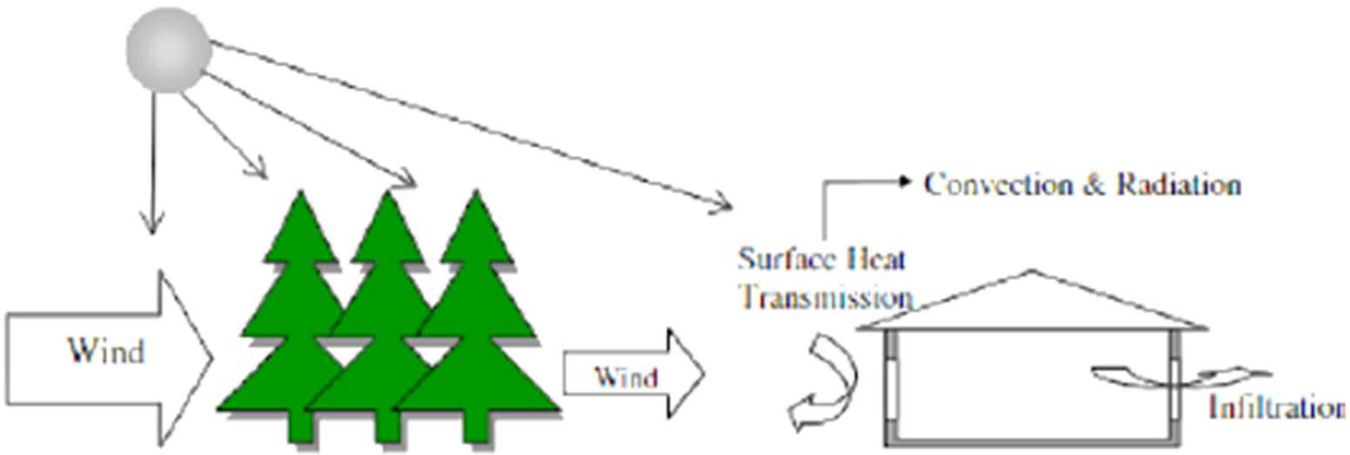


Fig. 1. Schematic diagram showing the effect of trees on building-energy consumption.

Assessing the effect of urban street trees on building cooling Energy needs:
the role of foliage density ond planting pattern

S.Tsoka, T.Leduc, A. Rodler

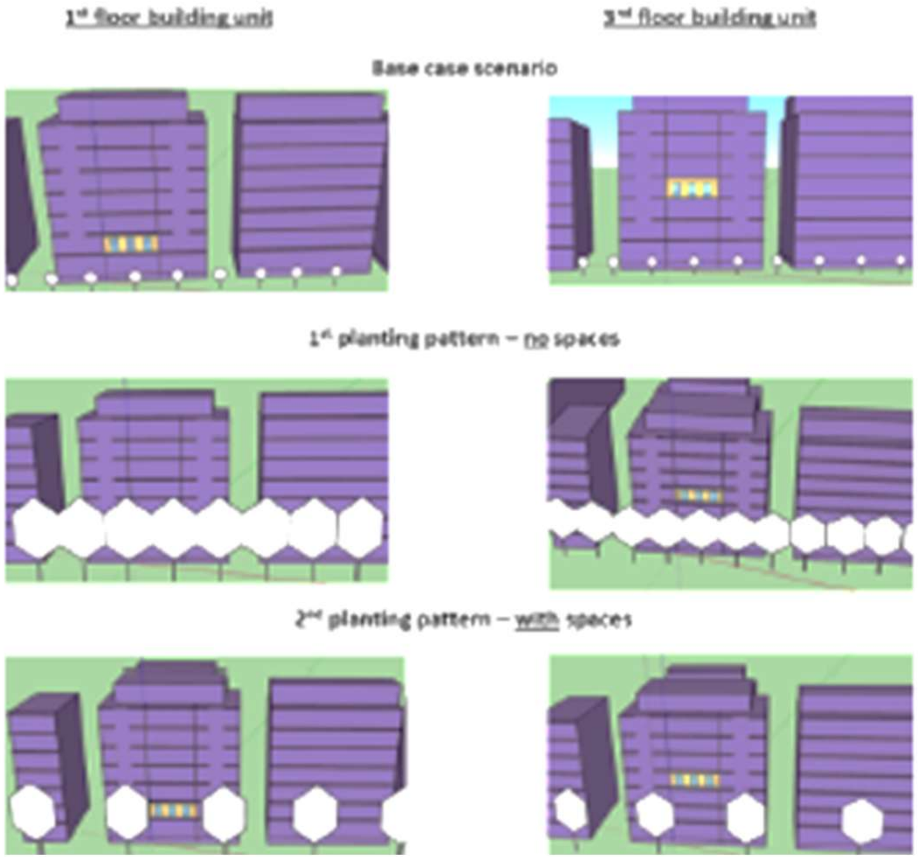
Effect of urban greenery on cooling energy demand of buildings by three comonnly used tree species (A. hippocastanum T. cordata and L. tulipifera) and two planting patterns (in rows and in rows with spacing)

simulation in the northen part of Greece.

*Street trees **decreased cooling enery demand for both examined building units** by combination of shadow effect and lower convective heat transfer.*

*The **higher the foliar density, the higher the solar radiation blockage** and the lower the solar heat gains of the thermal zone.*

*The higher **energy savings up to 54%** have been achived when the **trees formed a continiuous shading canopy** and the Leaf Area Density of 2,5 m2/m3.*



Trees and vegetation for residential energy conservation: A critical review for evidence-based urban greening in North America

Yekang Ko

- Evidence for trees' role in energy-saving is solid, especially for cooling.
- Energy savings widely varied from 2.3% to 90% (cooling) and 1% to 20% (heating).
- Careful attention to methods and assumptions is critical when interpreting results.

Planting medium to large stature solar-friendly trees around 9–10 meters away from the west wall of the building shows the largest cooling energy savings, followed by the east.

Planting tall trees on the south close to the house is not strongly recommended except in year-round very warm climates for multiple reasons: heating penalty in winter, potential structural issues by planting too close to the house to provide shade in summer, and potential conflicts with rooftop solar panels on south-facing roofs.

Biodiversity and climate change

Two questions:

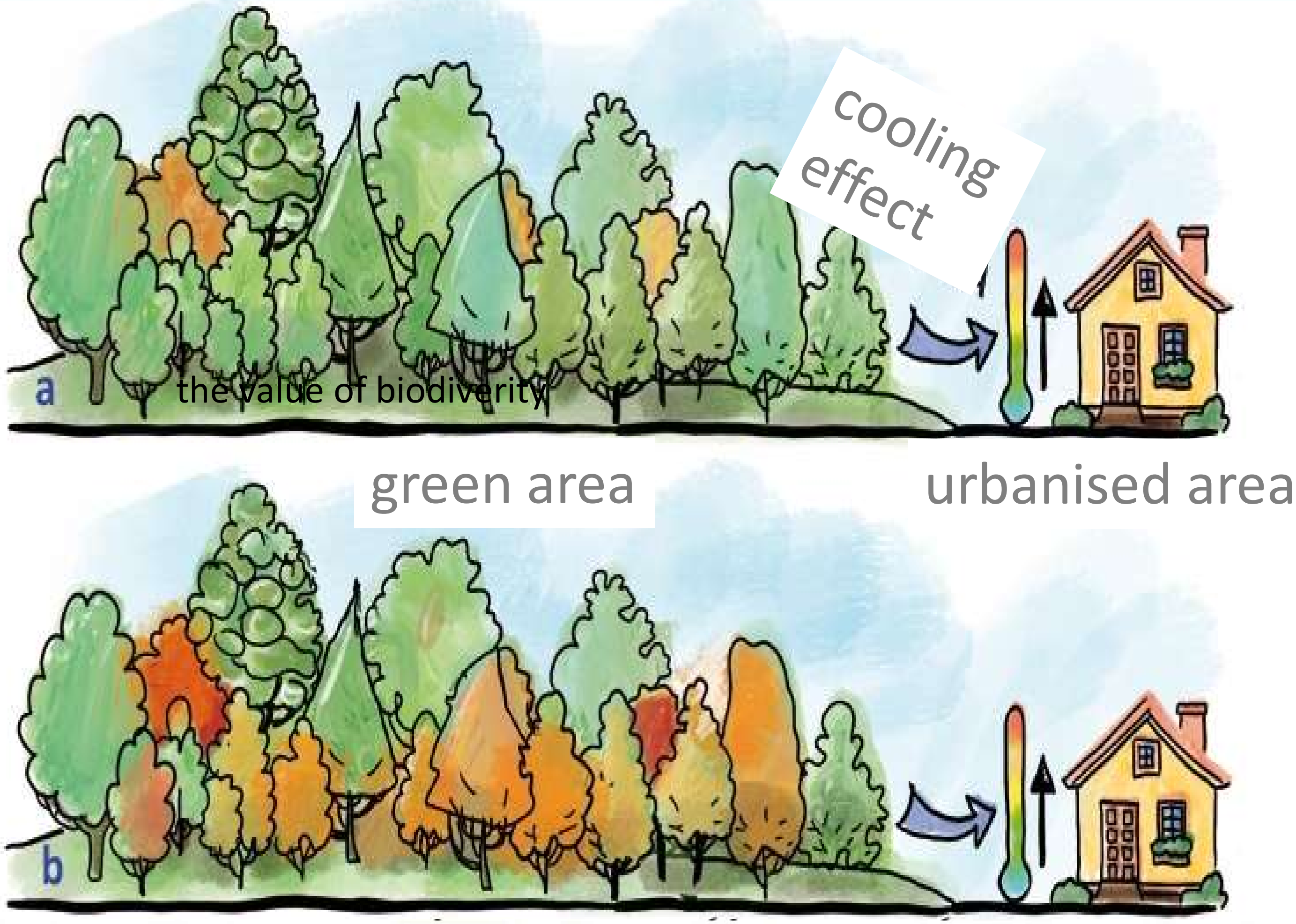
Why biodiversity is so imortant in the urban environment?

Is just a matter of the numer of the species?

MAMROT (Ministère des Affaires Municipales, des Régions et de l'Occupation du Territoire du Québec 2013):

Urban biodiversity refers to the variety of living organisms, including their genetic variations, as well as the multiplicity of habitats in and around dense human settlements.

Not only the tree cover, but also biodiversity was positively correlated with the extent of cooling (da Wong et al, 2021)



Greenspace (b) has a higher tree diversity. It provides a greater cooling effect than greenspace (a).

the value of biodiversity

Street Tree Diversity and Urban Heat

Rendon, P., Love, N., Pawlak, C., Yost, J., Ritter, M., & Doremus, J. (2024)

The article analysed whether greater street tree species diversity helps lower temperatures in California cities. Data from 136 urban areas from 2010-2018 were analysed. Data were derived from the urban tree inventory and official weather sources.

→ Tree diversity analysis based on the Shannon-Wiener Index.

→ Comparison of the effect of tree diversity on summer maximum and minimum temperatures.

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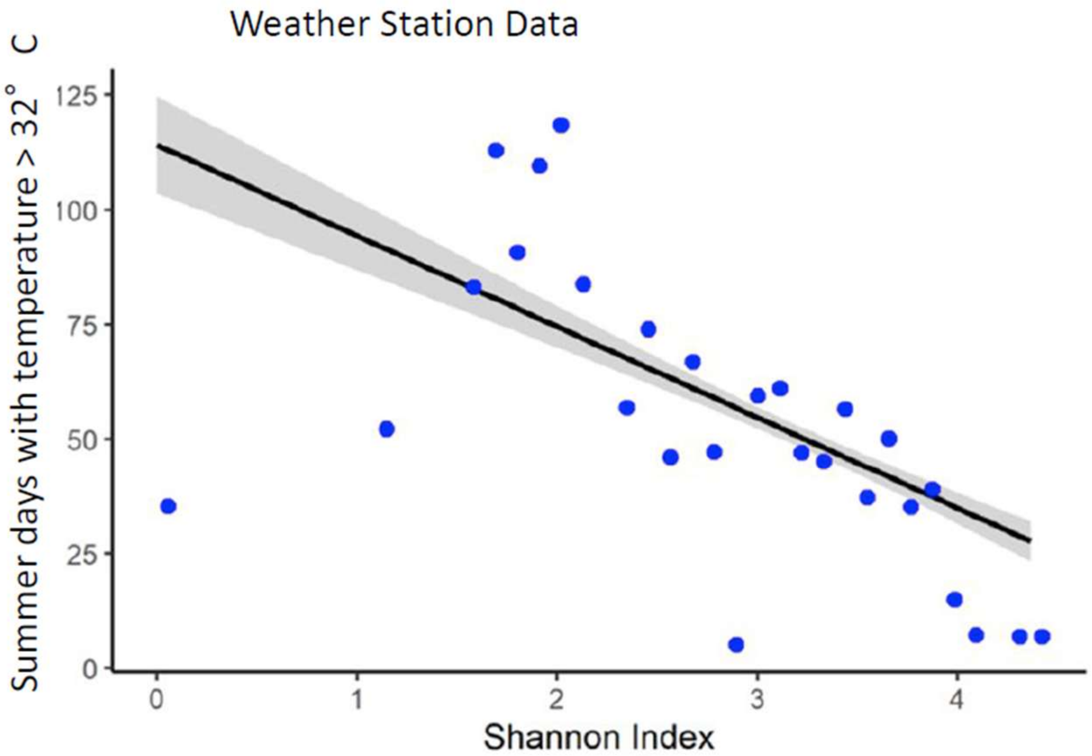
journal homepage: www.elsevier.com/locate/ufug

Street tree diversity and urban heat

Paola Rendon, Natalie Love, Camille Pawlak, Jenn Yost, Matthew Ritter, Jacqueline Doremus*

California Polytechnic State University, San Luis Obispo, USA



Data and results:

→ **Fewer extremely hot days (90°F / 32°C) in areas with diverse tree cover:**
A 1 unit increase in the Shannon-Wiener index resulted in up to 15% fewer hot days.

→ **Lower daily maximum temperatures:**
A 1 unit increase in tree diversity led to a 2.24-3.47°F (~1.2-1.9°C) reduction in daily maximum temperatures. This effect was independent of total canopy cover, demonstrating that biodiversity itself plays a role in cooling.

→ **Warmer night temperatures (heat storage effect):**
A 1 unit increase in tree diversity correlated with a 0.7-1.1°F (~0.4-0.6°C) increase in minimum night temperatures. Diverse tree crowns reduce temperature fluctuations.

→ **Structural diversity:**
Areas with greater variability in tree stem diameter (DBH) and height showed more significant cooling effects.

→ Greater tree diversity reduces maximum daily temperatures and the number of days above 90℉ (32°C).

→ Areas with higher tree diversity had cooler days but warmer nights, suggesting an insulating effect.

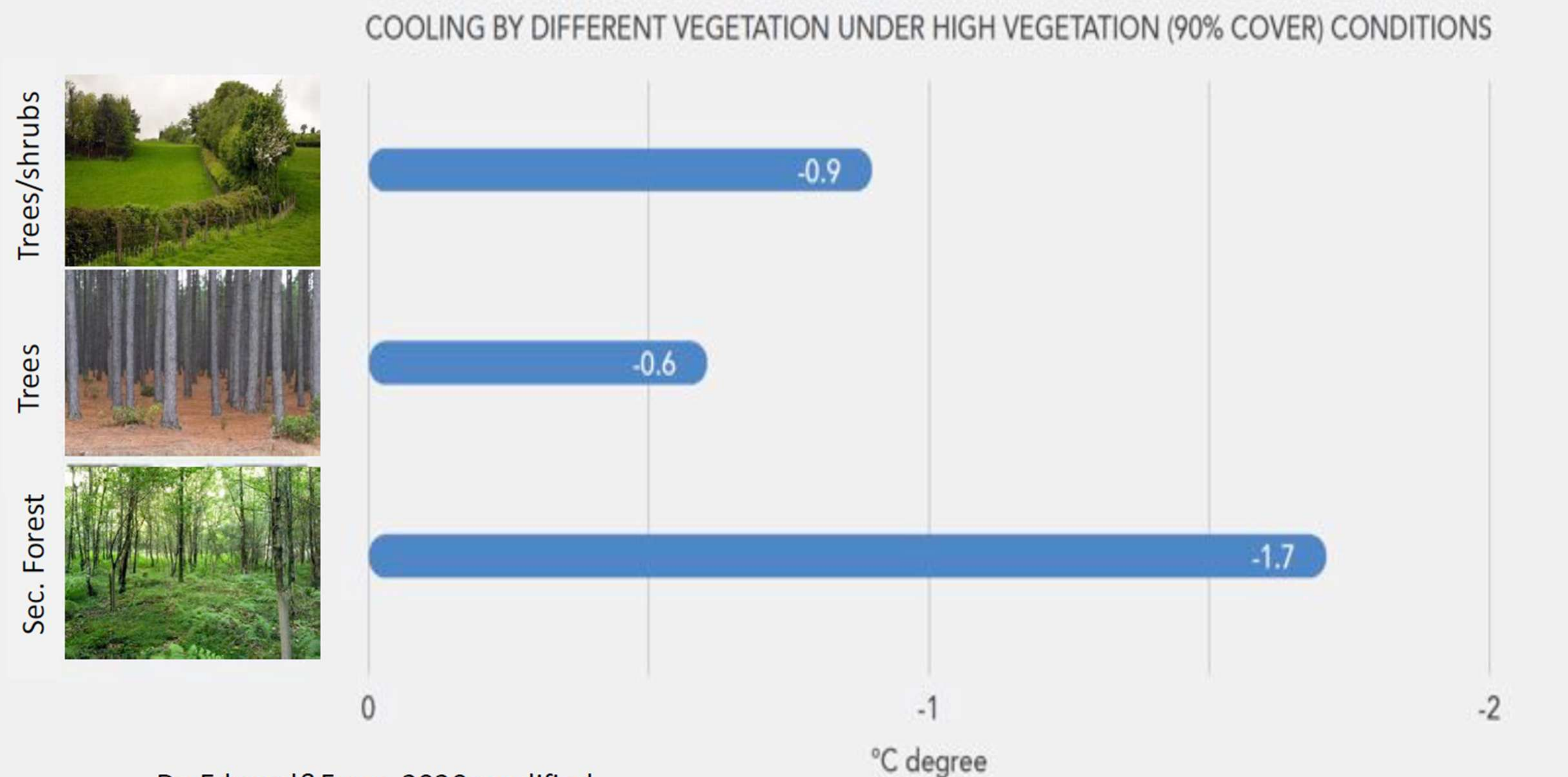
→ Species diversity may increase the ability of trees to cool cities, regardless of the amount of tree cover.

→ Diverse tree stands can be a key tool in city planning strategies to help adapt to climate change.

- **Biodiversity and Urban Heat Island**: The study of 136 urban zip codes in California shows that **greater tree species diversity is associated with lower summer maximum temperatures** and fewer days above 32° C, helping to mitigate the urban heat island effect.

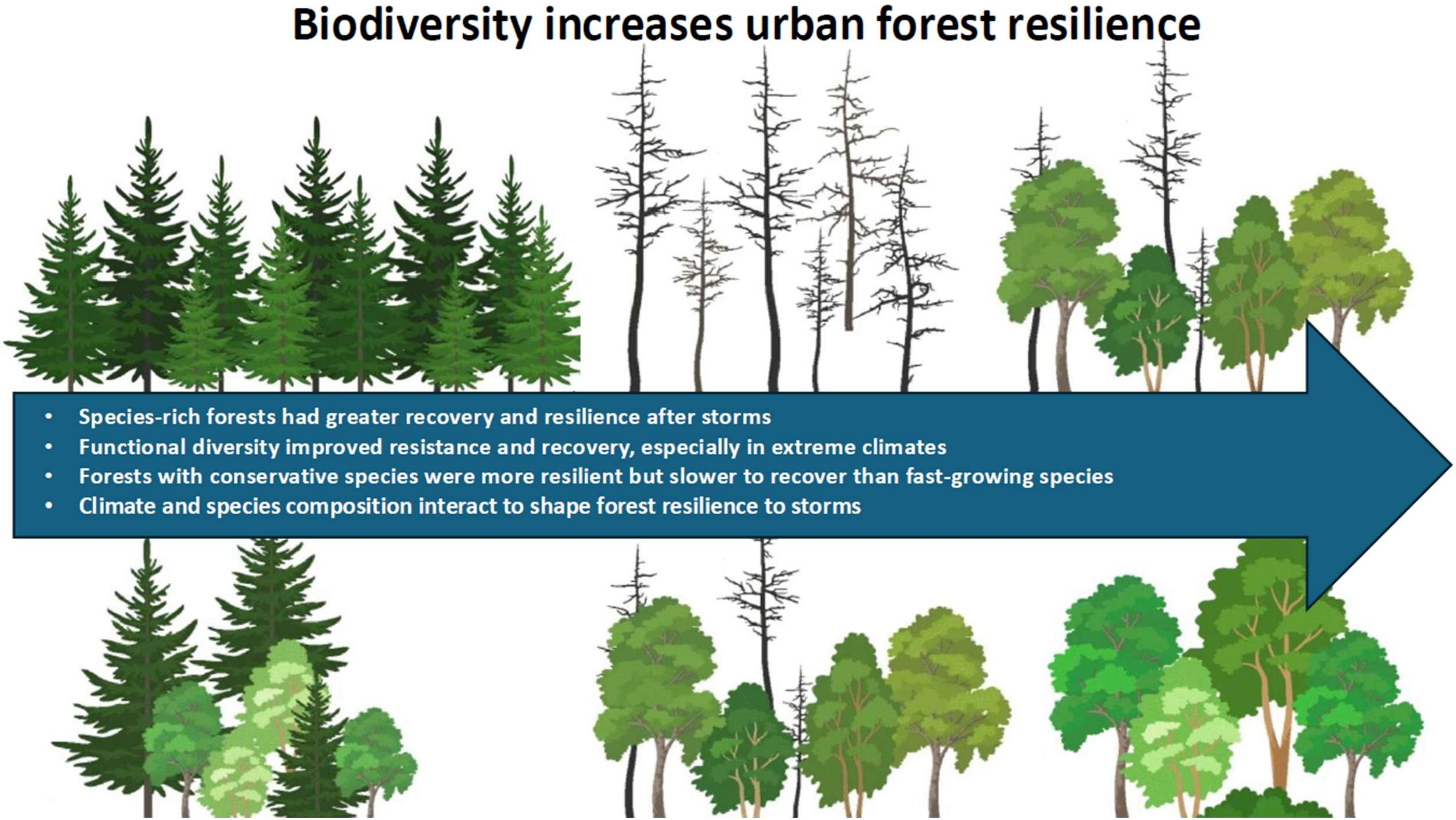
- **Impact independent of tree cover**: The results indicate that **the cooling effect of tree diversity is independent of tree canopy cover,** suggesting that species diversity plays a unique role in cooling urban areas.

- **Implications for urban planning**: The study suggests that **increasing tree diversity may be an effective strategy to reduce the impact of heat waves in cities**, especially in densely populated areas, providing equitable benefits to less affluent communities that cannot invest in artificial cooling systems.



Da Edward&Fung, 2020 modified

Sfondo da Coutts&Tapper, 2017


Biodiversity increases urban forest resilience
• Species-rich forests had greater recovery and resilience after storms
• Functional diversity improved resistance and recovery, especially in extreme climates
• Forests with conservative species were more resilient but slower to recover than fast-growing species
• Climate and species composition interact to shape forest resilience to storms

Nyssen, B., Ouden, J.D., Bindewald, A. *et al.* Established Invasive Tree Species Offer Opportunities for Forest Resilience to Climate Change. *Curr. For. Rep.* (2024). https://doi.org/10.1007/s40725-024-00232-6 (online 14.10.2024)

Functional diversity: the elements of biodiversity that influence how ecosystems function

Functional redundancy: The occurrence in the same ecosystem of species filling similar roles, which results in a sort of insurance in the ecosystem, with one species able to replace a similar species from the same functional niche.

a. Richness: 2 species
Functional diversity: high
Functional redundancy: low

b. Richness: 6 species
Functional diversity: high
Functional redundancy: high

Illustration of the concepts of **functional diversity and functional redundancy** within two stands.
a. Although the stand in the **upper panel consists of only two tree species**, it has high functional diversity because they have very different functional properties: for example, one species is a deciduous broadleaf tree, and the other an evergreen conifer. However, because of the large difference in functional properties between these two species, functional redundancy is weak; if one species disappears, several specific functional properties are lost.
b. The lower stand also **has high functional diversity because it consists of six different species,** four deciduous broadleaf species and two conifer species with relatively similar characteristics. However, functional redundancy is high in this case because if one species disappears, the variation in functional traits in the stand will be maintained (adapted from Messier et al. 2019)

Cooling Benefits of Urban Tree Canopy: A Systematic Review

Yin, Y., Li, S., Xing, X., Zhou, X., Kang, Y., Hu, Q., & Li, Y. (2024)

The aim of the study was to determine the impact of trees on reducing urban heat stress and the heat island effect (UHI) by analysing the cooling effects of tree crowns at different scales: **urban, neighbourhood, local and individual.**

Urban scale

Increasing tree cover from 20% to 50% reduces surface temperature:

→ Mixed forest patches: −0.6°C to −3.4°C
→ Shrubs and grasslands: −0.4°C to −3.0°C
→ Mixed forest and grasslands: −0.6°C to −3.7°C

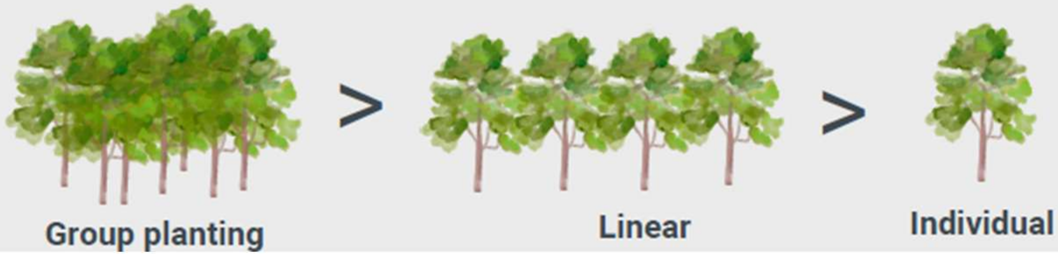
Best cooling effect occurs when:

→ Vegetation patches are larger and clustered
→ Patch shapes are compact (1 ha) or complex (>1 ha) depending on size

Neighbourhood

Deep canyons: require tall trees with sparse canopies for airflow.
Shallow canyons: benefit from dense canopy and lower trees.

Tree layout is important: Double - linear planting provides 1.7× better cooling than single - linear.



Local

Multi-layered vegetation (trees + shrubs + herbs) lowers the temperature:

→ 1.0°C on sunny days
→ 0.5°C on cloudy days

Double crown layers more effective than single crown layers

Individual tree

Species selection of trees is important

Tilia cordata: 4× more transpiration than Robinia pseudoacacia
Much more effective in cooling due to higher leaf mass and thinner leaves

Crown structure and shape

Trees with an umbrella-shaped crown provide the most shade and thermal comfort. This shape requires only 2.2 trees per 10,000 m^2 to reduce Physiological Equivalent Temperature (PET) by 1°C

Leaves - thickness, area, quantity

Thin leaves (<0.15 mm) = better transpiration and cooling capacity

Transpiration depends on the substrate

Combination with cool surfaces (albedo 0.8) increases the cooling effect.
On grass, trees transpire 10× more than on asphalt

- The effectiveness of cooling depends on the scale of the space being analysed. The smaller the scale, the greater the importance of plant features.
- Trees can reduce air and surface temperatures by up to 3-7°C, depending on their type, distribution and surroundings.
- Factors affecting cooling include crown cover, height and density; species diversity; climatic conditions and substrate type.
- The best results come from diverse, multi-layered and well-planned urban greenery

Influence of Trees on Heat Island Potential in an Urban Canyon

Gülten, A., Aksoy, U. T., & Öztop, H. F. (2016)

- Measurement of the effect of trees on HIP for selected summer days (1st, 11th and 21st of June, July and August).
- Comparison of results with and without the presence of trees.

Study area: Urban canyon - a street surrounded by tall buildings on both sides, restricting airflow and trapping heat.

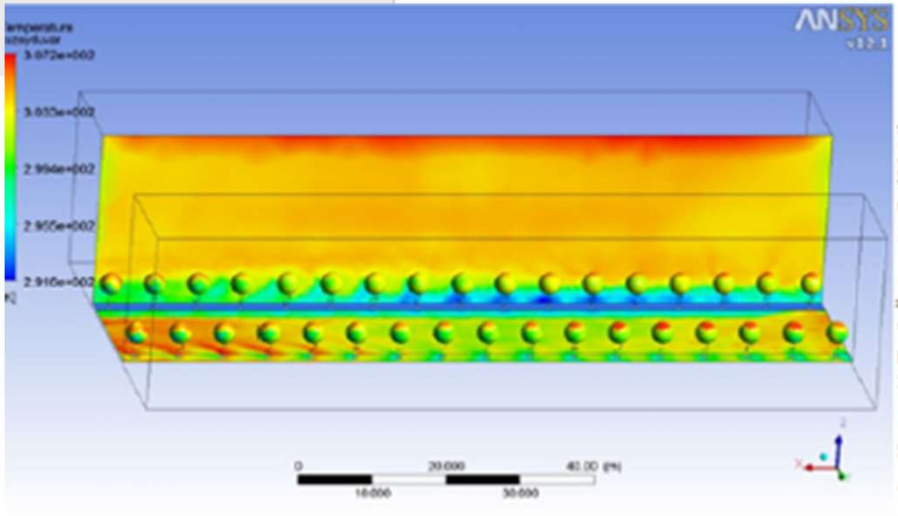


Fig. 9. Variation of surface temperatures by tree effect at June 11th for the hour 13.00.

Gülten, A., Aksoy, U. T., & Öztop, H. F. (2016)

Data and results:

Comparison Of Data With And Without Trees

	Date / Measurement	Without Trees	With Trees
1	Average HIP (June 11)	11.67°C	4.87°C (↓ ~60%)
2	Average HIP (July 11)	13.29°C	–2.25°C (↓ >100%)
3	Average HIP (August 11)	12.61°C	5.74°C (↓ ~55%)

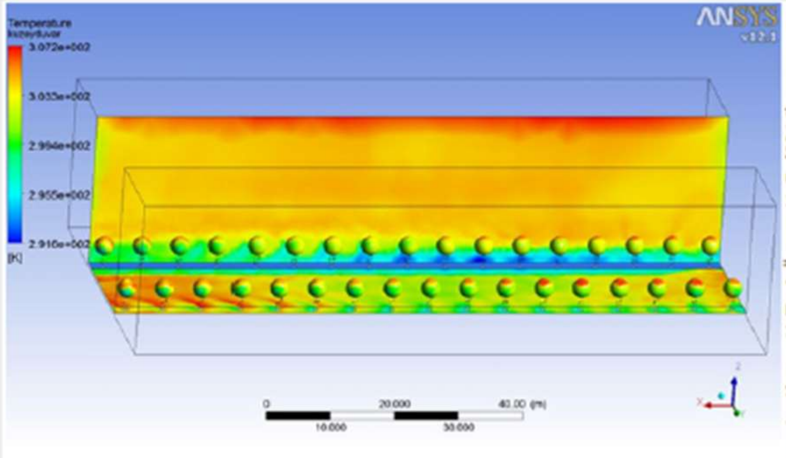


Fig. 9. Variation of surface temperatures by tree effect at June 11th for the hour 13.00.

Gülten, A., Aksoy, U. T., & Öztop, H. F. (2016)

Maximum pavement temperature withou trees:

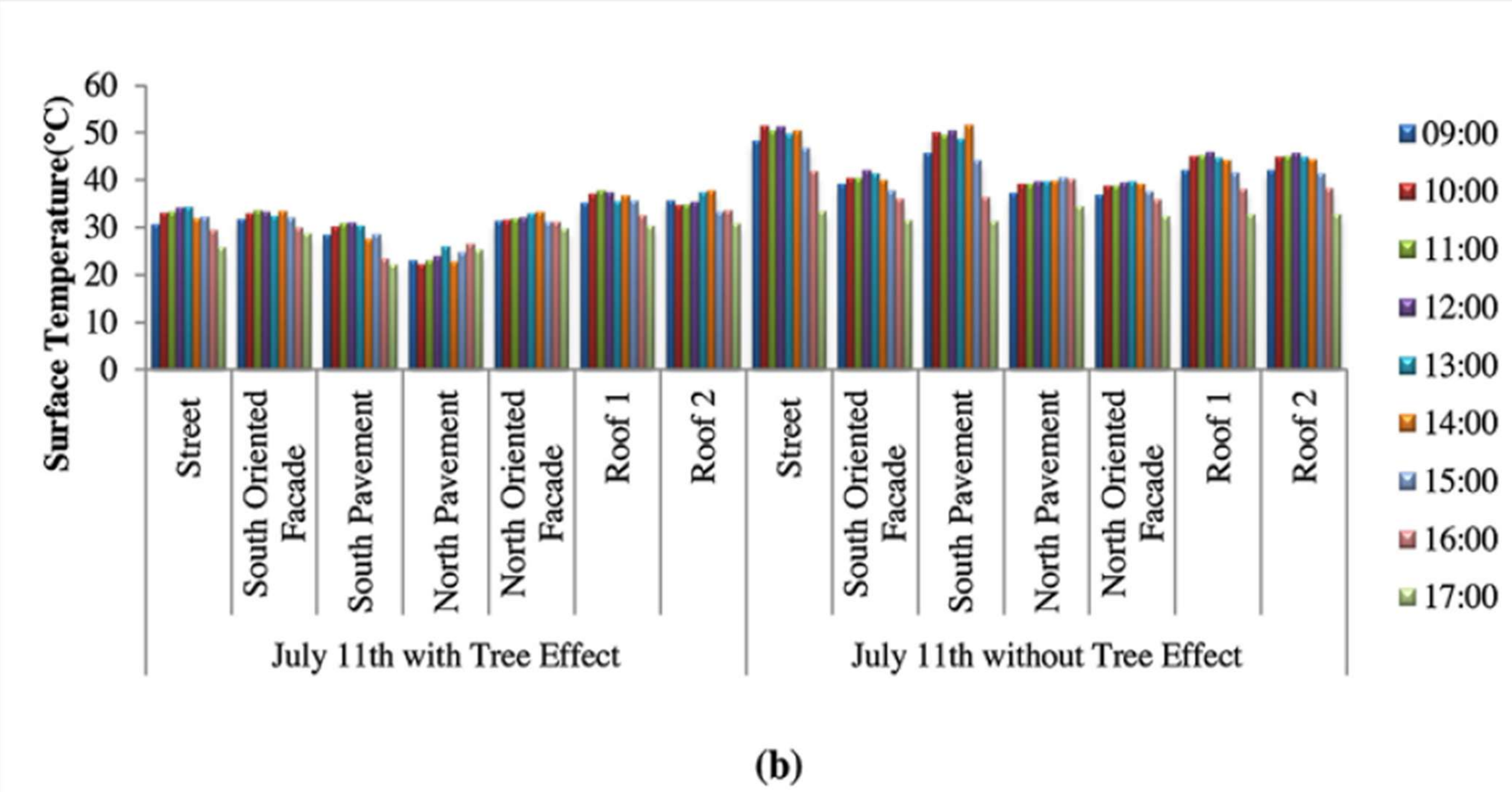
South pavement - 53°C (August 11, 12:00 pm)

Street - 51.93°C (August 1, 1pm)

Surface temperature reduction:

Up to 10-15°C less on pavements and elevations in the shade of trees.

The greatest cooling was observed in the afternoon (15:00-17:00).



Gülten, A., Aksoy, U. T., & Öztop, H. F. (2016)

Convection:

A study in the urban canyon of Elazığ (Turkey) also examined how trees affect convective cooling - cooling by air movement.

ON ROOFS:

Without trees: 4.76 W/m²
With trees: 3.26 W/m² by 31.5%.

ON PAVEMENTS:

Sunny side (without trees): 6.73 W/m²
Shaded side (with trees): 3.90 W/m² by 42%.

Irradiance - the flux of radiation per unit area (W/m2).

Despite the reduced convection, temperatures were generally lower in the presence of trees, so there was less need for intensive convective cooling.

- → Trees significantly reduce the heat island potential. HIP decreased by up to 60% in June and August, and fell by more than 100% in July .
- → The effect of trees on cooling depends on wind conditions - winds with low speed and appropriate direction were more effective in helping buildings cool.
- → The greatest temperature drop was recorded on pavements and building walls near trees. Roofs and upper parts of buildings had less cooling effect.
- → Trees can simultaneously protect against heat and reduce convection, which requires conscious planning of their placement in urban spaces.

Street trees and Urban Heat Island in Glasgow: Mitigation through the ‘Avenues Programme’

Ananyeva, O., & Emmanuel, R. (2023)

Aim:

The aim of the study was to investigate the impact of street trees on reducing the urban heat island (UHI) in Glasgow as part of the Avenues Programme.

Microclimate simulations (ENVI-met):

→ **Standard ‘Avenues’ model:** air temperature reduction of 0.91°C

→ **Alternative tree species (e.g. linden):** reduction of up to 1.27°C

→ **Green roofs:** reduction of only 0.96°C

→ **PET (thermal comfort) reduction:** from 42°C to 29-30°C.

Surface Urban Heat Island intensity:

Summer average Surface Urban Heat Island intensity in city centre: 4.0°C - 8.0°C.

Main 'hot spots' located in the city centre and along the River Clyde.

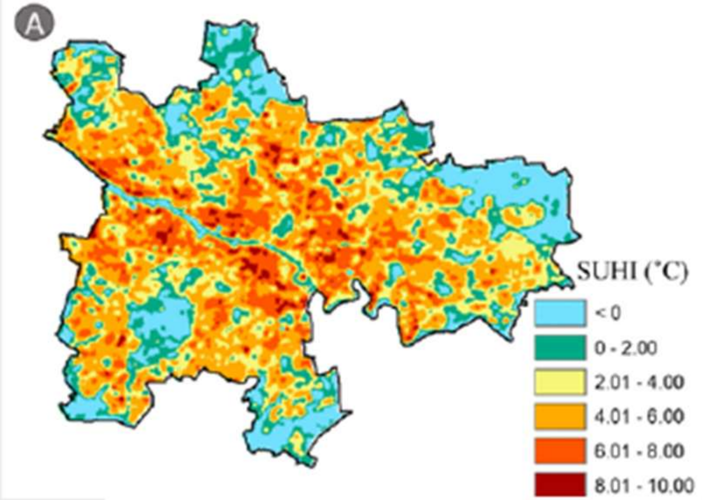


Fig. 9. (A) Mean summertime SUHI intensity in Glasgow;

Relationship to Urban Green Infrastructure:

Type of Urban Greenery	Correlation with SUHI	Interpretation
Total green cover	r = −0.60	**Strong correlation** – more greenery = lower surface temperatures
Trees only	r = −0.43	**Moderate correlation** – trees are effective at cooling the city
Trees + grass	r = −0.49	Similar to total green cover – strong combined effect
Grass only	r = −0.16	**Weak correlation** – grass alone has limited cooling effect
Shrubs	r = −0.21	Also weak effect

r = −1 Very strong negative correlation (more green = much less heat)

r = 0 No relationship

r = +1 Strong positive correlation (more green = more heat)

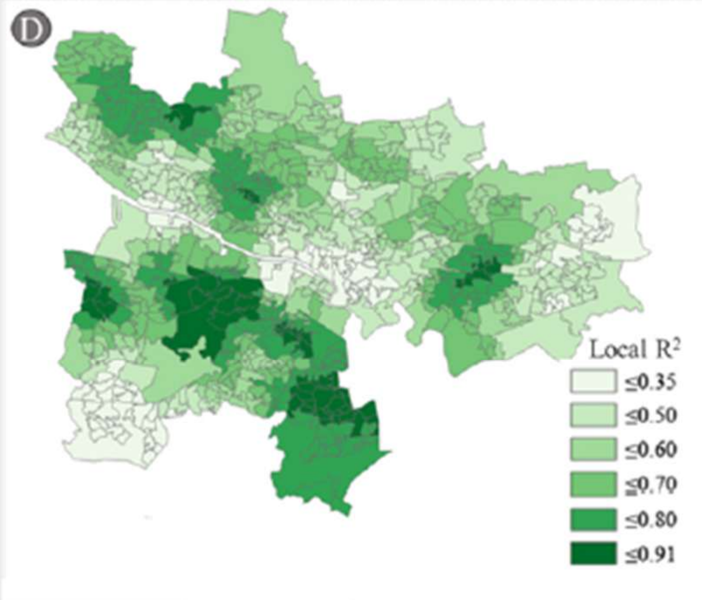


Fig. 9. Local R^2 of GWR between UGI and SUHI;

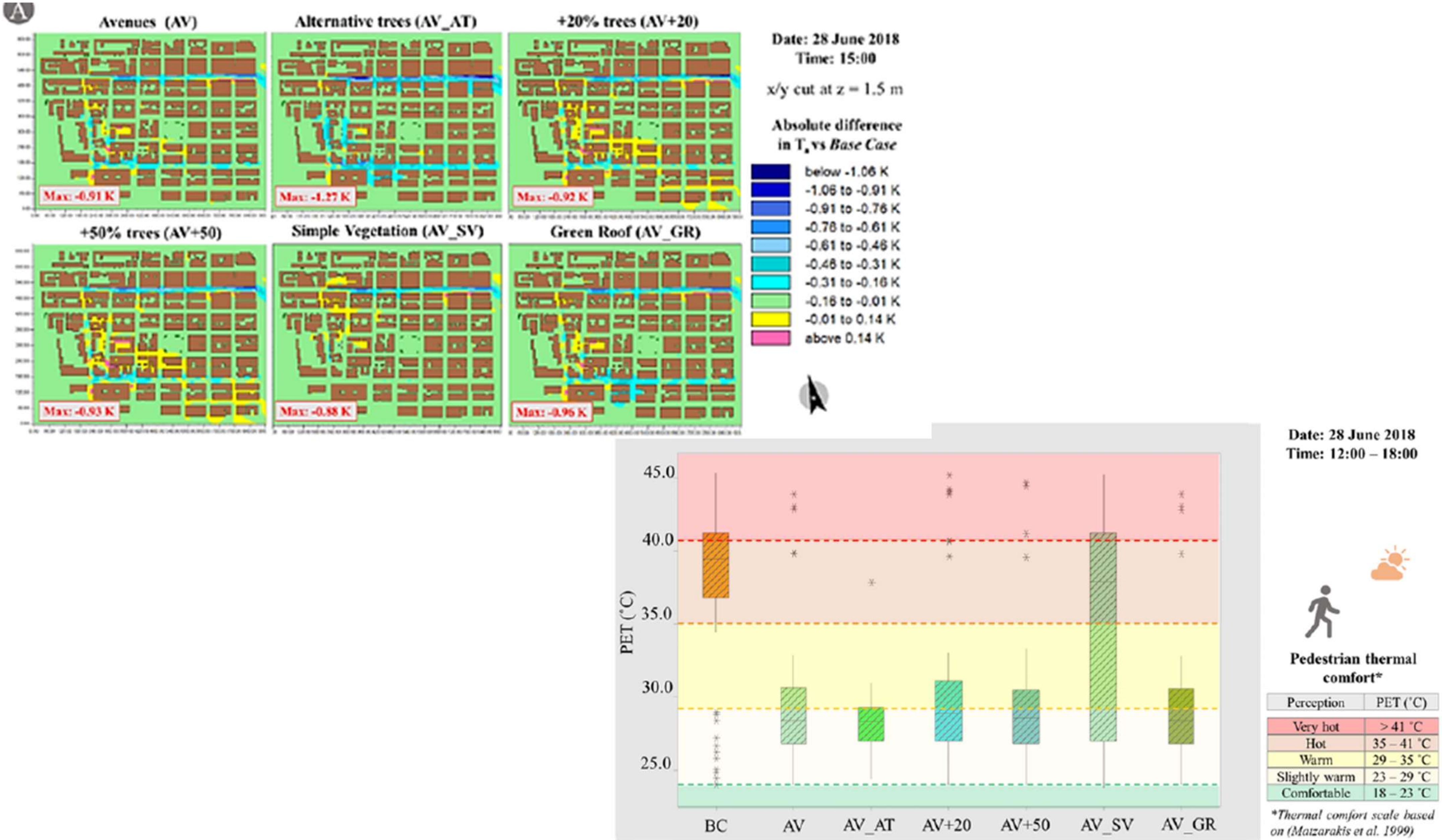


Fig. 10. Results of microclimate simulations: (A) Air temperature mitigation effect all scenarios.

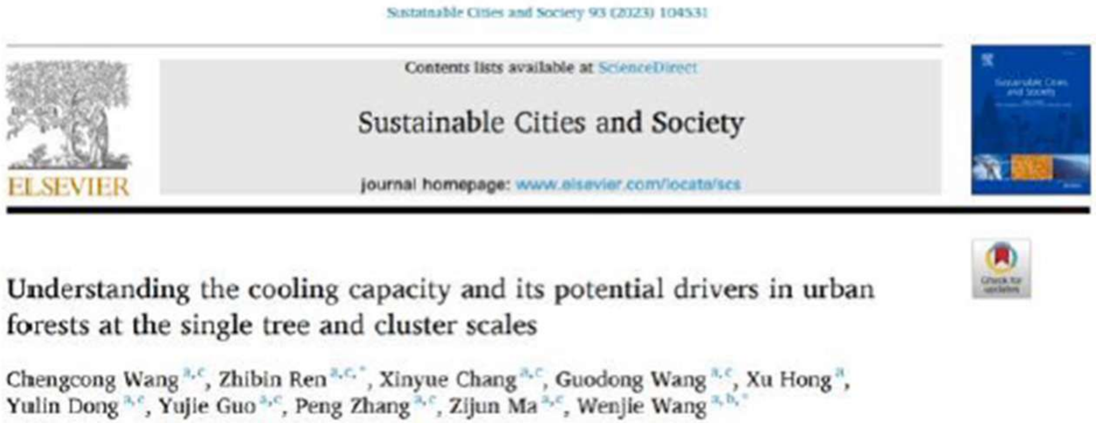
→ Glasgow city centre is experiencing strong SUHI effects - up to 10°C difference from green spaces.

→ Trees are the most effective element of green space in reducing surface and air temperatures.

→ Cooling effectiveness is greatest with canopy cover in the 50-100m range - small, isolated patches of greenery are ineffective.

→ The Avenues programme can significantly improve thermal comfort in the city centre by reducing temperature extremes.

→ The selection of appropriate tree species (e.g. Tilia) and their placement is very important - they can improve cooling efficiency by up to 40% more compared to other trees.



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Understanding the cooling capacity and its potential drivers in urban forests at the single tree and cluster scales

Chengcong Wang [a,c], Zhibin Ren [a,c,*], Xinyue Chang [a,c], Guodong Wang [a,c], Xu Hong [a], Yulin Dong [a,c], Yujie Guo [a,c], Peng Zhang [a,c], Zijun Ma [a,c], Wenjie Wang [a,b,*]

trees and biodiversity as a value

Based on article- Understanding the cooling capacity and its potential drivers in urban forests at the single tree and cluster scales

AIM

- Classification of tree species in urban areas using very high resolution UAVs.
- Analysis of differences in the cooling effect of urban trees based on precise thermal images and the influence of morphological features on cooling.
- Assessment of the influence of tree distribution on the cooling effect at the cluster scale.

area of campus about 50ha

The SVM classifier was used for final classification, achieving an overall accuracy of 87.34%, it has higher accuracy than KNN (80,11%)
Average temperatures of Buildings and roads - **43.03 ◦C** and **39.71 ◦C.** Grass - **32.68 ◦C** (cooling effect of 7.72 ◦C). In the study area, the temperature in the shaded area is concentrated at approximately **29.34 ◦C.** The average CI of shrubs and trees is **10.43 ◦C and 11.78 ◦C,** respectively, and their CIs (cooling) range from 5.05 ◦C to 16.12 ◦C. The cooling effect of trees was **1.35 ◦C** stronger than that of shrubs.

Tree morphology and cooling effect:

Trunk diameter (DBH), tree height (TH), crown diameter (CD) and crown thickness (CT) are key factors influencing cooling intensity. An increase in each of these parameters leads to an increase in cooling intensity by 0.5°C:

DBH: +3.64 cm

TH: +1.82 m

CD: +0.85 m

CT: +1.3 m

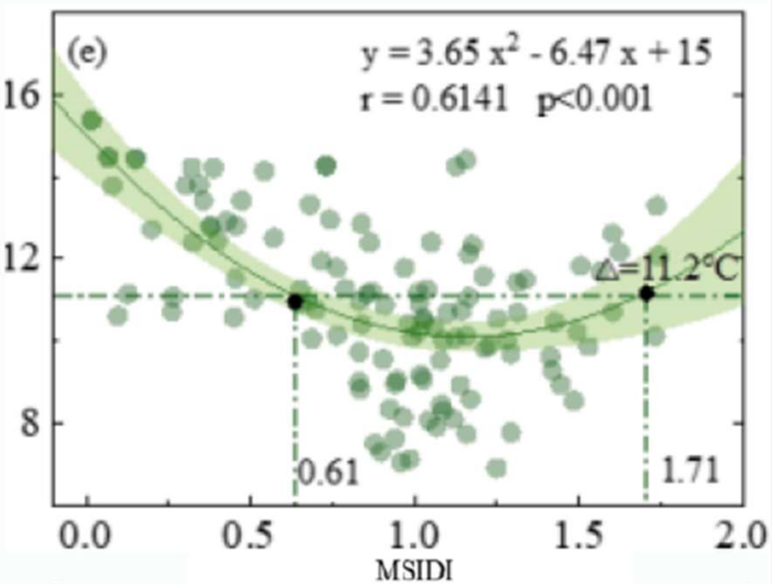
Leaf characteristics and cooling effect:

Cooling increases by 0.5°C with:

Increase in **NDVI** (vegetation index) by 0.02

Decrease in **leaf brightness** by 10 units

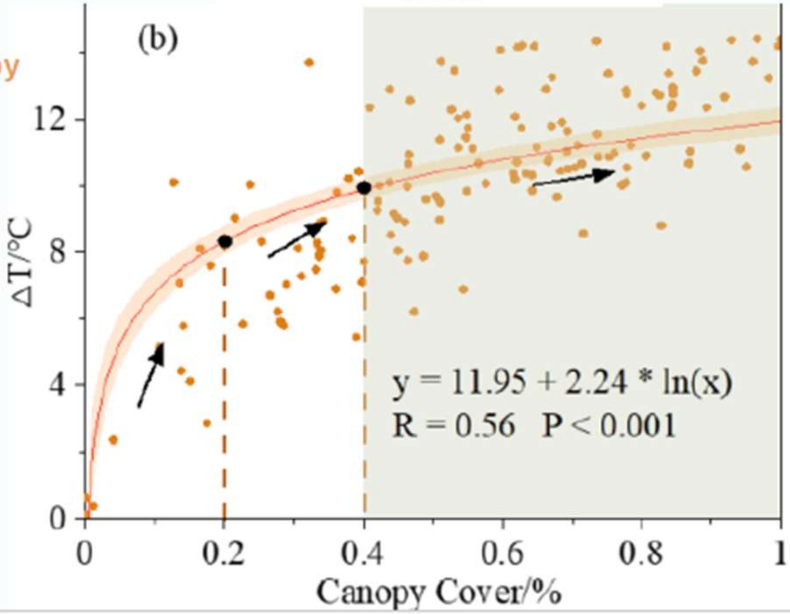
Reduction in **leaf thickness** by 0.03 mm



The relationship between species diversity and cooling effect follows a V-curve trend:

Cooling intensity is higher when diversity metrics are either very low (<0.61) or very high (>1.71).

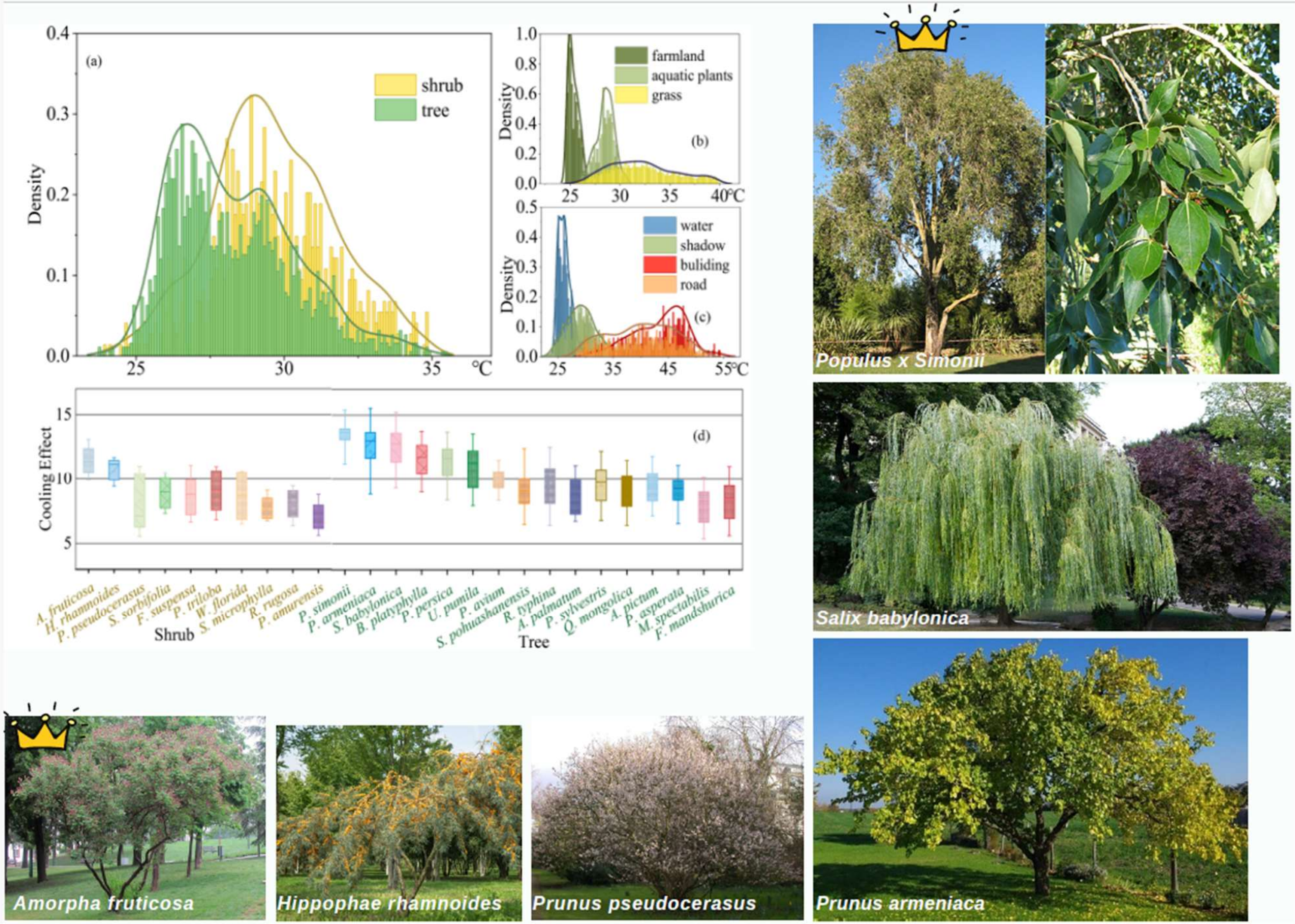
Cooling efficiency starts to slow when canopy cover reaches 20%. At 40% canopy cover, cooling reaches its maximum efficiency



*In the cluster unit, areas with lower average temperatures and smaller temperature variations are concentrated where trees exhibit:

High aggregation (trees are grouped into compact clusters)

High connectivity (tree patches form larger, coherent areas)



(a)
shrub
tree
Density
0.0
0.1
0.2
0.3
0.4
25
30
35
℃
(b)
farmland
aquatic plants
grass
Density
0.0
0.2
0.4
0.6
0.8
1.0
25
30
35
40℃
(c)
water
shadow
buliding
road
Density
0.0
0.1
0.2
0.3
0.4
0.5
25
35
45
55℃
(d)
Cooling Effect
5
10
15
A. fruticosa
H. rhamnoides
P. pseudocerasus
S. sorbifolia
F. suspensa
P. triloba
W. florida
S. microphylla
R. rugosa
P. amurensis
Shrub
P. simonii
P. armeniaca
S. babylonica
B. platyphylla
P. persica
U. pumila
P. avium
S. pohuashanensis
R. typhina
A. palmatum
P. sylvestris
Q. mongolica
A. pictum
P. asperata
M. spectabilis
F. mandshurica
Tree
Populus x Simonii
Salix babylonica
Prunus armeniaca
Amorpha fruticosa
Hippophae rhamnoides
Prunus pseudocerasus

«Regarding the diversity of cluster units, it has been shown that the higher the vegetation diversity, the better the cooling intensity of the species»

*The trees have a higher cooling capacity than shrubs by about 1.35 ◦C.

*The tree species with larger crown diameter, thicker canopy, and the thinner and darker leaves would have higher cooling intensity.

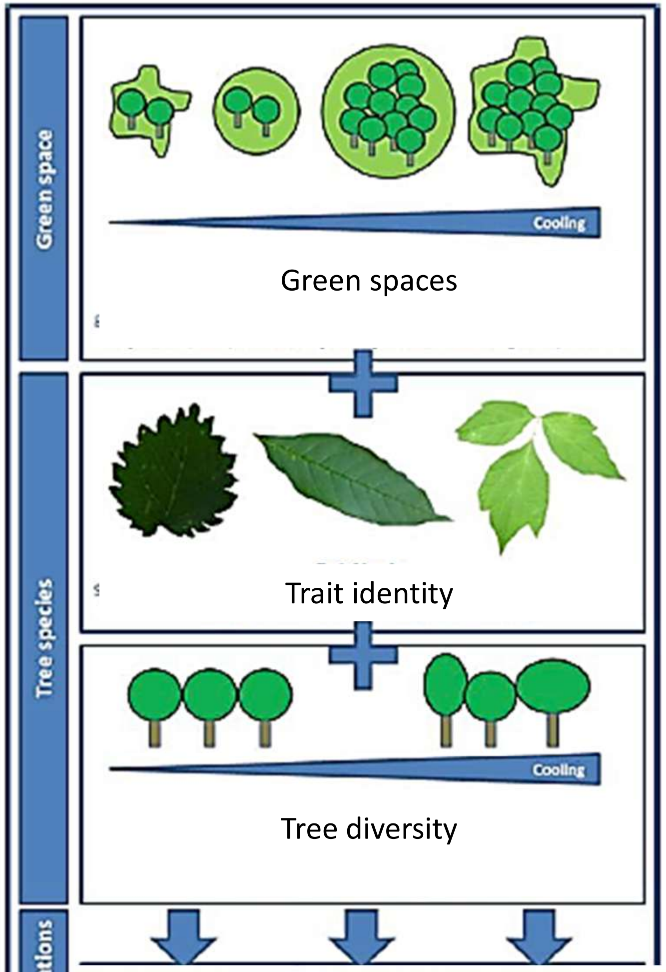
*The spatial distribution of tree species at the cluster scale is also very important for increasing the cooling intensity.

*When the tree canopy coverage was larger than 40%, the cooling intensity had no more increase with the increasing canopy coverage.

*Aggregation, connectivity, and diversity of tree species with a certain threshold should also be considered to produce a better cooling effect.

*The efficiency threshold and the proportion of different tree species need to be determined in advance to achieve better cooling effect in cities.

Summary of findings on the effects of green space configuration and tree diversity on climate regulation that should be considered when creating new urban green spaces (da Knapp et al., 2019)



Green spaces

and their characteristics affect surrounding temperatures: Forests and large green spaces have higher cooling effects than parks and small green spaces; an irregular shape improves cooling for large but not for small green spaces [4].

Trait identity

Specific characteristics of tree species can affect surrounding temperatures. An example of such traits is the leaf type of trees [6].

Trait diversity

Variation in the traits represented in a group of trees can affect surrounding temperatures. An example is the variation in the height of trees with higher variation increasing the cooling effect of parks [8].

Climate regulation in urban areas will improve by designing and maintaining large, irregulary shaped forests and parks with various tree species that provide a high diversity of relevant traits.

What impact do trees have on reducing the urban heat island (UHI)?

All articles confirm that trees reduce air and surface temperatures through shading and transpiration. The cooling effect depends on crown size, planting density, species diversity and location (e.g. urban canyons, streets, parks).

E.g.

- In the study from Elazığ (Turkey), the average Heat Island Potential dropped from 13.29°C to 4.87°C after taking into account the effect of trees in the simulation.
- In Curitiba, the temperature difference between green areas and the city centre was as much as 10°C

Does plant species diversity have an impact on the reduction of heat stress in cities?

Yes. The California article shows that greater tree species diversity leads to better daytime cooling effects and greater microclimate stability. Different species provide diverse ecological functions.

E.g.

- Mean Shannon-Wiener Index of tree diversity in California: 3.21, max: 4.37 - higher diversity = lower maximum daily temperature.
- In cities with higher species diversity, trees reduced temperatures up to 2.2°C more (with higher Leaf Area Density).

What urban solutions increase the effectiveness of trees in combating heat stress?

Research from Glasgow and Brazil indicates that strategic placement of trees, particularly in densely built and deprived areas, increases their effectiveness. Urban programmes, such as the Avenues Programme, show that proper planning can completely eliminate the UHI effect in some places.

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