Theme for today's lecture

Drought tolerance, ecosystem services, and biodiversity values of trees in urban and peri-urban forests and their implication on arboriculture and urban silviculture

Somidh Saha

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GrüneLunge

Funded by Federal Ministry of Education and Research

FONA Research for Sustainability

Thanks to PowerPoint template Designer -Angela Beckmann-Wübbelt

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Trees in urban and peri-urban forests

Photo: Markus Breig/KIT

Urban and peri-urban forests as critical infrastructure and nature-based solutions

- In Post covid cities, high urbanization and climate change increase risks as well as demand for urban green spaces


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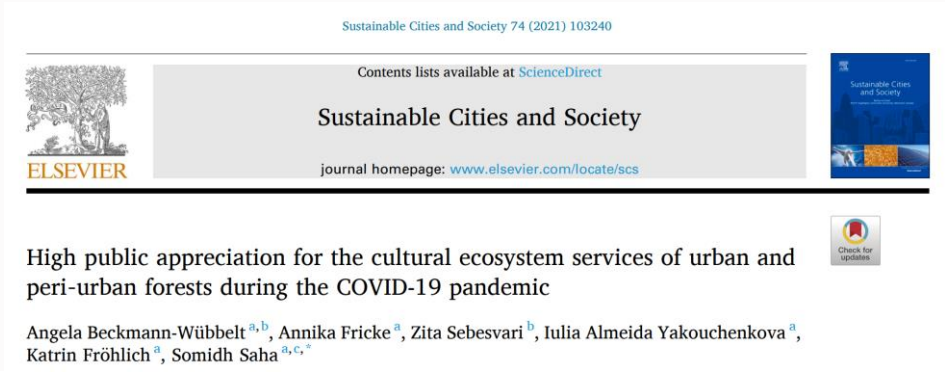
UNECE supports Sustainable Urban and Peri-Urban Forestry for public health, climate resilience and green recovery

Trees in cities | Climate Change | Covid-19 | Forestry | Sustainable Development

22 February 2022

Spending extended periods of time at home under COVID-19 restrictions highlighted the need for accessible green spaces like never before, particularly for city dwellers who sought out green spaces for fresh air, exercise and a break from the confines of their apartments. Access to green open spaces is critical to maintaining positive mental and physical health, yet a recent pan-European study showed that more than 60% of people in European cities live in areas with insufficient green space according to World Health Organization standards.


Sustainable Cities and Society 74 (2021) 103240

Contents lists available at ScienceDirect

Sustainable Cities and Society

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

ELSEVIER

Check for updates

High public appreciation for the cultural ecosystem services of urban and peri-urban forests during the COVID-19 pandemic

Angela Beckmann-Wübbelt [a,b], Annika Fricke [a], Zita Sebesvari [b], Iulia Almeida Yakouchenkova [a], Katrin Fröhlich [a], Somidh Saha [a,c,*]


npj | urban sustainability

www.nature.com/npjUrbanSustain

ARTICLE OPEN

Check for updates

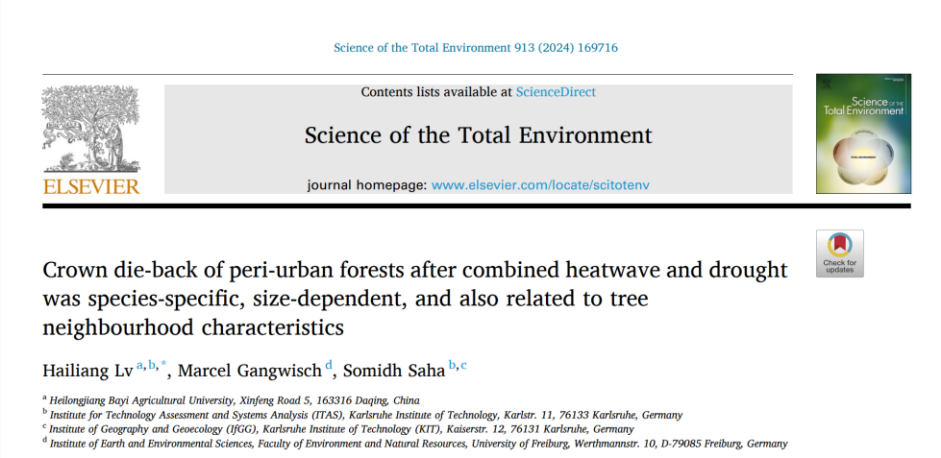
Climate change adaptation measures conflicted with the recreational demands on city forests during COVID-19 pandemic

Angela Beckmann-Wübbelt[1], Lynn Türk[1], Iulia Almeida[1], Annika Fricke[1], Metodi Sotirov[2] and Somidh Saha[1,3]✉

Trees are dying in Germany at a high rate

- High death of trees in Karlsruhe region due to climate change impacts and diseases

- Tolerance to stress changes among same species in contrasting habitat



Science of the Total Environment 913 (2024) 169716

Contents lists available at ScienceDirect

Science of the Total Environment

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

ELSEVIER

Crown die-back of peri-urban forests after combined heatwave and drought was species-specific, size-dependent, and also related to tree neighbourhood characteristics

Hailiang Lv [a,b,*], Marcel Gangwisch [d], Somidh Saha [b,c]

[a] Heilongjiang Bayi Agricultural University, Xinfeng Road 5, 163316 Daqing, China
[b] Institute for Technology Assessment and Systems Analysis (ITAS), Karlsruhe Institute of Technology, Karlstr. 11, 76133 Karlsruhe, Germany
[c] Institute of Geography and Geoecology (IfGG), Karlsruhe Institute of Technology (KIT), Kaiserstr. 12, 76131 Karlsruhe, Germany
[d] Institute of Earth and Environmental Sciences, Faculty of Environment and Natural Resources, University of Freiburg, Werthmannstr. 10, D-79085 Freiburg, Germany

Trees (2023) 37:111–131
https://doi.org/10.1007/s00468-022-02294-0

ORIGINAL ARTICLE

Drought tolerance differs between urban tree species but is not affected by the intensity of traffic pollution

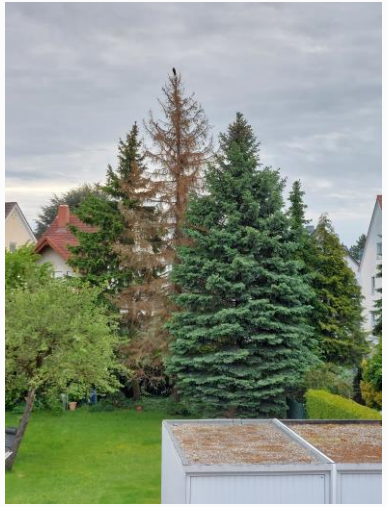
Mareike Hirsch[1,2] · Helena Böddeker[1] · Axel Albrecht[1] · Somidh Saha[3,4]

Received: 28 October 2021 / Accepted: 15 March 2022 / Published online: 27 May 2022

Tree death in cities can have high negative impact

- Our study showed that high tree mortality and increase in concrete areas in city negatively impacts human wellbeing

A dying hazel nut trees near a nursing home, Karlsruhe
(Photo: Somidh Saha, June 2024)



A dead Spruce tree in a backyard garden, Karlsruhe
(Photo: Jutta Jahnel, May 2024)

Europaplatz Karlsruhe
(Photo: Jörg Donecker)

Learning goals

- To get an idea about supporting/habitat values, cooling potential and cultural ecosystem services from urban forests
- To know about impact of drought on past growth of city trees
- To know about the cultural values or cultural ecosystem services of urban forests
- To know how to select trees for future planting in cities

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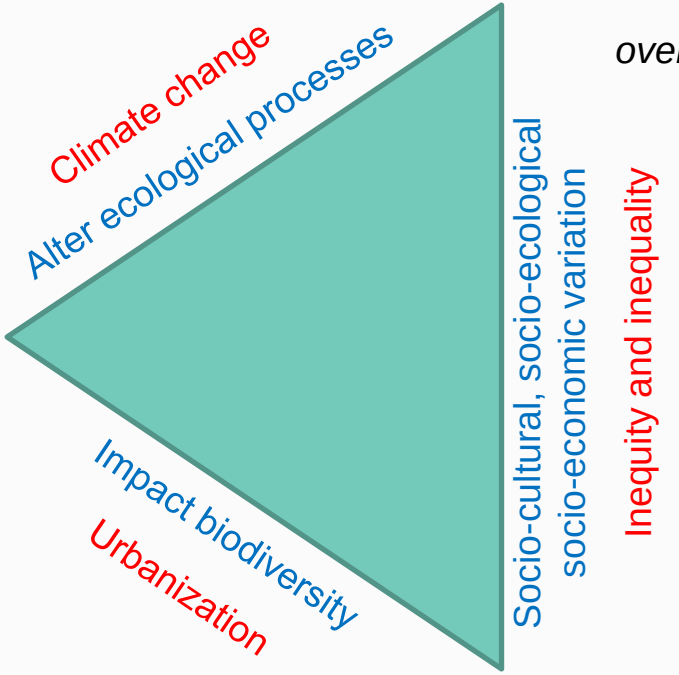
Biodiversity and Ecosystem Function

Benefits to human and nature

(„services“ over „disservices“!)

Biodiversity

(organismic, structure, genetic)



Human intervention

How does BEF happen in the built environment, such as street and park trees?

(change in plant-plant, plant-animal, plant-human and plant-environment interactions)

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Our mission ☺

- To fight for saving city trees from climate change and urbanization
- To improve the scientific knowledge about them
- To support City Horticulture and City Forest Department as well as citizens to improve for the care of city trees as well as create awareness about the importance of city trees

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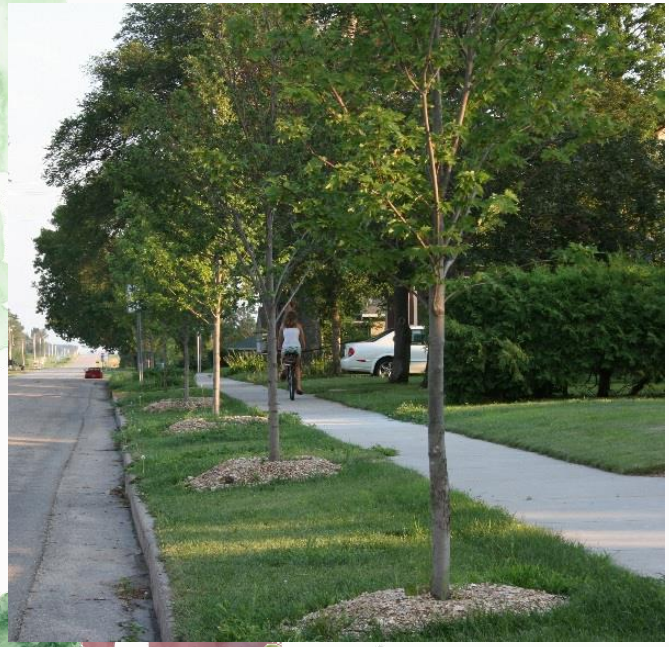
Solitary street trees



Photos: Pixabay

Solitary park trees

Photos: Pixabay

Are solitary trees in parks and streets lonely?

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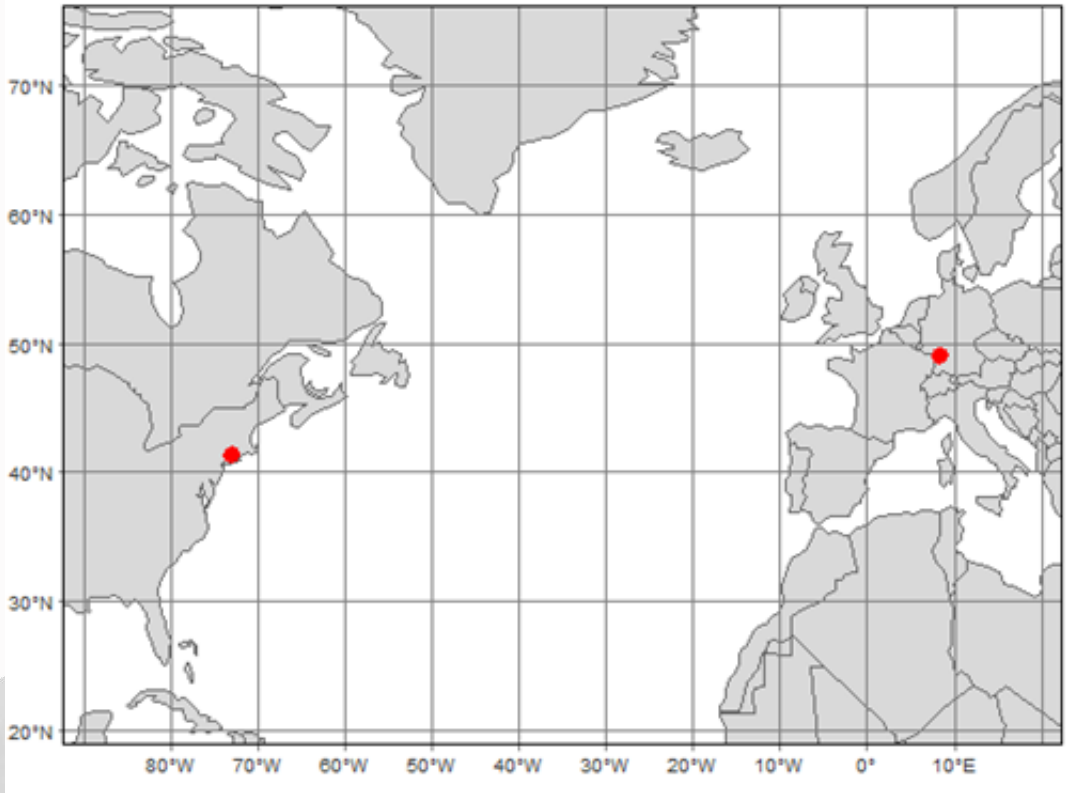
Pilot pond eDNA study

New Haven, USA
Yale School of Environment

Red oak, New Haven Native Exotic in Karlsruhe



Karlsruhe, KIT

Norway maple, Karlsruhe native Invasive/exotic in New Haven

Rubio, A; Bell, M.; Saha, S (study ongoing)

Photos: Pixabay

But both are common lonely trees in parks and streets of both cities

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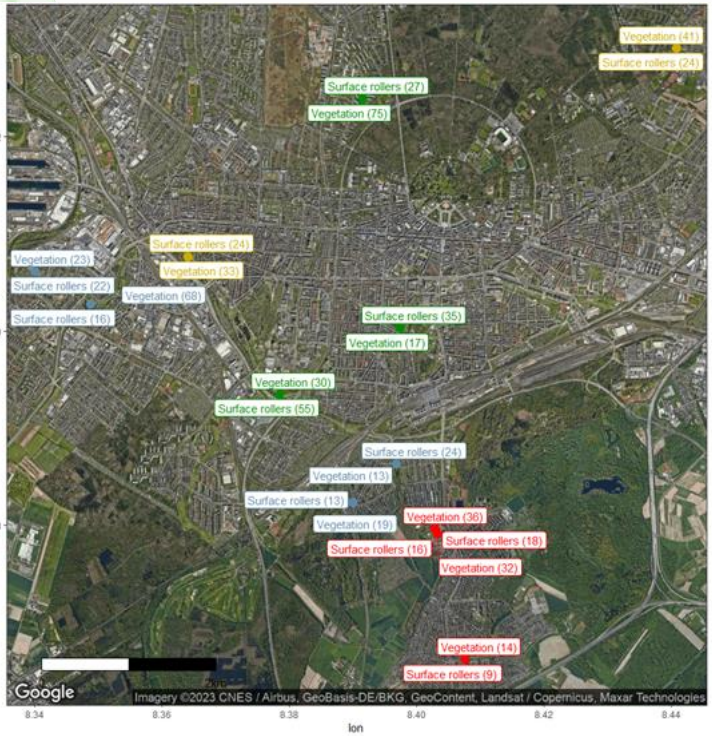
Karlsruhe

Red oak park: 3
Red oak street: 3
Norway maple park: 3
Norwaly maple street: 3



DBH more than 40 cm

New Haven

Red oak park: 3
Red oak street: 3
Norway maple park: 3
Norwaly maple street: 3

Rubio, A; Bell, M.; Saha, S (study ongoing)

Sample collection for eDNA analysis

Rubio, A; Bell, M.;
Saha, S (study ongoing)

eDNA analysis by
SGS Global, Lisbon

Photos: Ferdinand Betting, Aaron Peter

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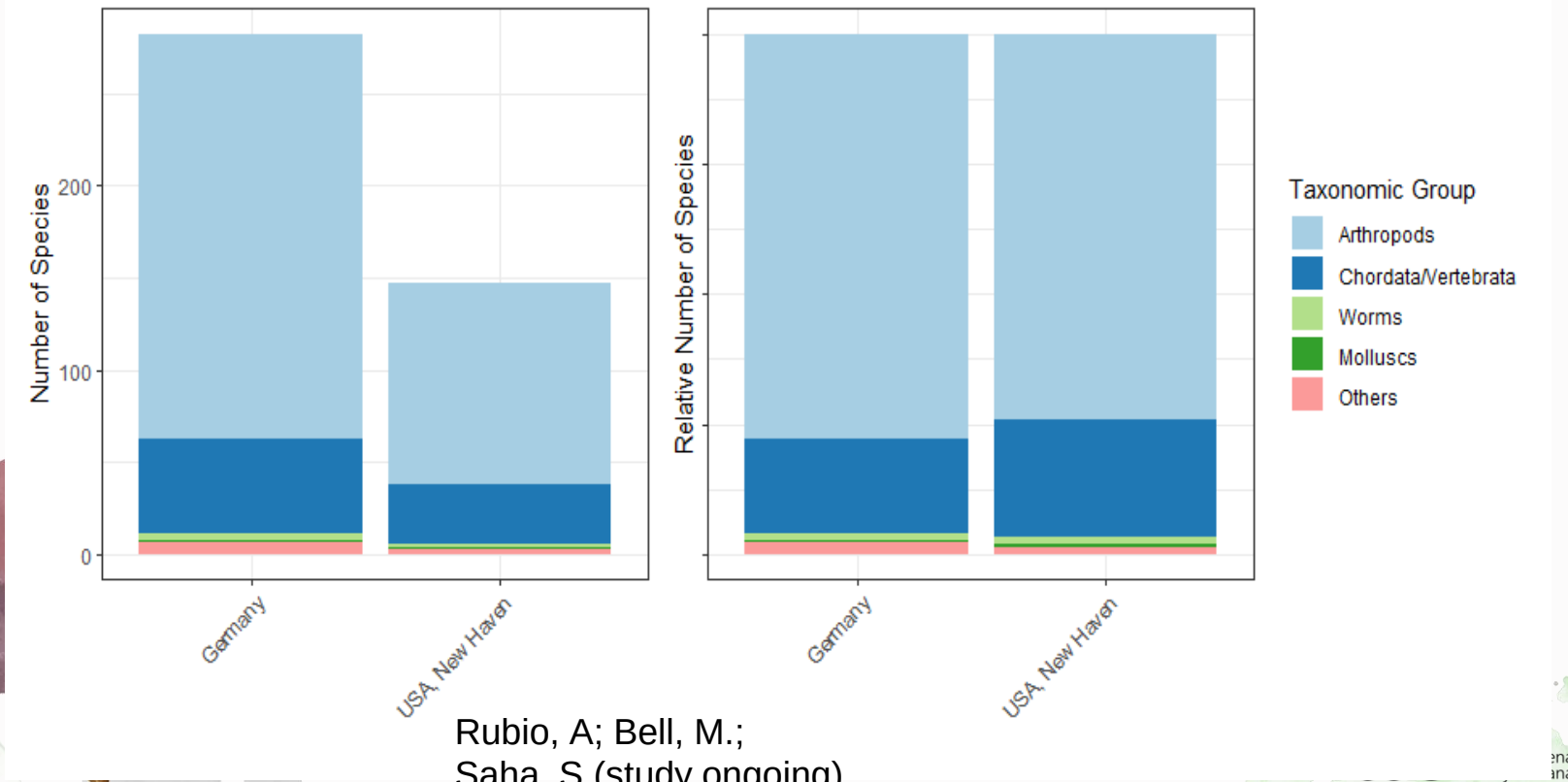
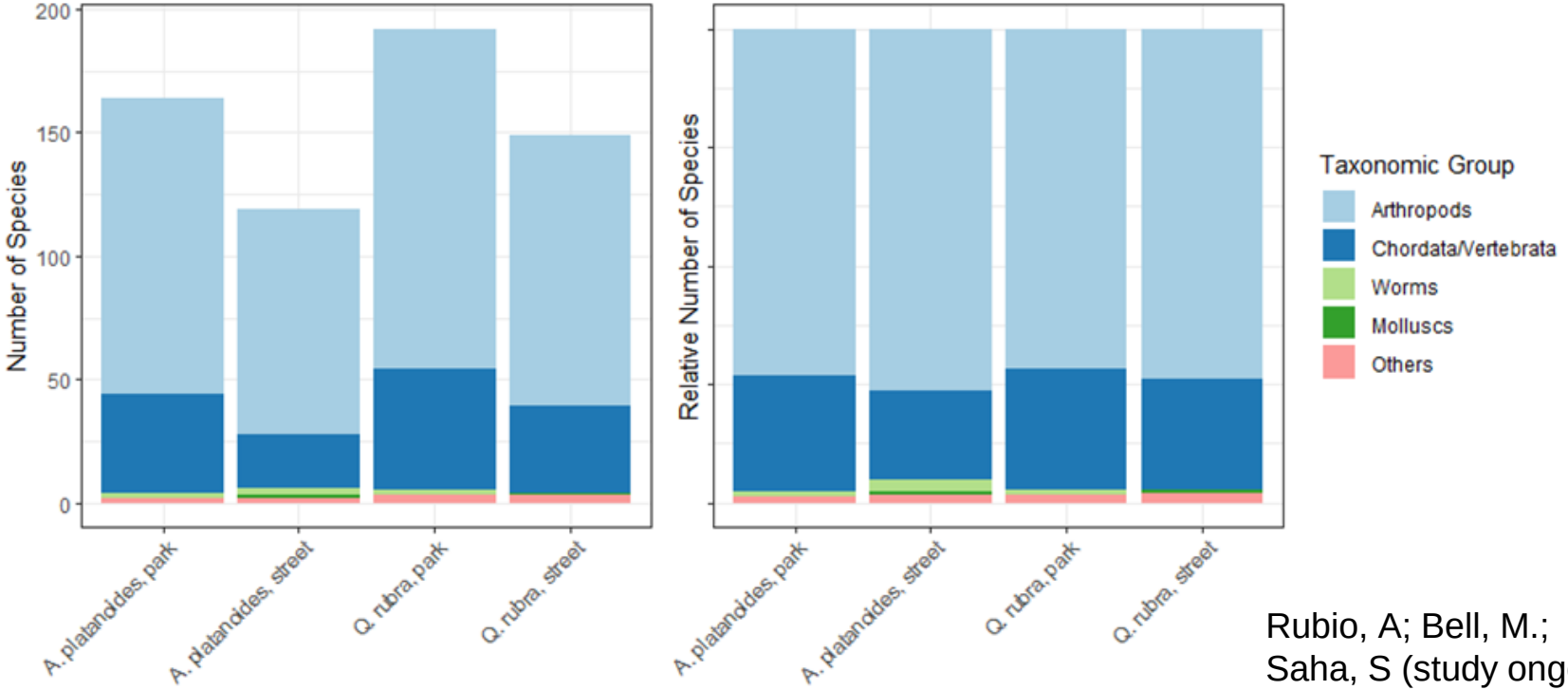
Karlsruhe trees had DNA of ca. 280 species of vertebrates and invertebrates than ca. 150 species of New Haven trees



Rubio, A; Bell, M.;
Saha, S (study ongoing)

Park trees harbor DNA of more species than street trees

Red oaks harbor more species than Norway maples both in streets and parks

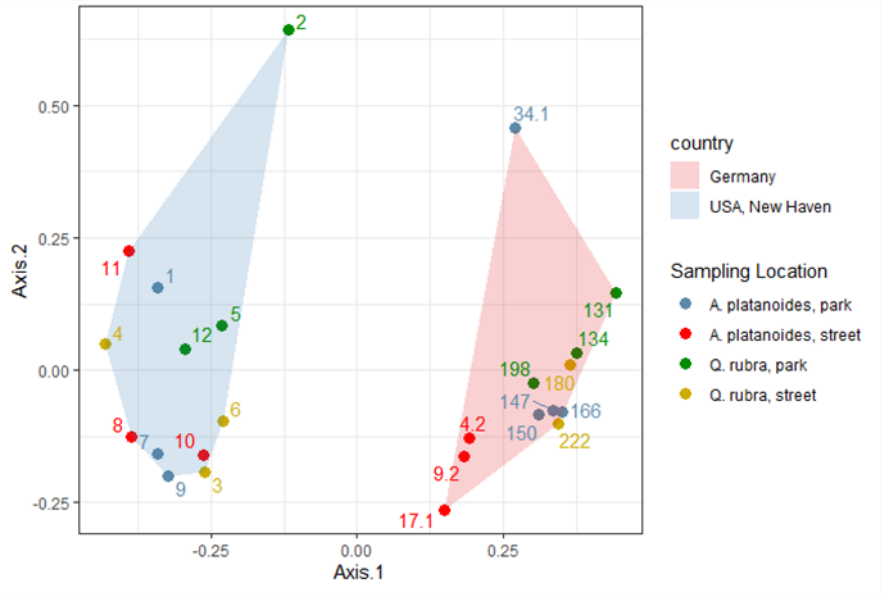


Rubio, A; Bell, M.;
Saha, S (study ongoing)

ätzung

Vertebrates

(different communities between two sides of the pond!)



Rubio, A; Bell, M.;
Saha, S (study ongoing)

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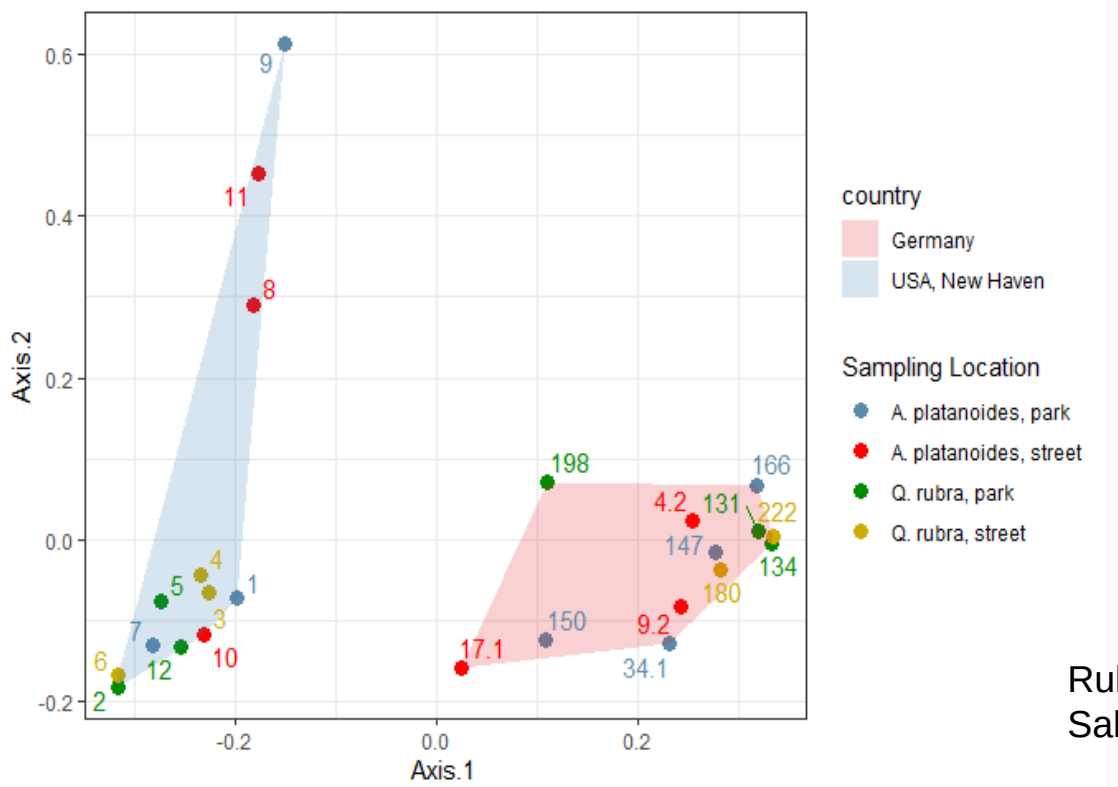
Invertebrates

(different community between two sides of pond!)



Rubio, A; Bell, M.;
Saha, S (study ongoing)

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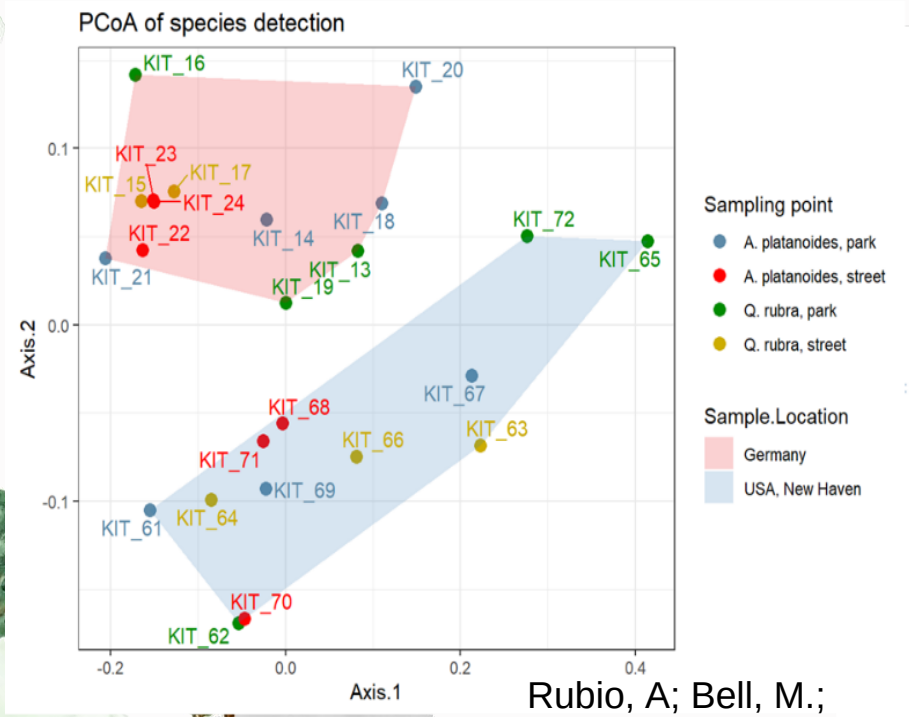
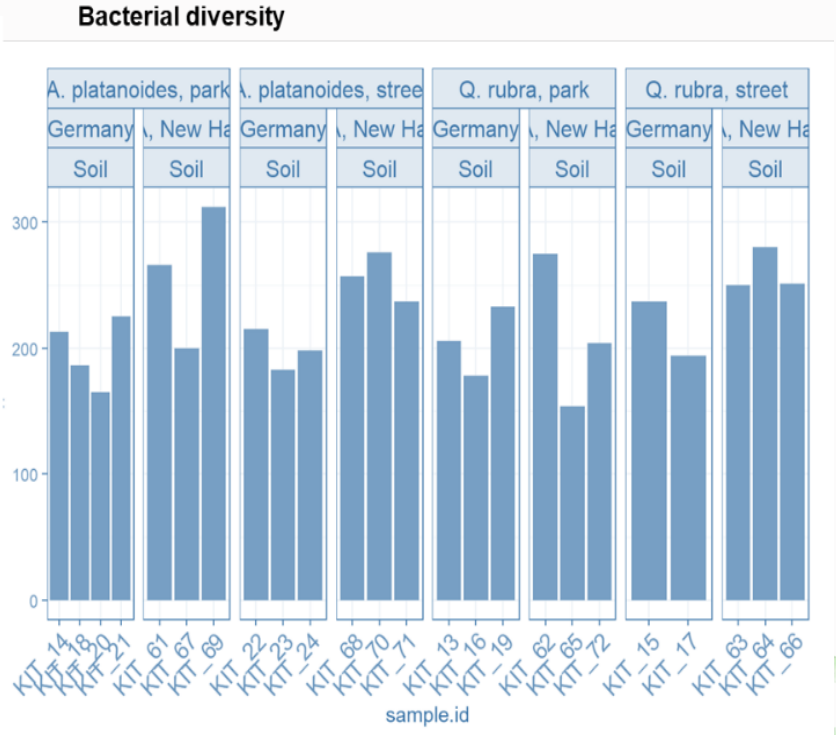
Soil bacteria

(New Haven samples have more bacterial diversity than Karlsruhe; different communities in Karlsruhe and New Haven)





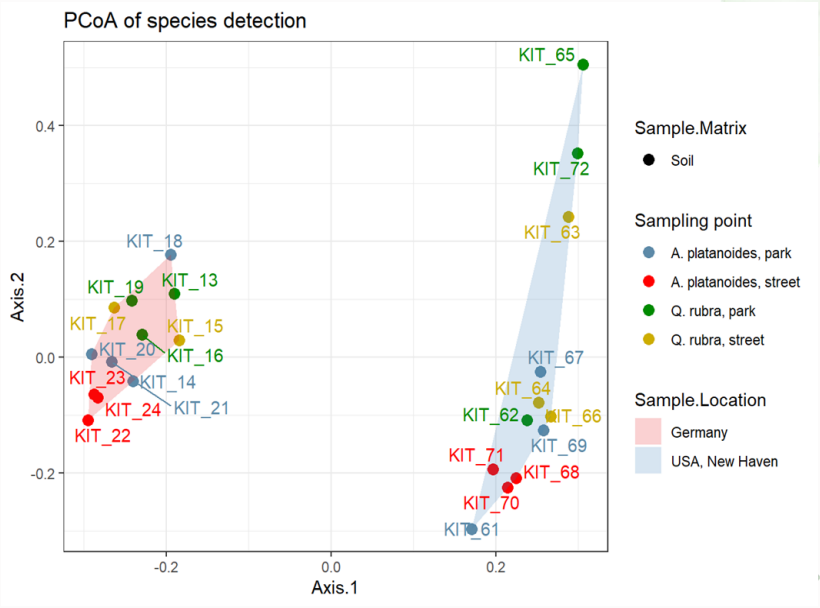
Rubio, A; Bell, M.;
Saha, S (study ongoing)

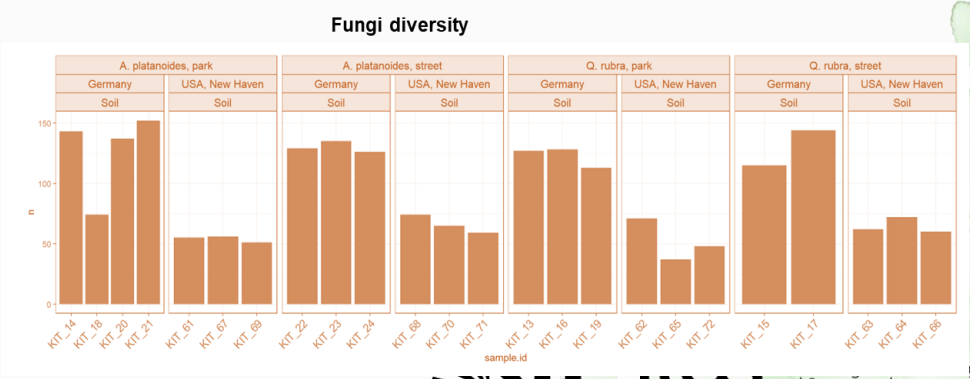
Soil fungi

(Karlsruhe soil samples contain DNA of ca. 150 fungi in comparison to ca. 50 fungi species in New Haven;

different communities in Karlsruhe and New Haven)

Rubio, A; Bell, M.;
Saha, S (study ongoing)





Herbivores chewing insects (Hymenoptera, Orthoptera, Psocoptera) were more frequent in maples of Karlsruhe but not in New Haven!!

One reason why Norway maple is invasive in New Haven?

Support Enemy Release Hypothesis?

Rubio, A; Bell, M.;
Saha, S (study ongoing)

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Technikfolgenabschätzung und Systemanalyse

Are solitary trees in parks and streets lonely?

- **No, absolutely not ☺ Rather, many, many species!**
- **Park trees harbor more species than street trees (make sense)**
- **Tree species variation can be there (e.g red oaks vs.Norway Maples)**

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Tree health condition, radial growth and tree cover impact on cooling

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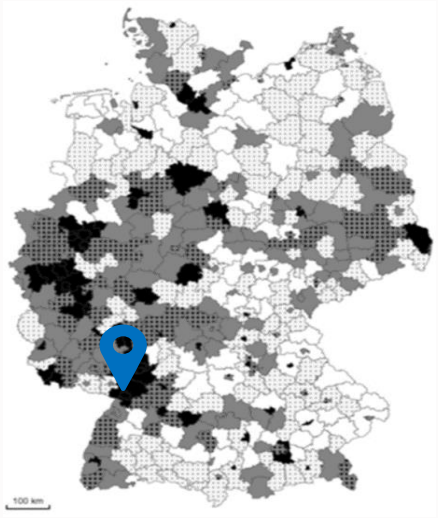
Global change impacts in Germany

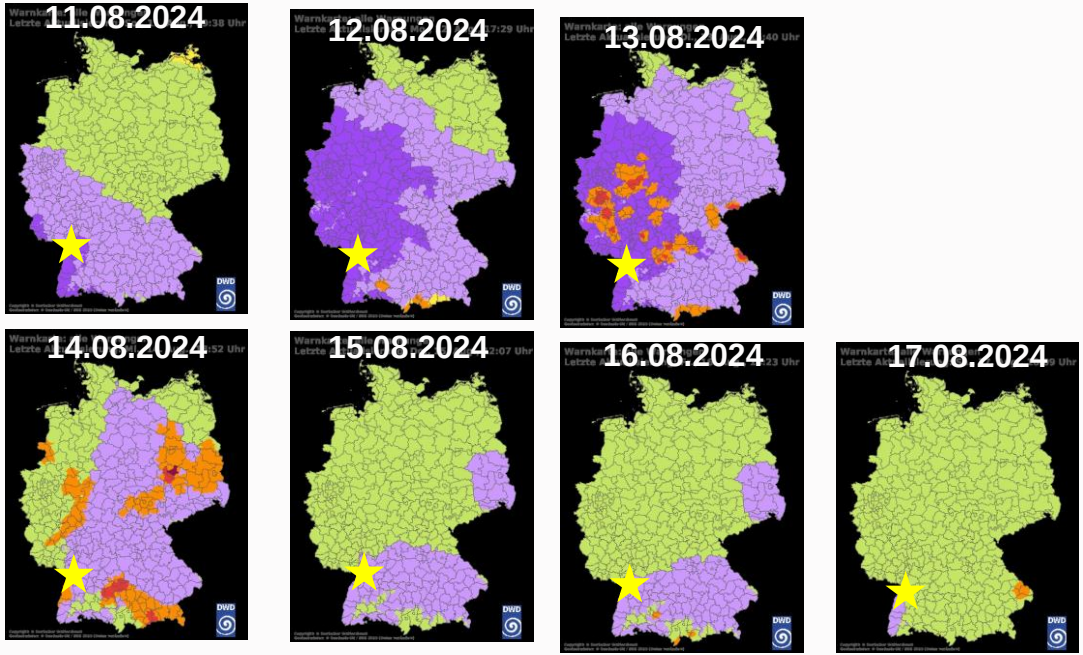


High vulnerability to climate change impacts (Rannow et al 2010)

- High urbanization: commercial growth, population growth, housing crisis
- More frequent and intense heatwaves, droughts, extreme rainfall events, large-scale tree deaths

Increase in urbanization (Siedentop und Fina 2010)

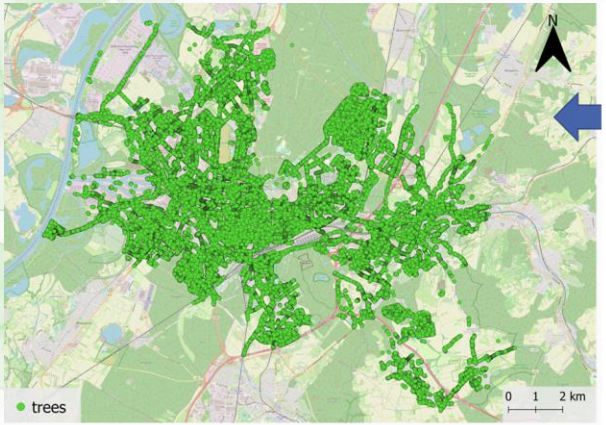
An example of a recent heatwave in Karlsruhe



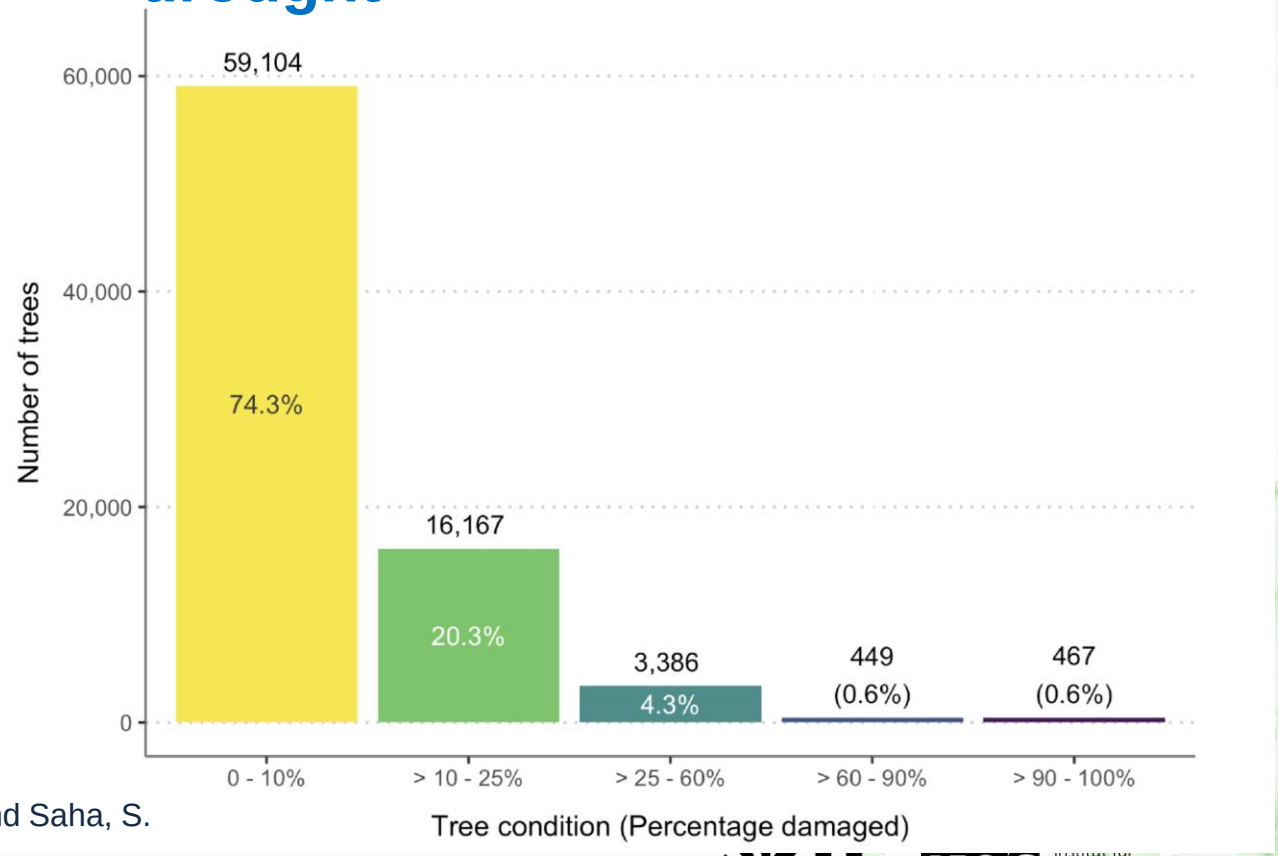
- Searing heatwave lasting seven consecutive days
- Maximum temperature above 5°C of normal and above 30°C

Source: *Deutscher Wetterdienst*

Crown damage in solitary trees of Karlsruhe after 2018 drought



N_{trees} = 79,573



Schobert. M and Saha, S.
in preparation

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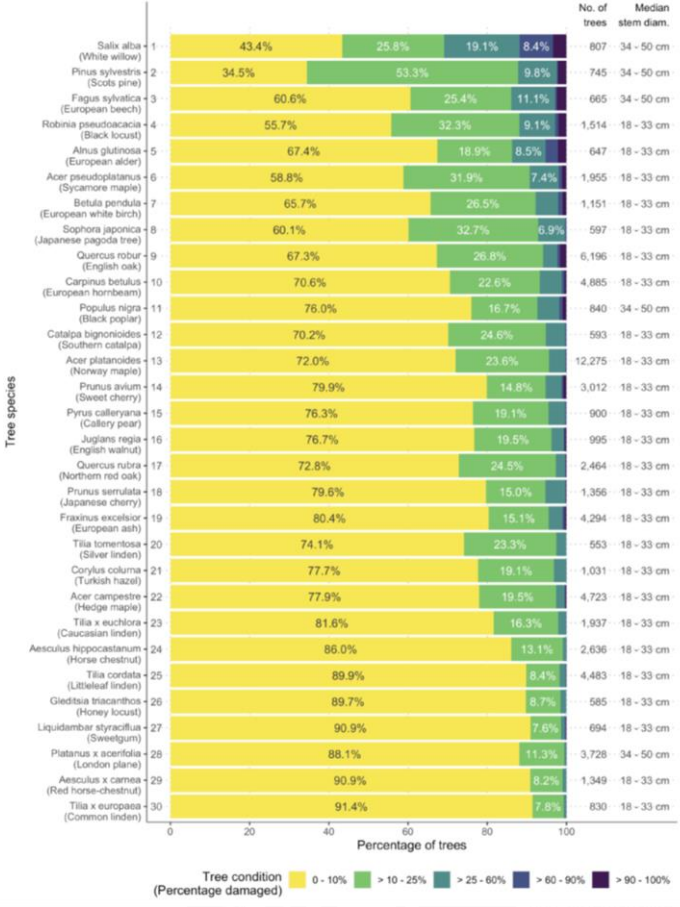
Crown damage in solitary trees after 2018 drought

- **28 out of 30 species had 10% or more crown damage**
- **Evergreen trees are more prone to crown damage**
- **Tolerance of roots to soil compaction reduces crown damage**
- **Moderate level of crown damage increases with tree size**



Schobert. M and Saha, S.
in preparation

Lyu, H; Gangwisch, M.; Saha, S 2024
Science of the Total Environment

Karlsruher Institut für Technologie

Tree ring growth, response to drought, and internal trunk damage between red oaks and native oaks

Tree ring research and sonic impulse tomography were used in this study in addition to standard dendrometric assessment.

Photos: Lisa Spoden

Lyu, H, Spoden, L, Saha, S.
In preparation

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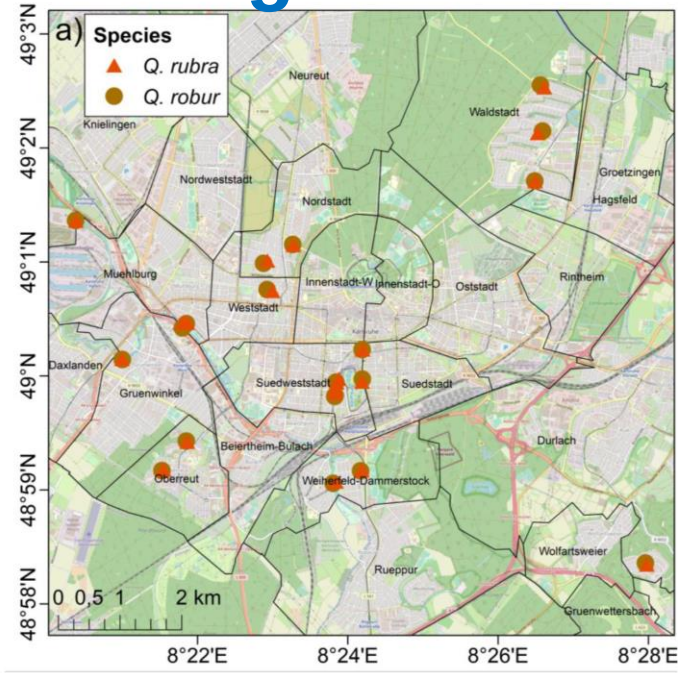
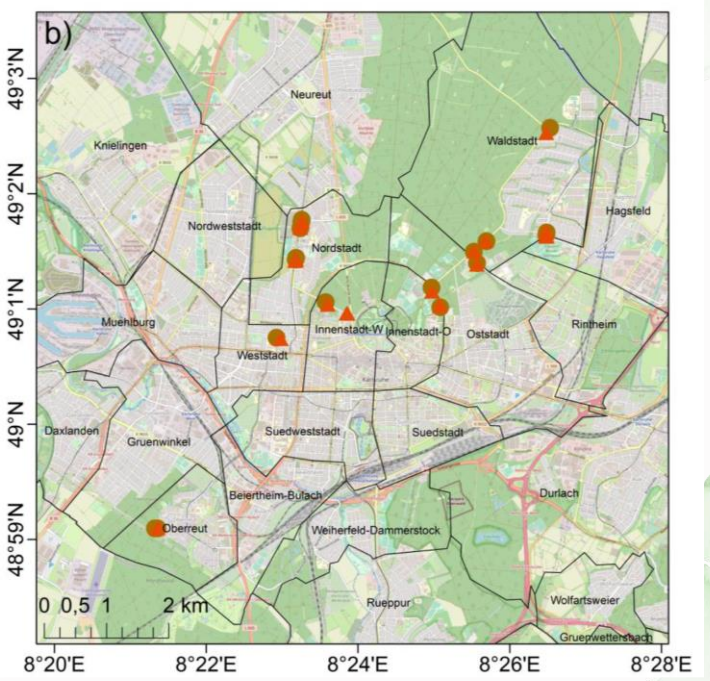
Tree ring growth, response to drought, and internal trunk damage





	Quercus robur		*Quercus rubra*		
	vit. class 0	vit. class > 0	vit. class 0	vit. class > 0	**Total**
Park	8	12	8	12	40
Street	8	12	8	12	40
Total	16	24	16	24	**80**

Parks

Streets

Lyu, H, Spoden, L, Saha, S.
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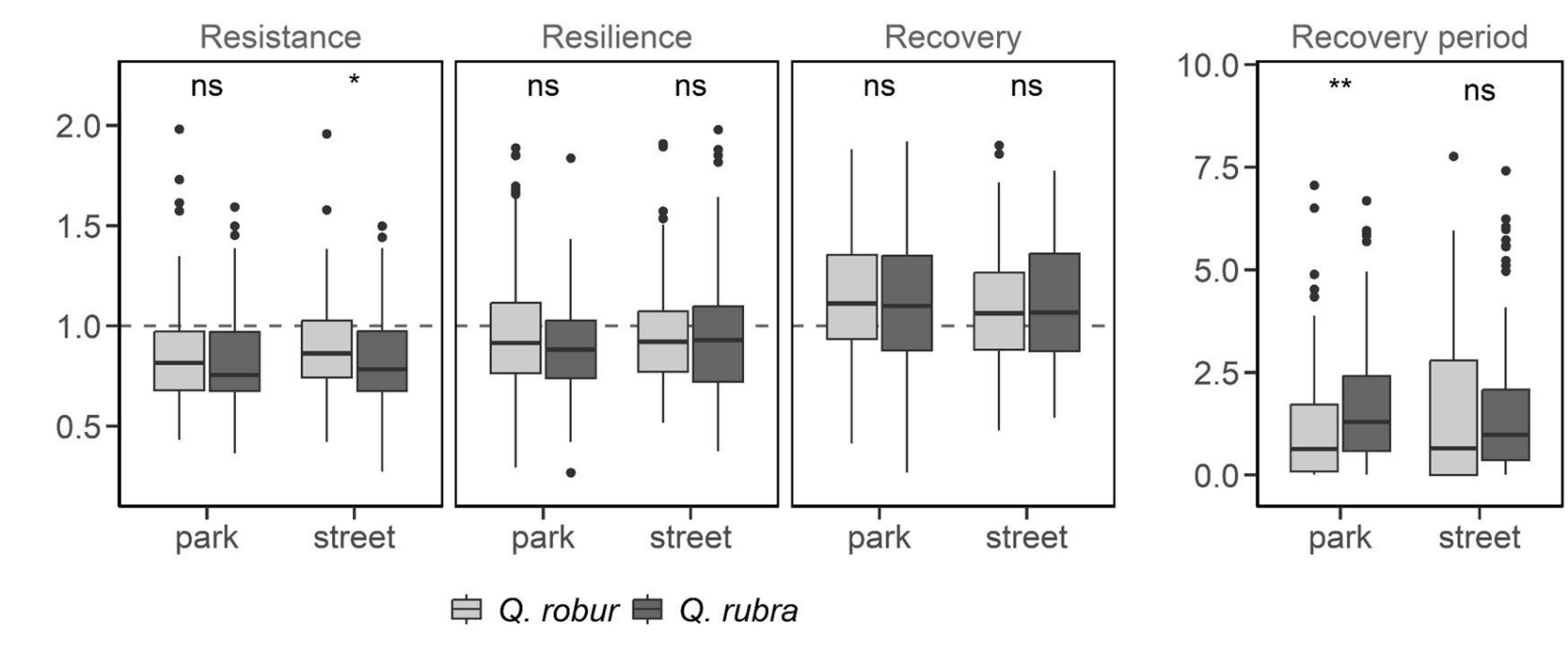
Pedunculate oak had higher resistance to drought in the street and lower recovery time from drought stress in parks



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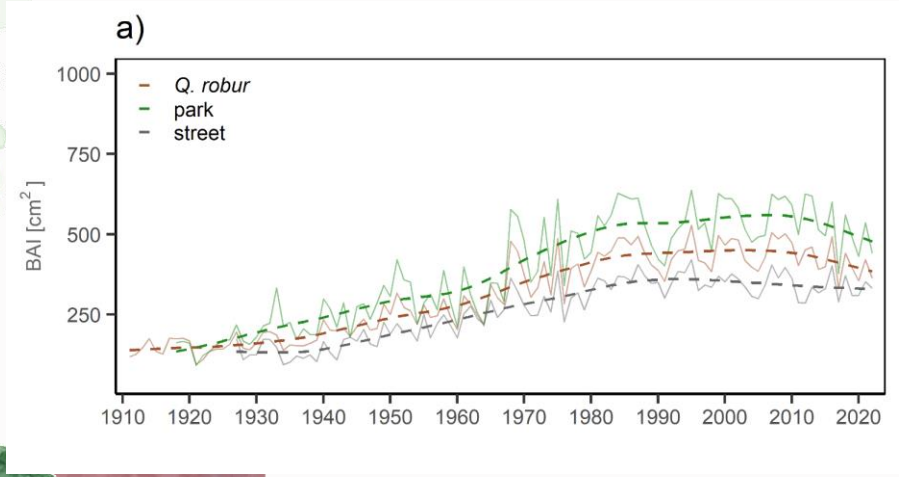
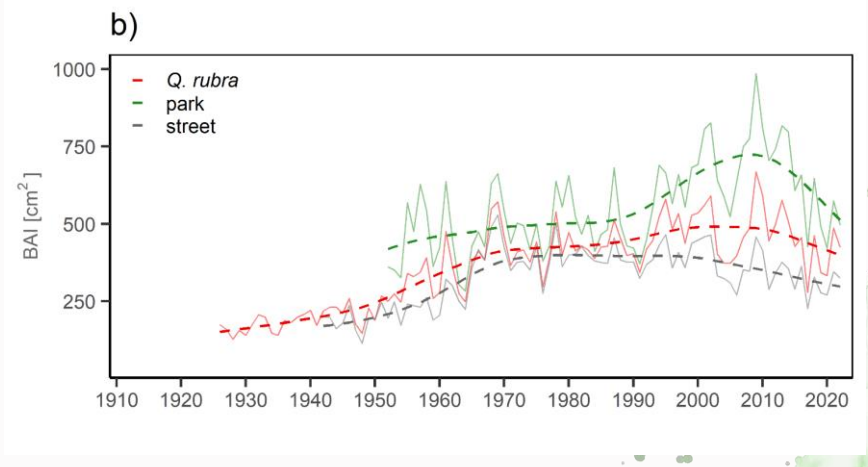
Pedunculate oak grew slower than red oak, but the growth of red oaks fell after 80 years!





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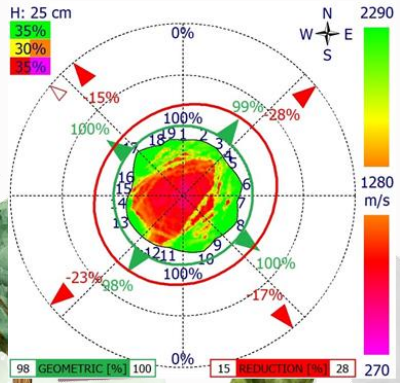
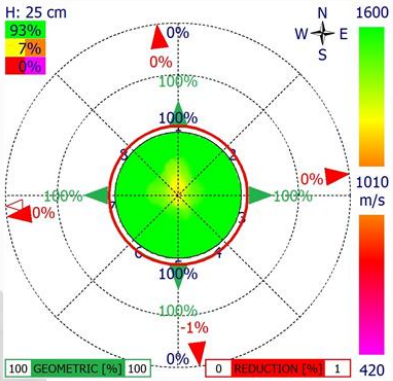
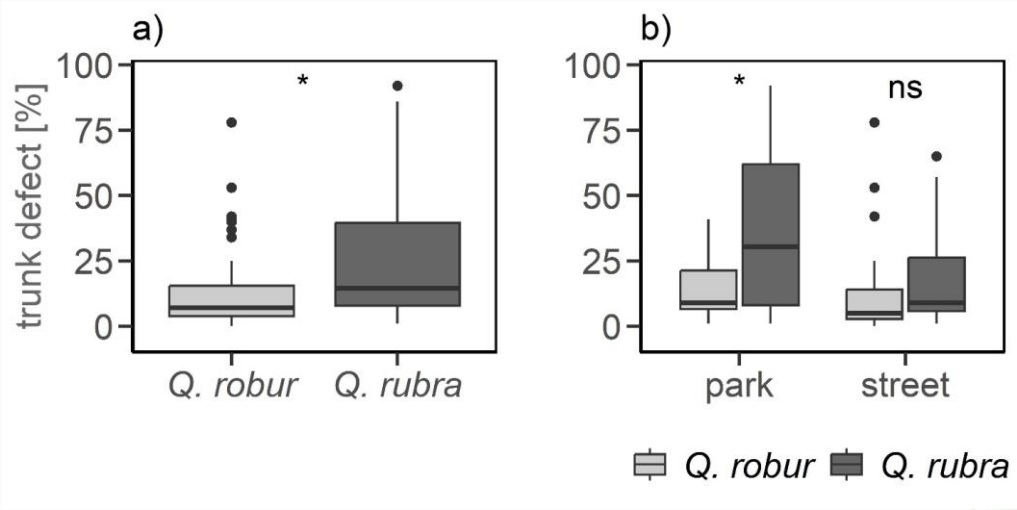
Red oaks had more trunk damage in parks than pedunculate oaks



35% trunk damage



0% trunk damage



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Impact of drought on radial growth in other species

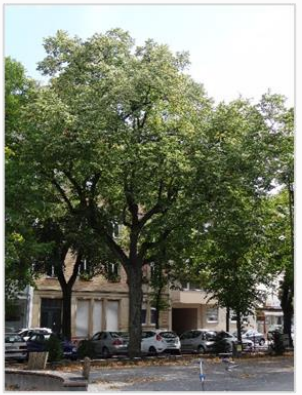
Norway maple
Acer platanoides

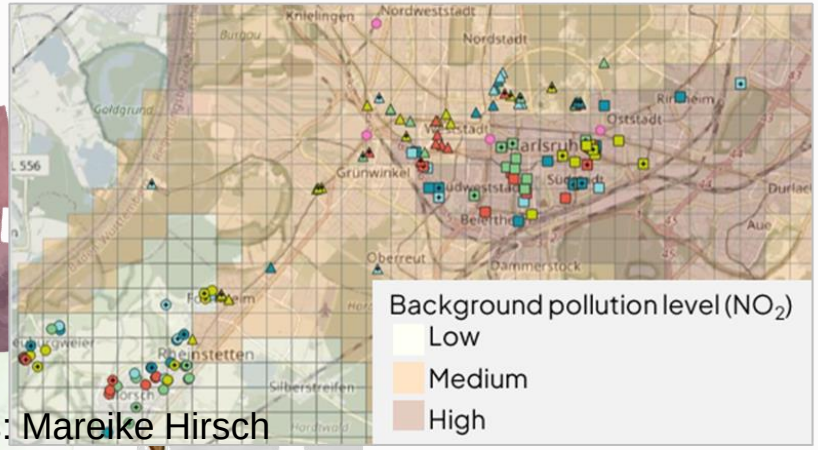
Hornbeam
Carpinus betulus

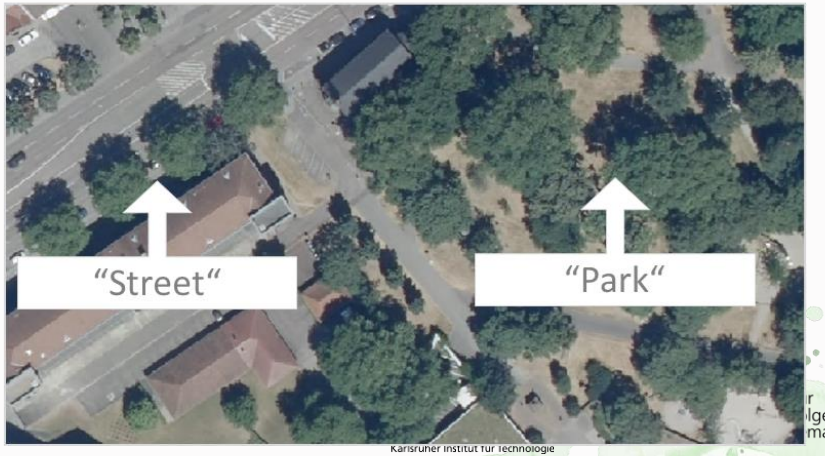
London plane
Platanus × hispanica

Common oak
Quercus robur

Small-leaved lime
Tilia cordata

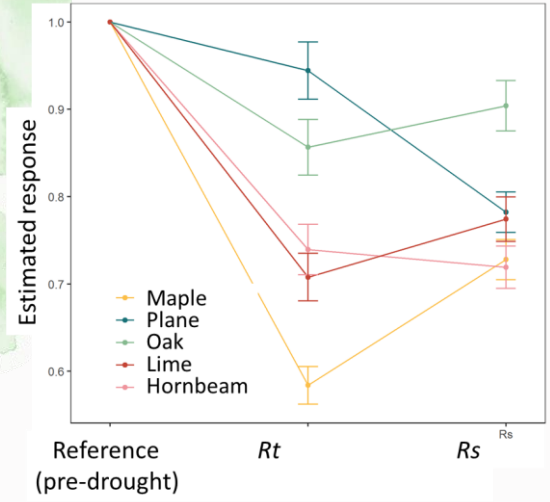






Photos: Mareike Hirsch

Plane and pedunculate oak trees are more resistant to drought and spring precipitation had impacted maple, oak, and lime trees



Time period: 1982-2018		March	April	May	June	July	Sum JJA (prev. year)
Maple	TRW_i	↑		↑			
	$\delta^{13}C$			↓			
	$\delta^{18}O$			↓			
Oak	TRW_i	↑		↑	↑		
	$\delta^{13}C$						
	$\delta^{18}O$			↓			
Hornbeam	TRW_i			↑			
Lime	TRW_i	↑		↑		↑	
	$\delta^{13}C$			↓			
	$\delta^{18}O$			↓			
Plane	TRW_i						↑
	$\delta^{13}C$						
	$\delta^{18}O$			↓			↑

Hirsch, M, ….Saha, S. 2023
Trees - Structure and Function

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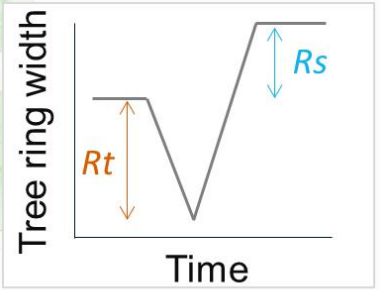
Soil and tree characteristics were the main drivers controlling growth, resistance and resilience

Resilience indices



- ✗ Distance to street
- ✗ Traffic emissions
- (✓) Soil properties
- ✓ Tree properties

Photos: Mareike Hirsch

Hirsch, M, ….Saha, S. 2023
Trees - Structure and Function

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Norway maples‘ response during heatwaves

vs.

Photos: Ferdinand Betting

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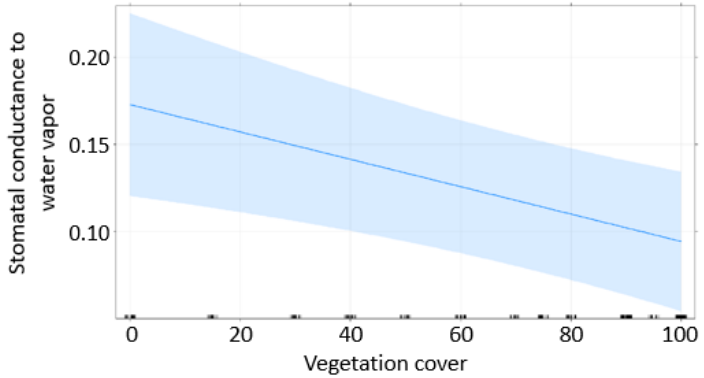
Norway maples‘ response during heatwaves (more ground vegetation reduces stomatal conductance)

Stomatal conductance to H_2O – Linear mixed-effects Model



Marginal R^2: 0.11;
conditional R^2: 0.53

Figure 3: Linear mixed-effects model of square root transformed stomatal conductance to water vapor depending vegetation cover as a fixed effect. The 95% confidence interval for the fitted values is shown as a blue-shaded area.

Kramer. D.; Saha, S.
In preperation

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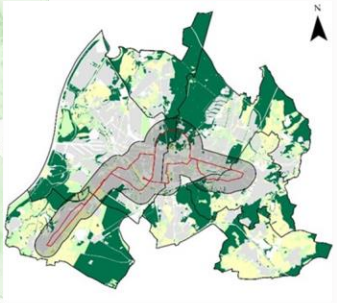
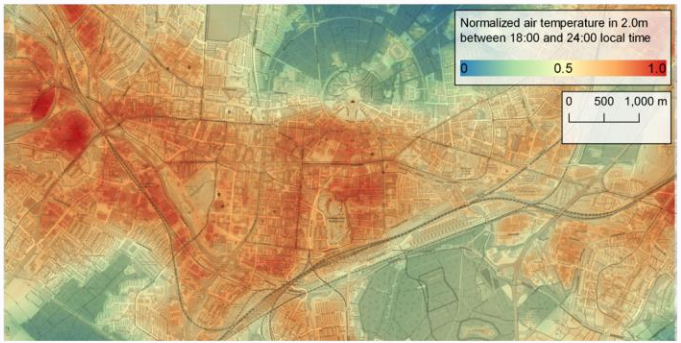
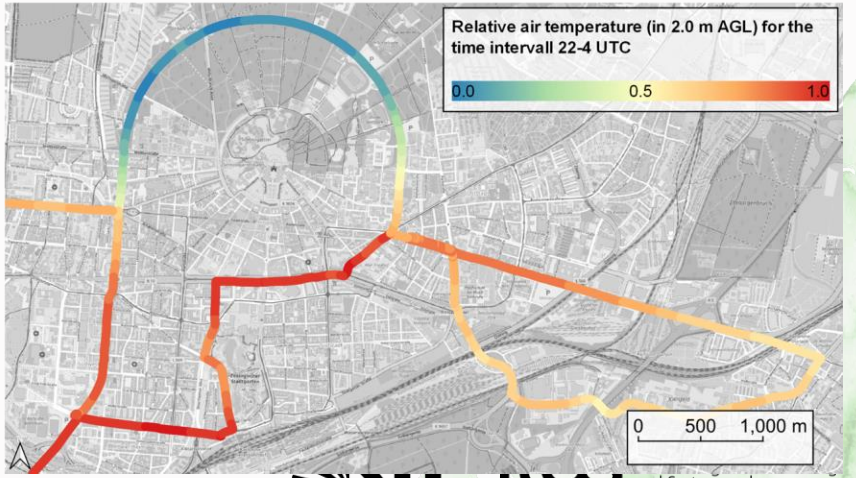
Tree cover and heatwaves







Graphics and photos:
Marcel Gangwisch/DWD

Gangwisch, M.; **Saha**, S.; Matzarakis, A. (2023)
(Urban Climate)
https://www.sciencedirect.com/science/article/pii/S2212095523002183

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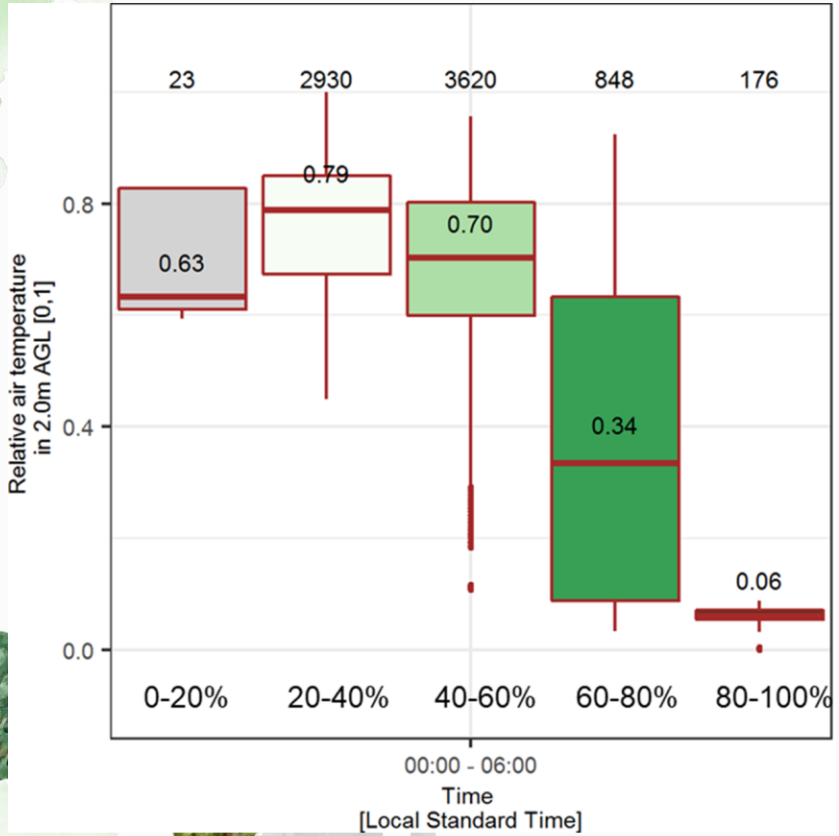
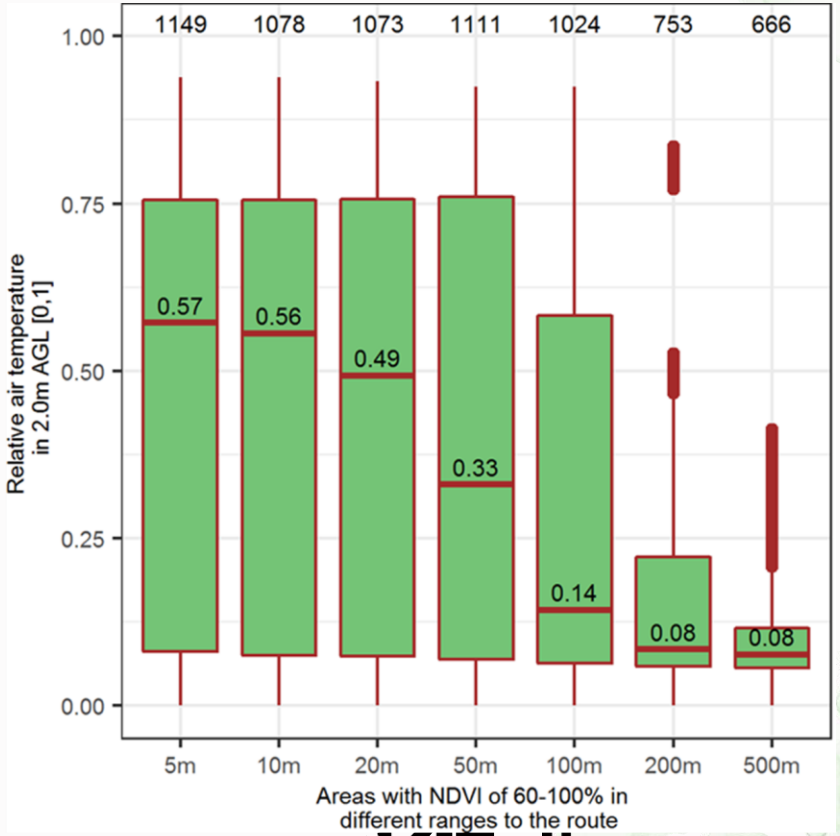
und Systemanalyse

Cooling increased with tree cover percentage and proximity to green space





Gangwisch, M.; **Saha**, S.; Matzarakis, A. (2023)
(Urban Climate)
https://www.sciencedirect.com/science/article/pii/S2212095523002183

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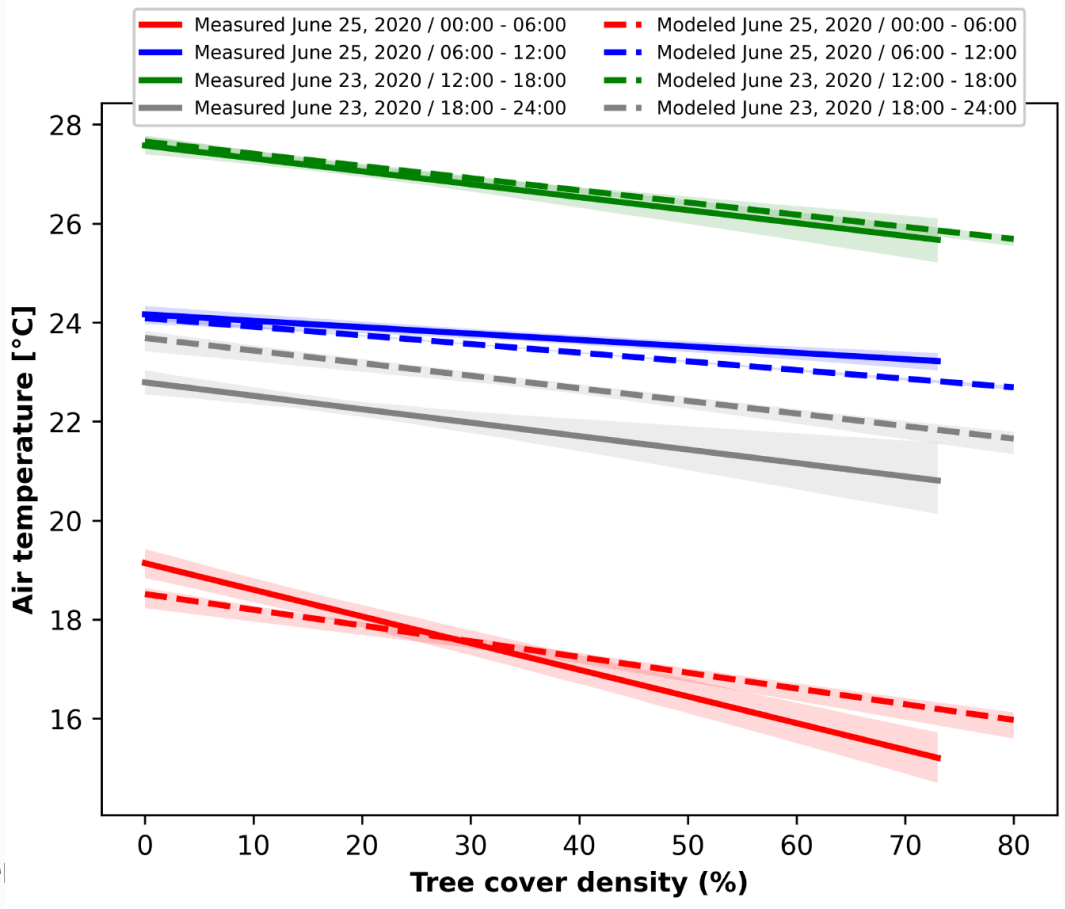
Tree cover and air-temperature



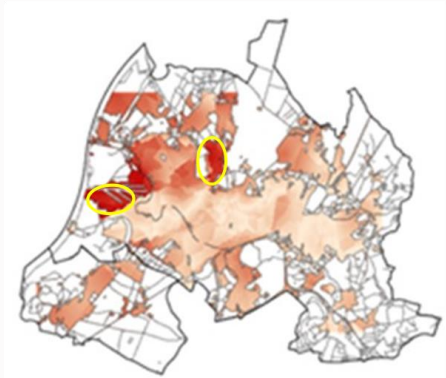
Gangwisch et al 2023, Urban Climate

Pace et al., under review

Supply of ecosystem services by solitary trees and trade-offs between them

Supporting ES

Regulating ES



Cueva, J, …., Saha, S.
2022 (Sustainable Cities and Society)

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Why do trade-offs happen between regulating ecosystem services and supporting ecosystem services?

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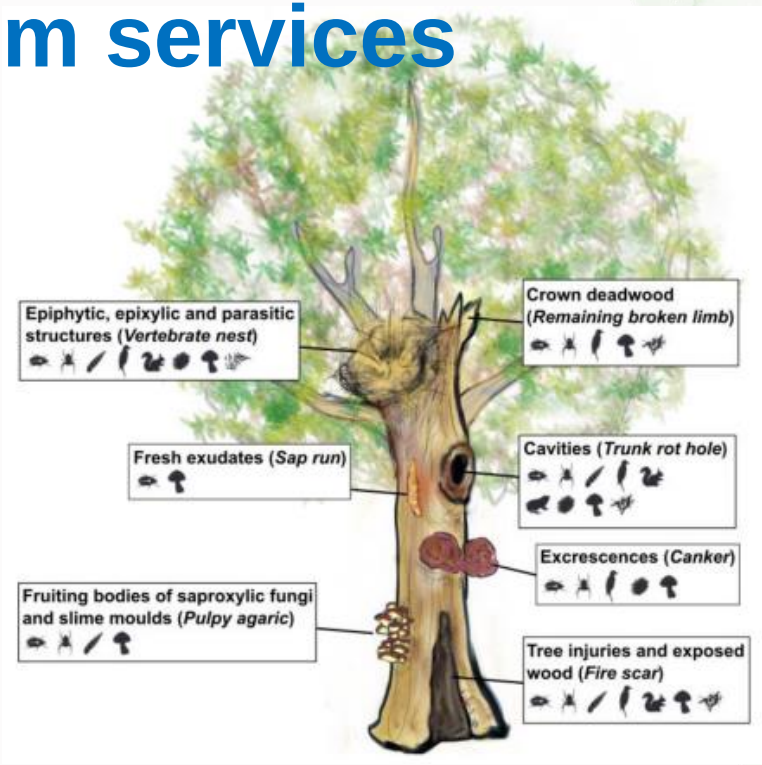
Tree-related microhabitats are crucial for supporting ecosystem services

Tree-related microhabitats (TreMs)

=

small structures on trees that provide habitats for species



Seven tree-related microhabitat forms by Larrieu et al. 2018. Drawing by Valentina Buttò and Celine Emberger (from Martin et al. 2022).

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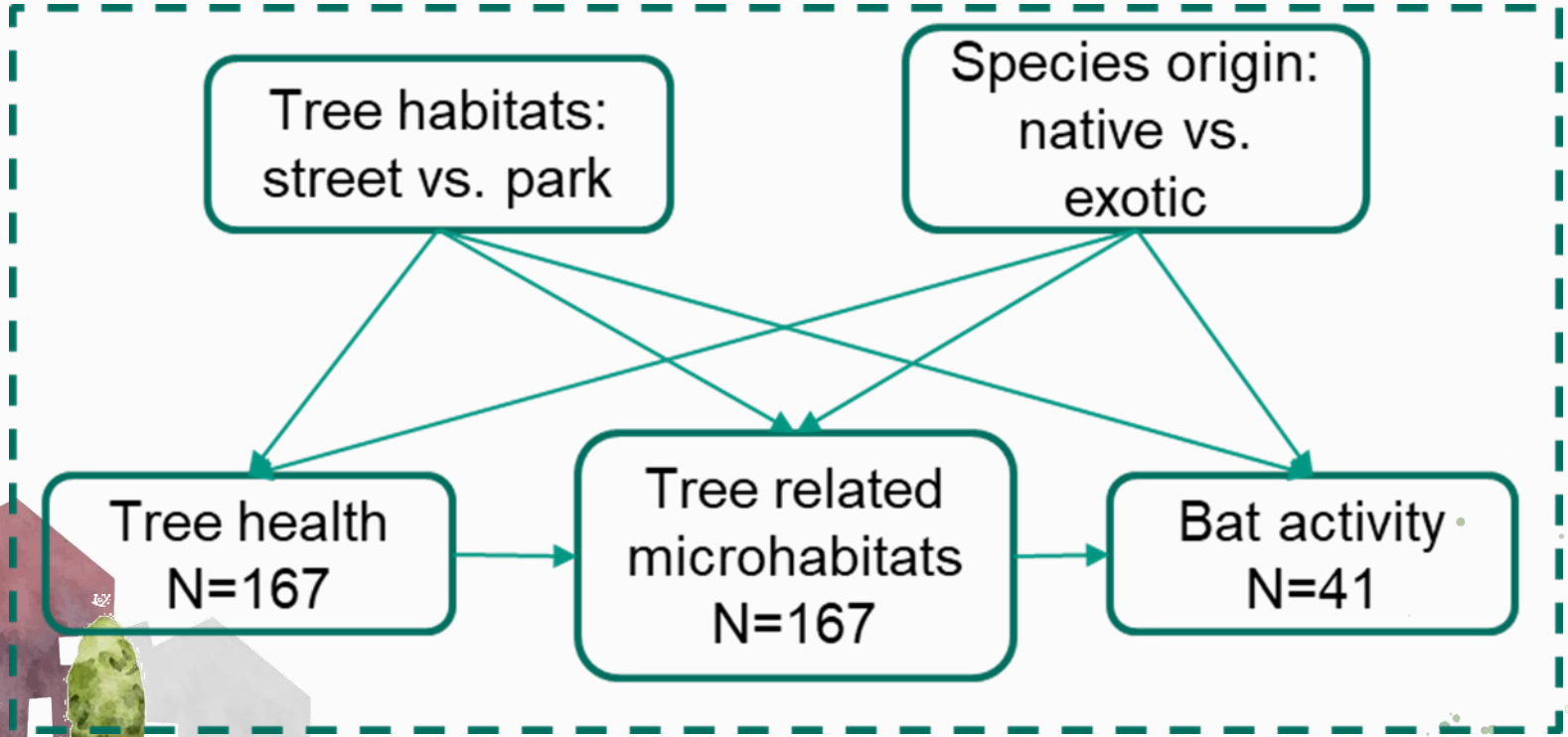
Tree microhabitats, bats, and health symptoms



Lyu, H, …., Saha, S.
2022 (Science of The Total Environment)

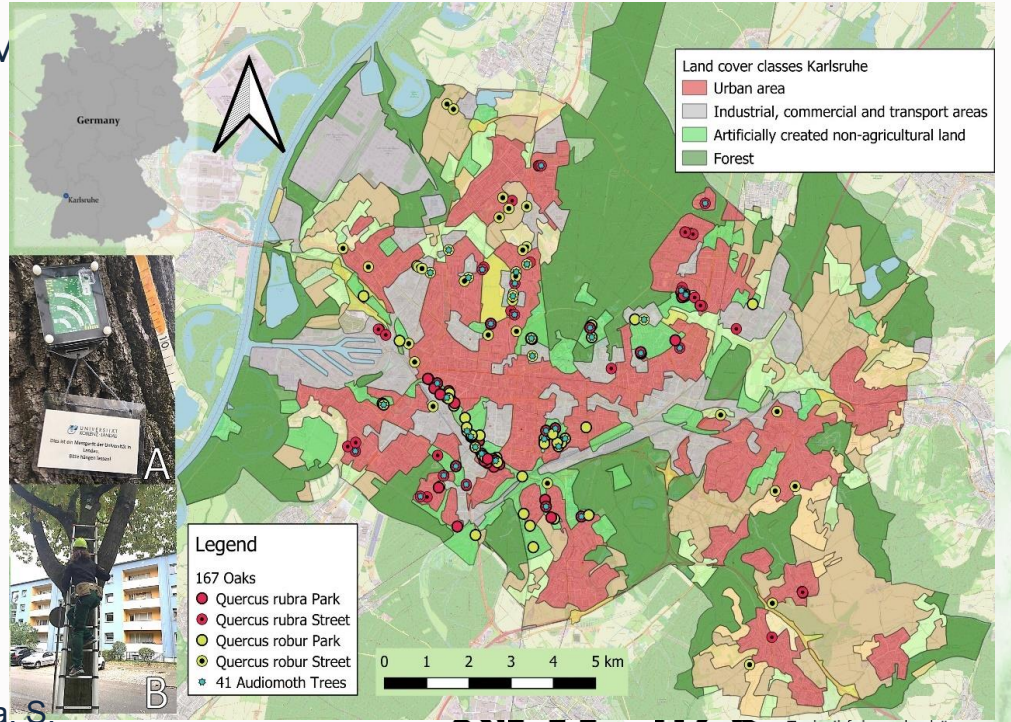
Tree microhabitats, bats, and health symptoms

Trees selection for health and microhabitats

- Diameter at 1.3 m height/DBH > 20CM
- Random selected
- 42 trees for each category
  - street vs. park
  - native vs. non-native
  - one tree died during field data colleciton

Trees selection for bat activity

- DBH > 50CM
- Random selected within 167 trees
- 10 trees for each category
  - street vs. park
  - native vs. non-native
  - and 5 more



Lyu, H, …., Saha, S. 2022 (Science of The Total Environment)

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Tree microhabitats, bats, and health symptoms

Dendrometry Variables
Tree ID
Street/Park tree
Species
DBH
Number of cut branches
Dieback
Total height
Height to crown top
Height to crown base
Crown width
Crown missing
Impervious beneath canopy
Shrub cover beneath canopy
Crown Light Exposure (CLE)
Crown openness %

Tree health variables	
Tree stress	Dieback
	Epicormic sprouts
	Wilted foliage
	Abiotic stress
	Biotic stress
	Tree stress notes
	Tree stress area
Signs and symptoms of foliage and twigs	Defoliation
	Discoloured foliage
	Abnormal foliage
	Insect signs
	Foliage and twigs area
	Foliage and twigs notes
Signs and symptoms of branches and bole	BB insect signs
	Insect presence
	Disease signs
	Problem location
	Loose bark
	Branch and bole notes

Four of 11 observed tree health symptoms were involved in the calculation of tree health score

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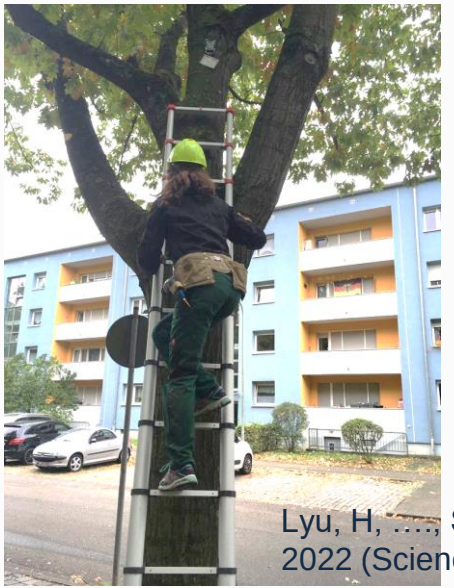
Tree microhabitats, bats, and health symptoms

- Experimental equipment: AudioMoth acoustic recorders
- Attach tree height: 4m
- Recording time: 6:30 pm - 9:30 am, 2 October to 5 October 2020
- Sampling rate: 256 kHz, Gain: Medium



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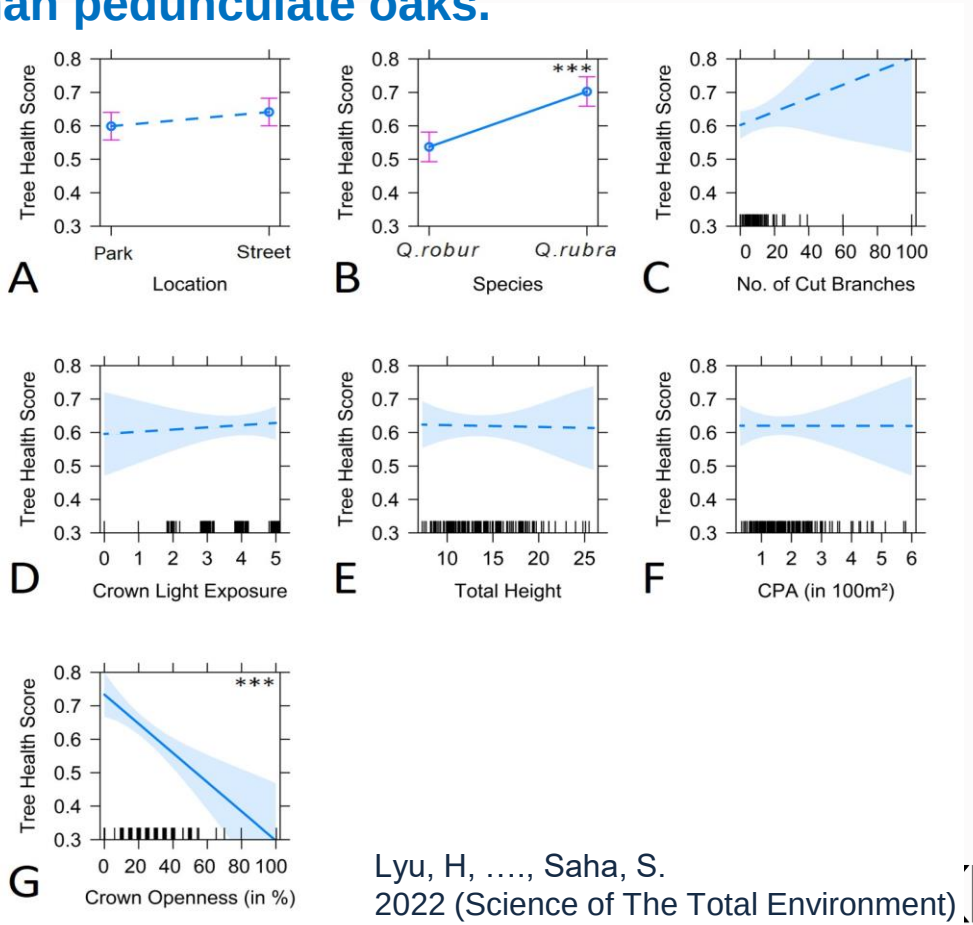
Red oaks had better health (lower crown die-back, defoliation, and discoloration) than pedunculate oaks.



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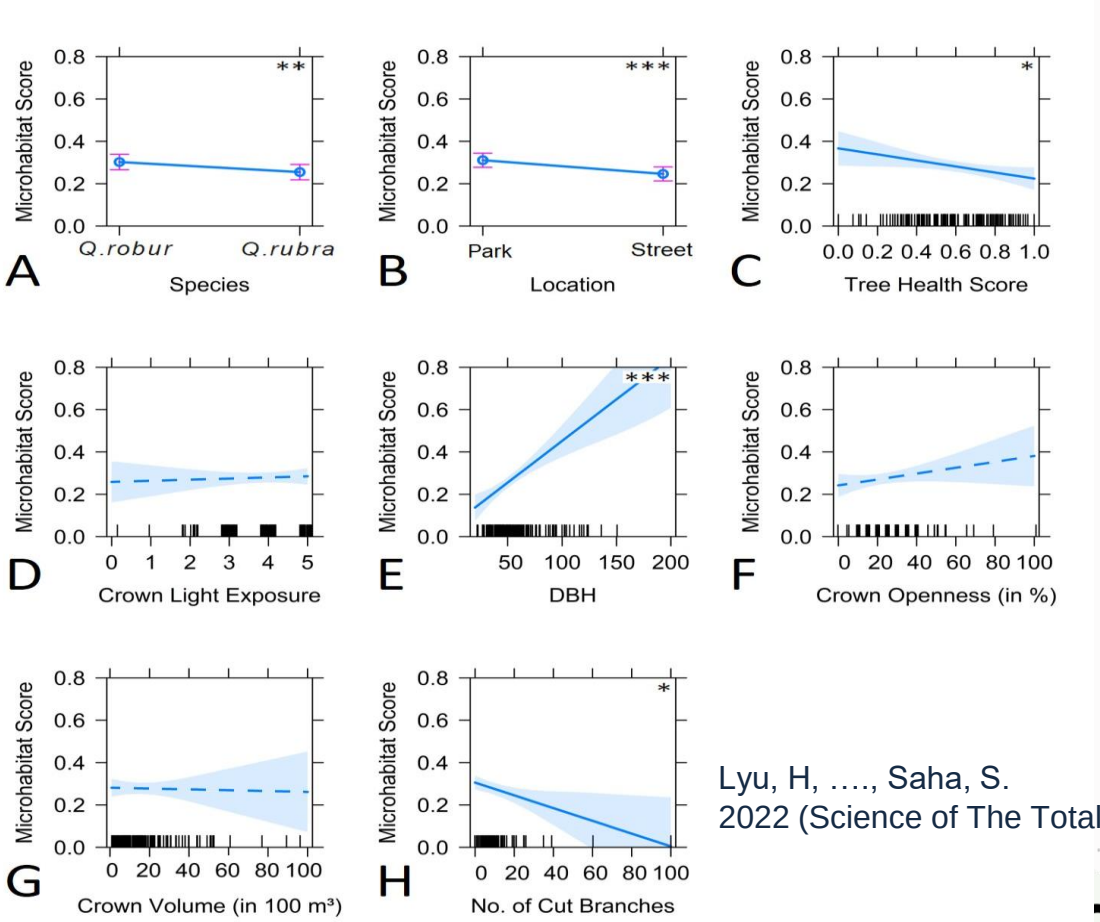
But diversity and abundance of microhabitats are higher in native pedunculate oaks than exotic red oaks



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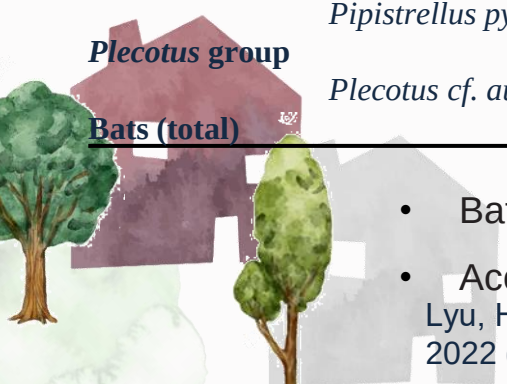
Bat activities recorded in AudioMoth survey (we found 9 species of bat in Karlsruhe ☺)

Bat group	Bat species (English name)	Active minutes	% of sites with group
***Myotis* group**		**72**	**12.2**
	Myotis daubentonii (Daubenton's bat)	72	
Nyctaloid group		**623**	**65.9**
	Nyctalus leisleri (Lesser noctule)	51	
	Nyctalus noctula (Common noctule)	567	
	Eptesicus serotinus (Serotine bat)	5	
***Pipistrellus* group**		**10,287**	**100.0**
	Pipistrellus kuhlii (Kuhl's pipistrelle) / *Pipistrellus nathusii* (Nathusius's pipistrelle)	576	
	Pipistrellus pipistrellus (Common pipistrelle)	9,388	
	Pipistrellus pygmaeus (Soprano pipistrelle)	323	
***Plecotus* group**		**356**	**48.8**
	Plecotus cf. auritus (Brown long eared bat)	356	
Bats (total)		**11,338**	



- Bat activity: number of minutes with calls of each species.
- Acoustically similar bats were grouped to avoid misidentification

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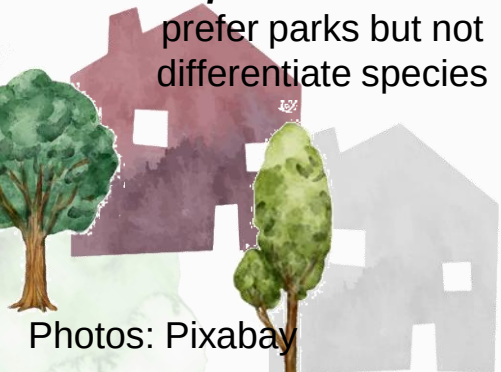
Bat activities near-native and exotic oak trees at street and park

***Pipistrellus* bats:**
prefer parks but not differentiate species

Brown long-eared bats (*Plecotus*):
prefer native oaks
prefer parks
prefer trees with fork split, sunscald damage and woodpecker holes

Noctule bats (Nyctalus):
neither differentiate between trees nor between habitats



Photos: Pixabay

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Why do trade-offs happen between regulating ecosystem services and supporting ecosystem services?

- Large trees with diverse microhabitats can provide more biodiversity
- But it can conflict with regulating ecosystem services that need healthy leaf areas for transpirational cooling
- The number of large trees is declining

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Outlook

- Monitor and study city trees and promote them as Sentinels rather than Trojan Horses against invasive species
- Need more field ecological and ecophysiological studies (photosynthesis, transpiration, radial growth)
- Park and street trees should be managed differently
- Why a US city in lower latitude had lesser diversity than Karlsruhe? (need more data)
- Trade-off can be mitigated by increasing large trees in city whenever possible

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Thank you

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