Session 1.3

In the Cool of the Day: The role of urban forests in improving microclimate and reducing the heat island effect

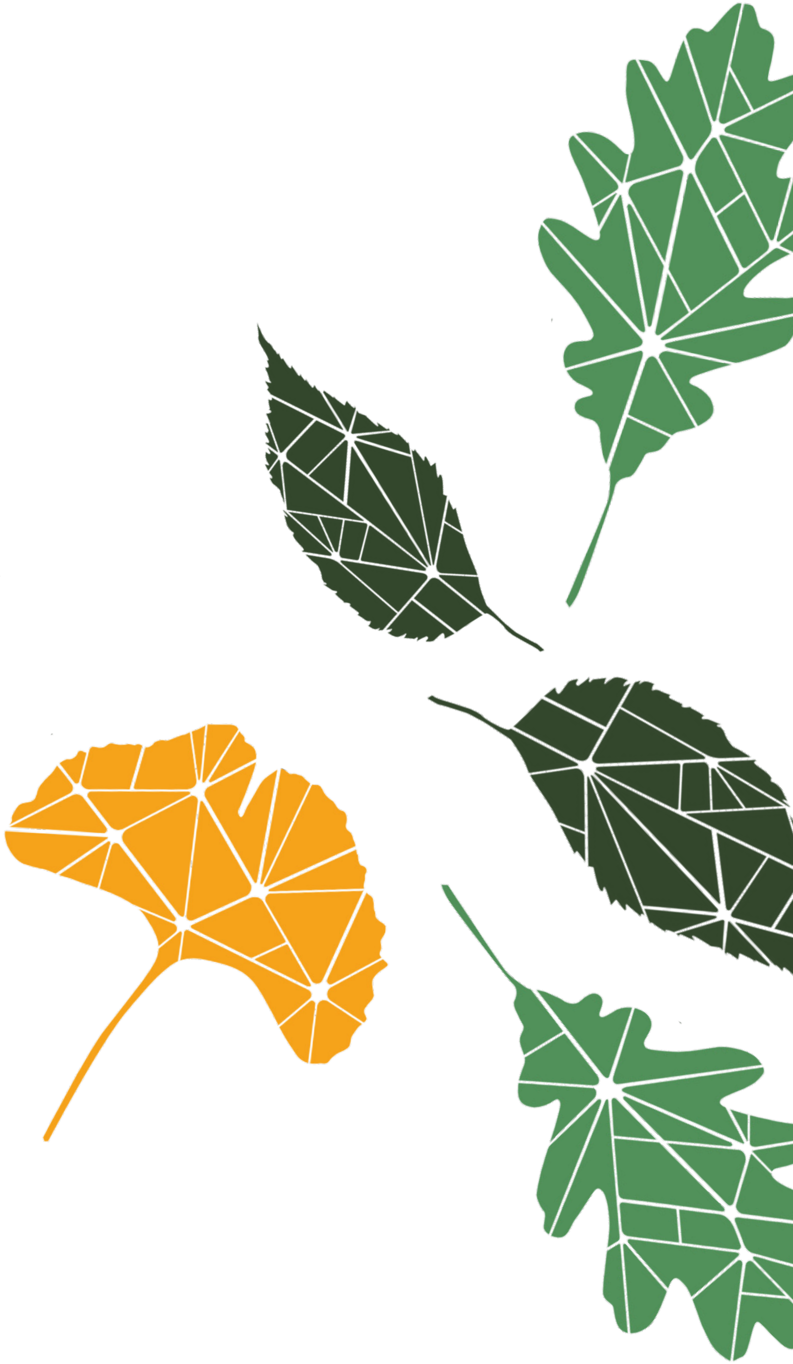
Chair: Francisco Escobedo

World Forum on
Urban Forests

2nd World Forum on Urban Forests
Washington DC, 2023

In the Cool of the Day

Amount and distribution of street trees for cooler neighborhoods



Presented by
Yehan Wu
Landscape architecture and spatial planning group

Wageningen University, The Netherlands

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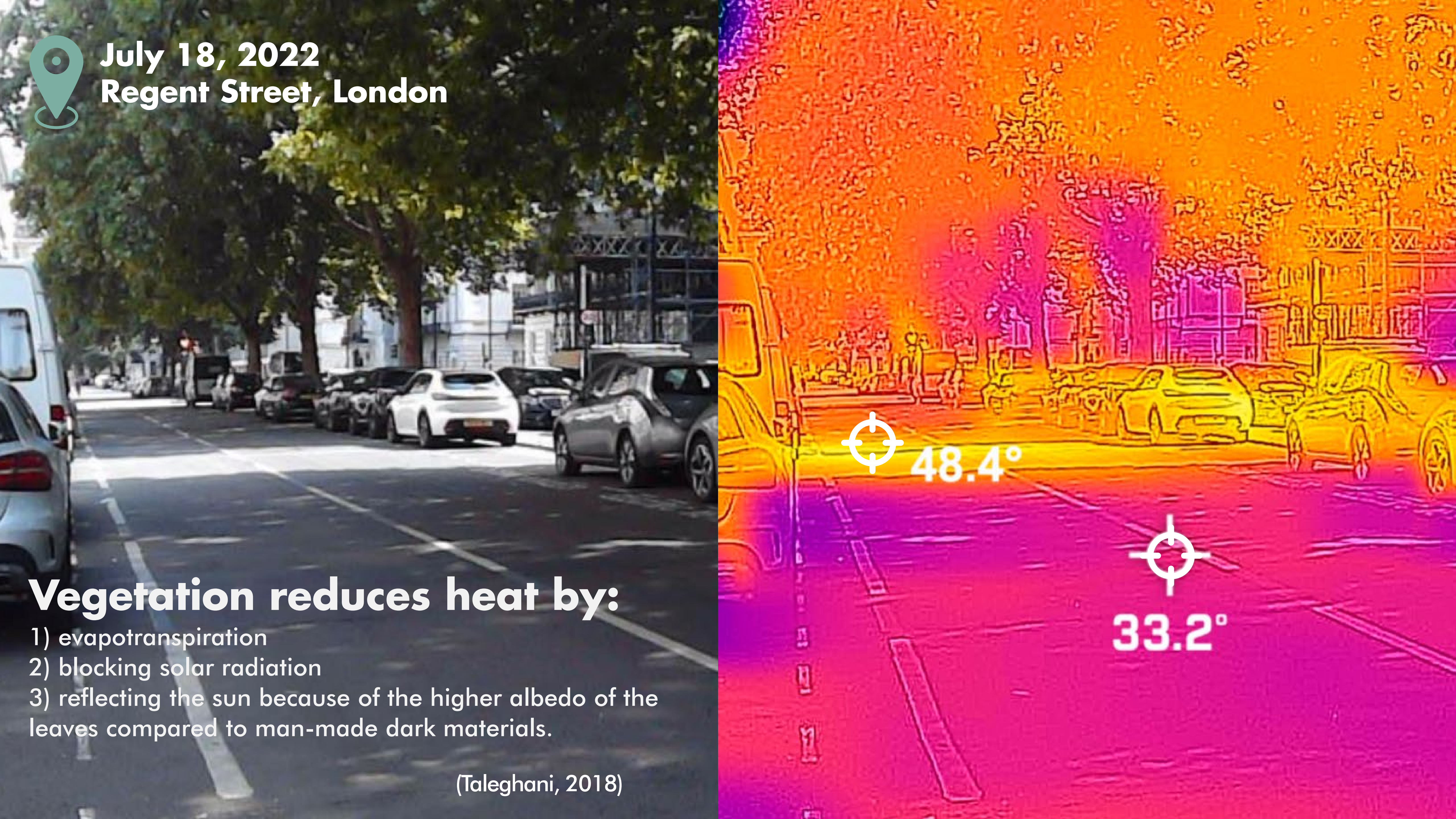
SOLOCLIM
SOLUTIONS FOR OUTDOOR CLIMATE ADAPTATION

European Commission

Horizon 2020
European Union funding
for Research & Innovation

July 18, 2022
Regent Street, London



Vegetation reduces heat by:

1) evapotranspiration
2) blocking solar radiation
3) reflecting the sun because of the higher albedo of the leaves compared to man-made dark materials.

(Taleghani, 2018)

Vegetation-based design interventions for cooling the neighbourhood are urgently needed.

Oxford circus, London

Masdar city plan, Foster + Partners

Knowledge gap

Neighbourhood morphology

- "The surrounding urban form in the neighbourhood can affect the cooling performance of trees." (Middel et al., 2014)

Amount

- "Daytime air temperature was substantially reduced with canopy cover ≥40% ." (Ziter et al., 2019)
- "Building and street coverage in dense neighbourhoods can exceed 80%" (Demuzele et al., 2019)

Distribution

- "Tree placement can influence overall ventilation and result in heat trapping ." (Wong et al., 2021)

Research question

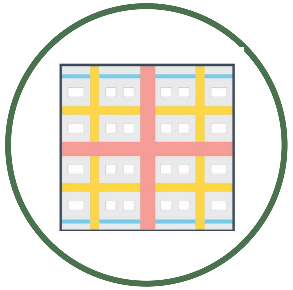
How to design street trees in the neighborhood for better cooling effects considering amount and distribution?

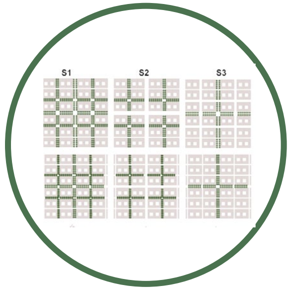
Pre-process scientific knowledge

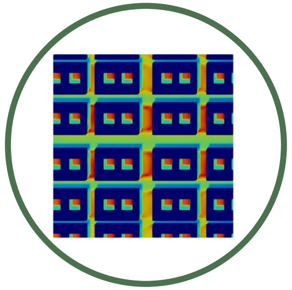
Design guidelines →

To be applicable to many situations

WORKFLOW







a **Cooling effects vary among typologies.**

b **Distribution matters for the same size of green space.**

c **Bigger is not always the better.**

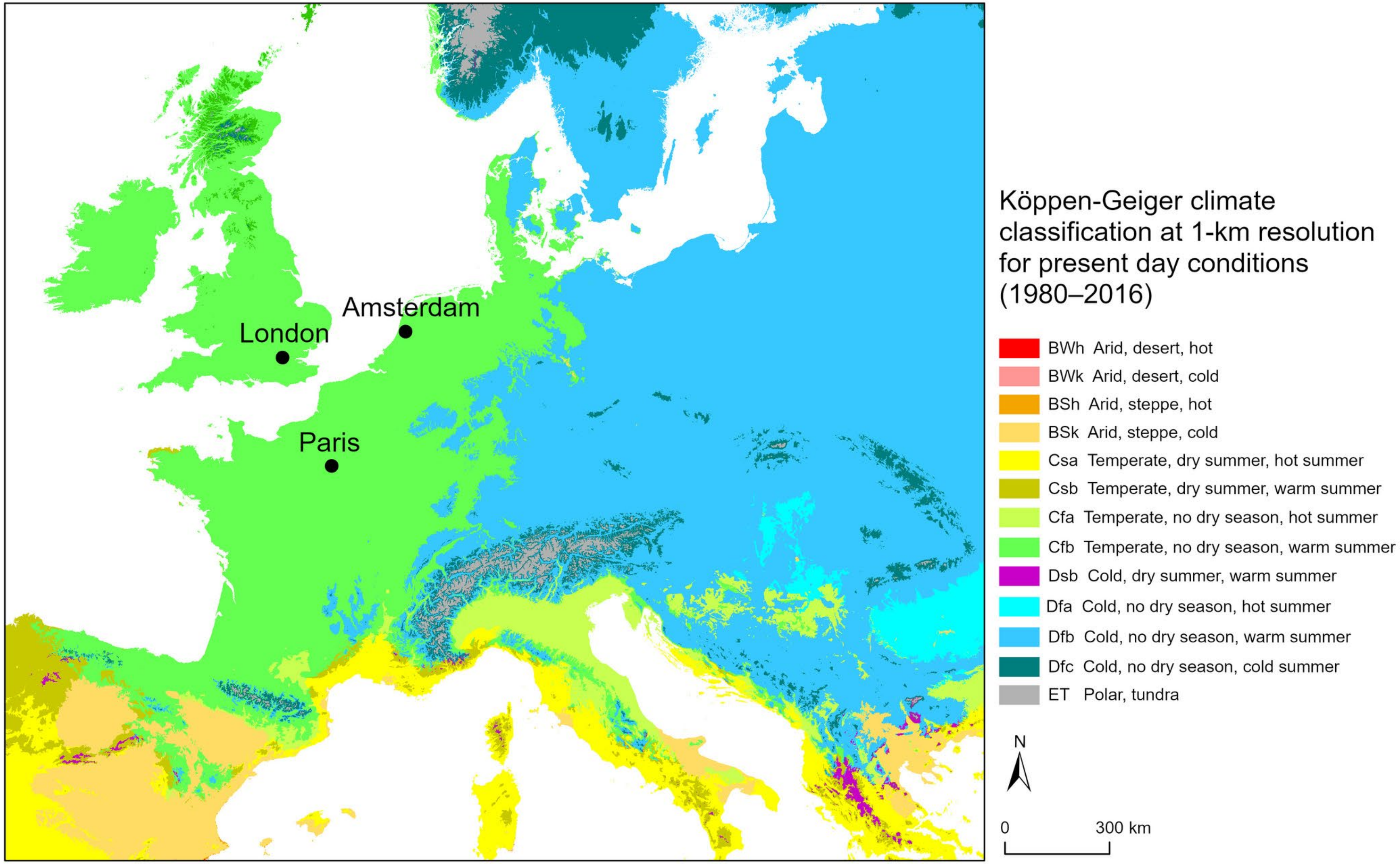
d **The scattered, the cooler.**

e **Covering trees or grass on main streets should be prioritised.**

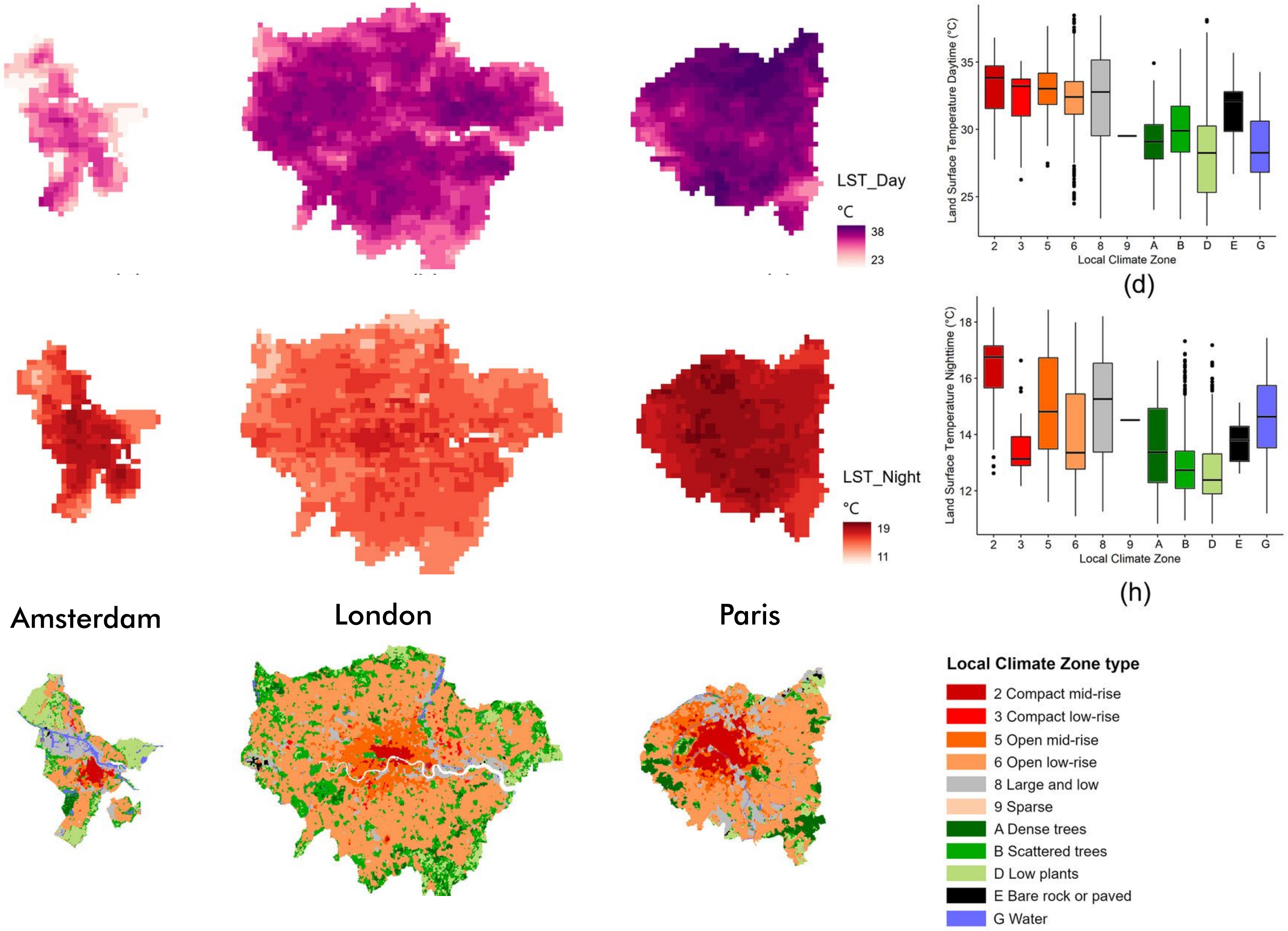
f **One row of trees can be more efficient than two rows.**

1. Typology --- 2. Scenario --- 3. Simulation --- 4. Designer assessment --- 5. Guidelines

Focused cities



Heat-prone areas: compact mid-rise



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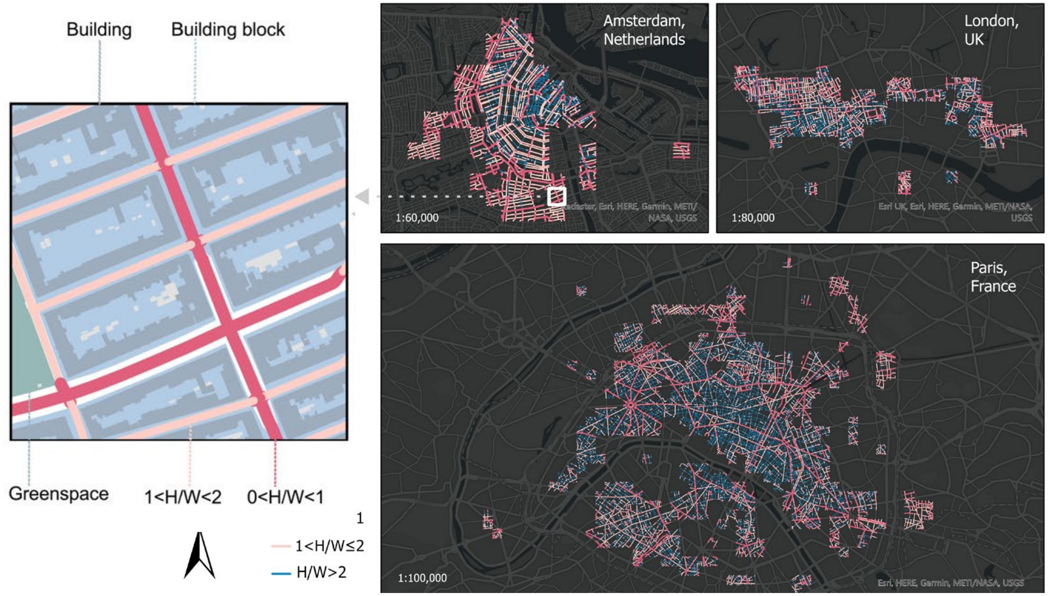
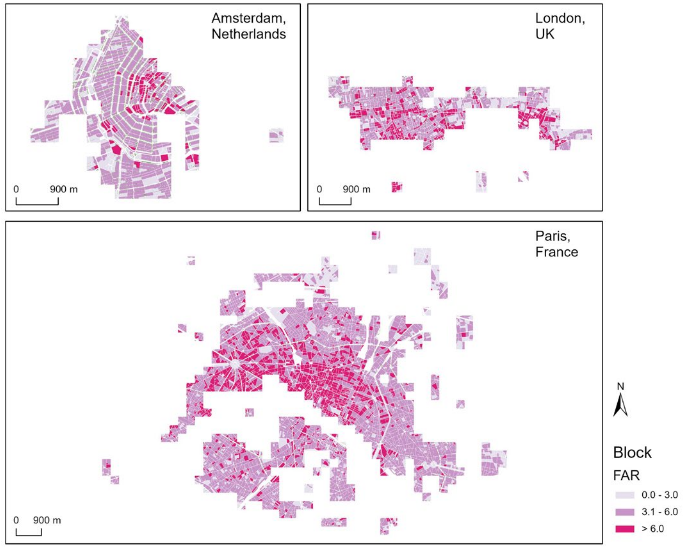
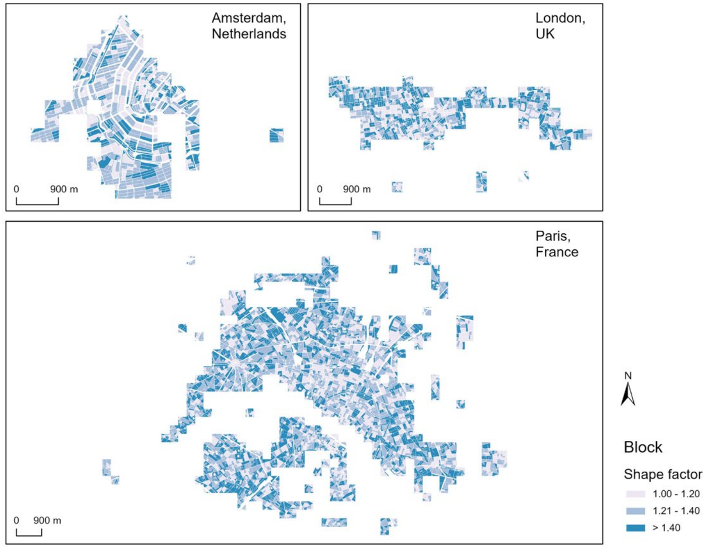
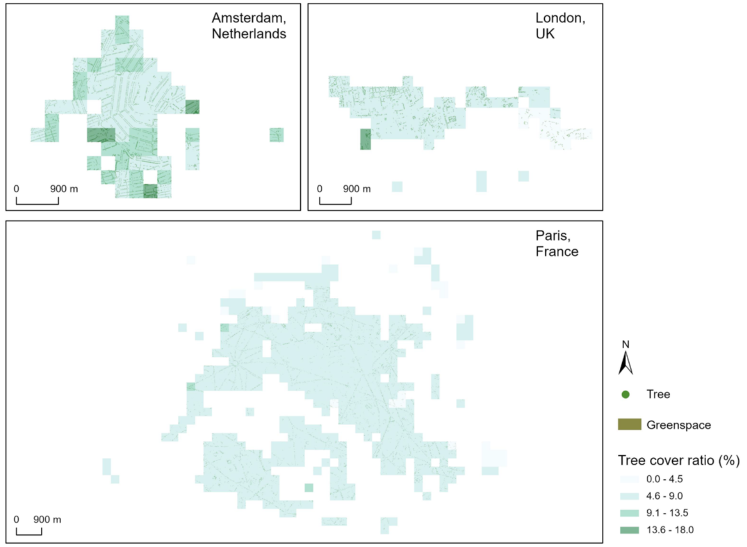
Morphological analysis of 656 neighbourhoods

1) **Street Height-to-Width ratios**
2) **Street orientations**
3) **Street total length**
4) **Building block's floor area ratio (FAR)**
5) **Building block's shape factor**
6) **Green space area**
7) **Tree cover ratio**





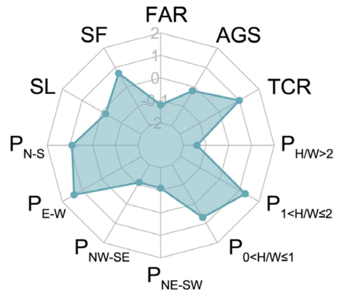




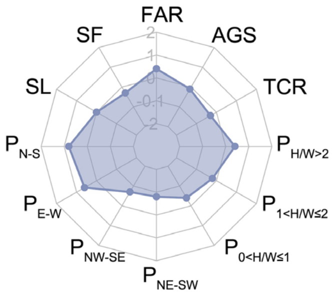
1. Typology – 2. Scenario – 3. Simulation – 4. Designer – 5. Guidelines

Cluster analysis

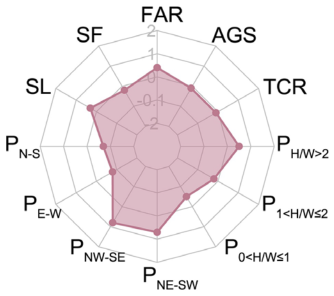
Typology 1
Orthogonal 0°- Shallow



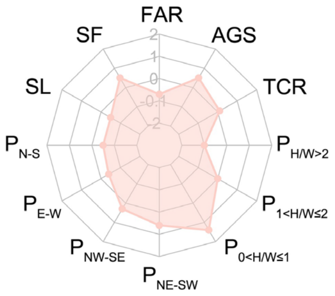
Typology 2
Orthogonal 0°- Deep

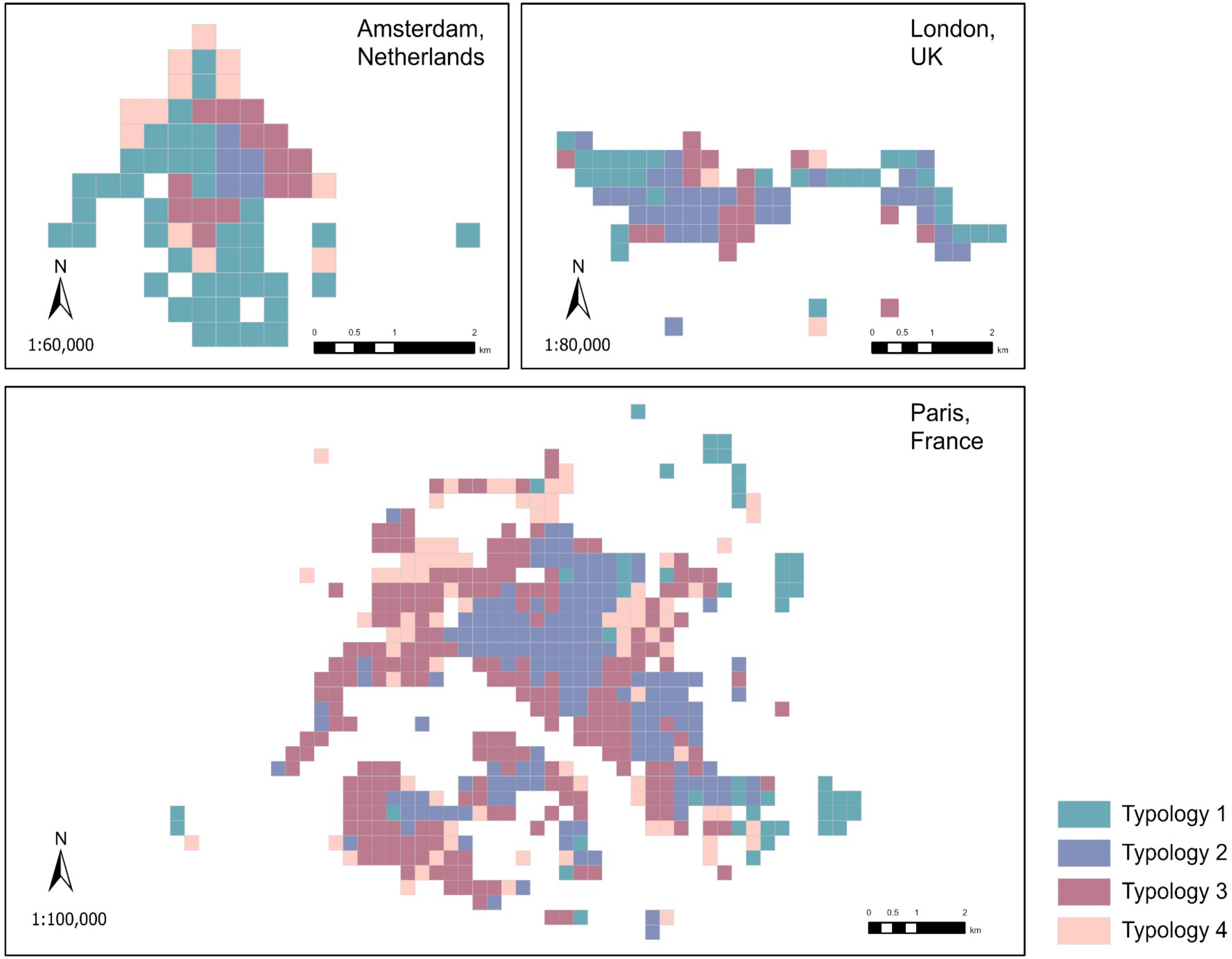


Typology 3
Orthogonal 45°- Deep



Typology 4
Cross - Shallow





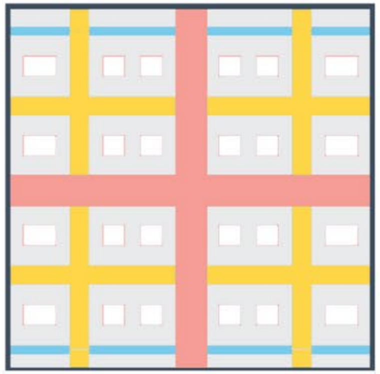
Four generalised neighbourhood typologies

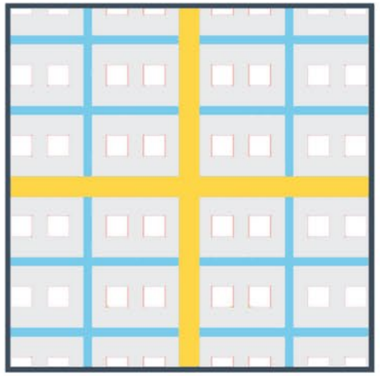

Amsterdam

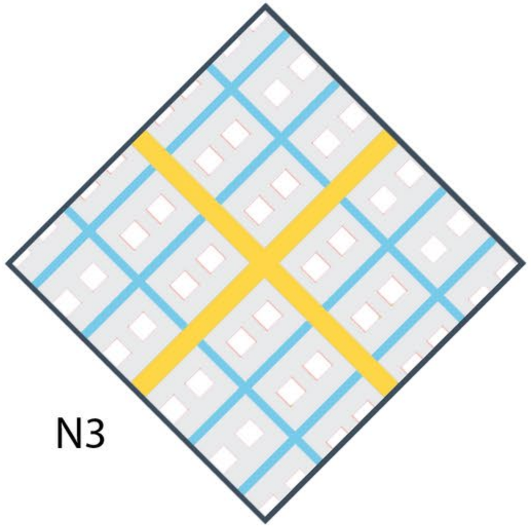

London

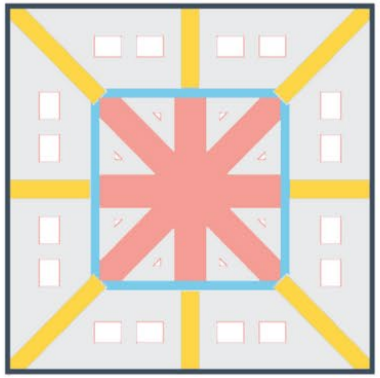

Paris


Paris


N1

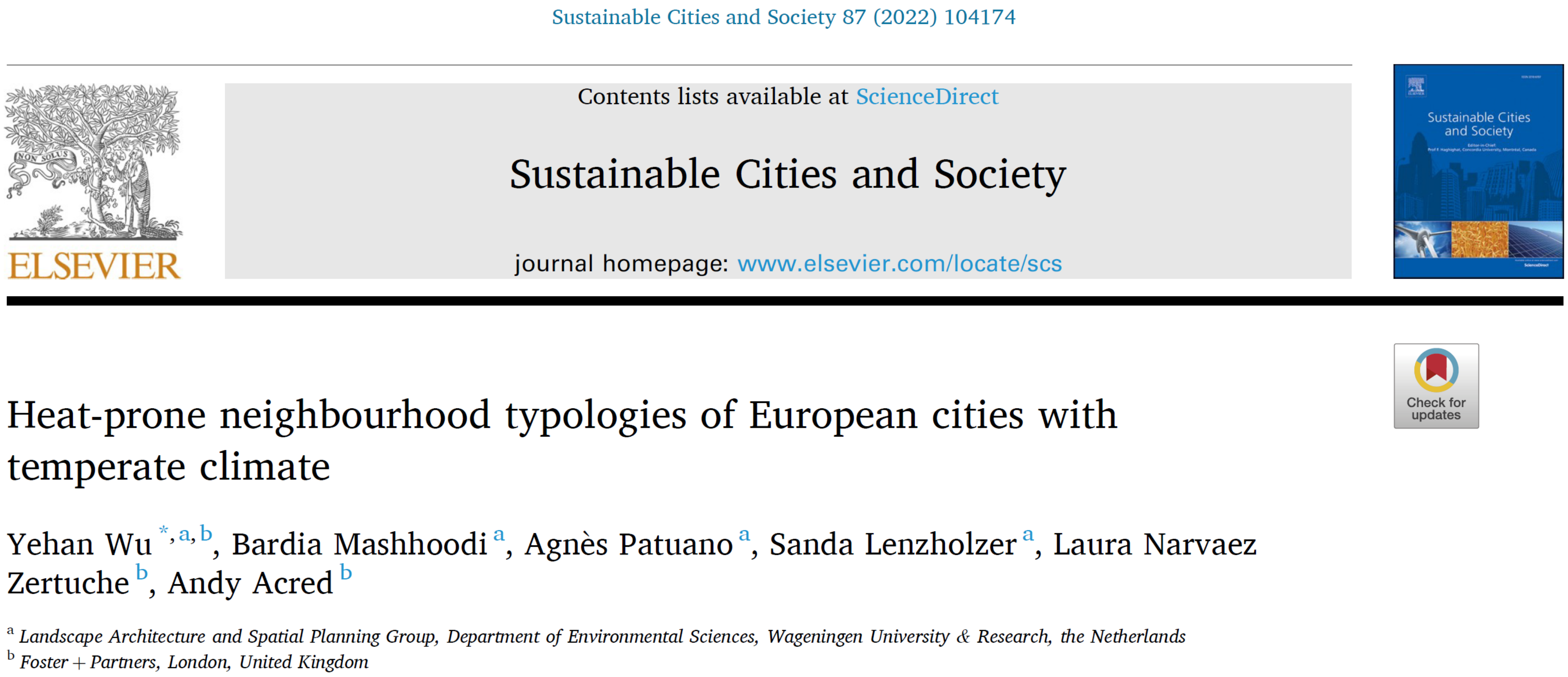

N2


N3


N4

⬜ Block
🟥 24m street
🟨 16m street
🟦 8m street
N

More details can be found in our published paper



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Heat-prone neighbourhood typologies of European cities with temperate climate

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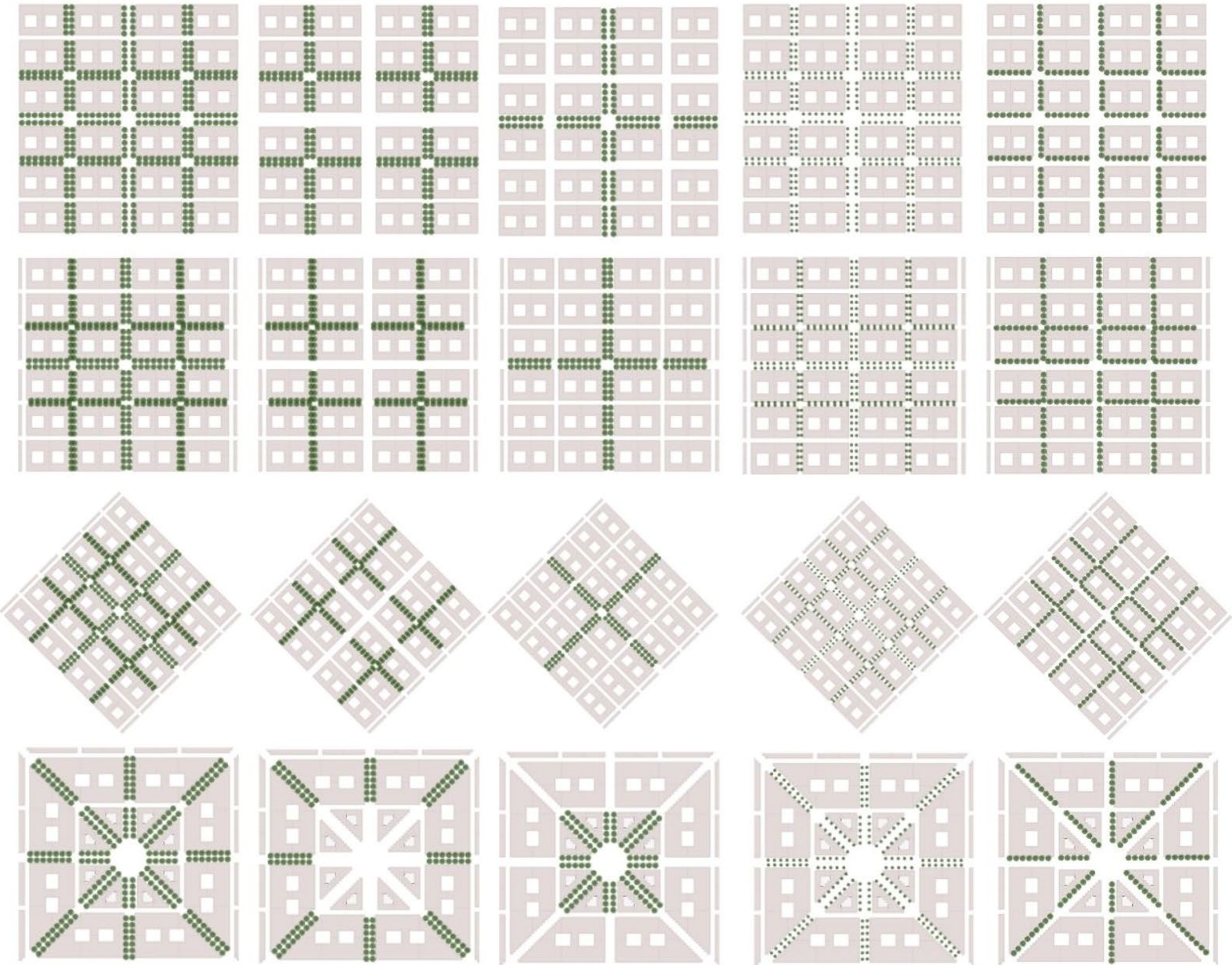
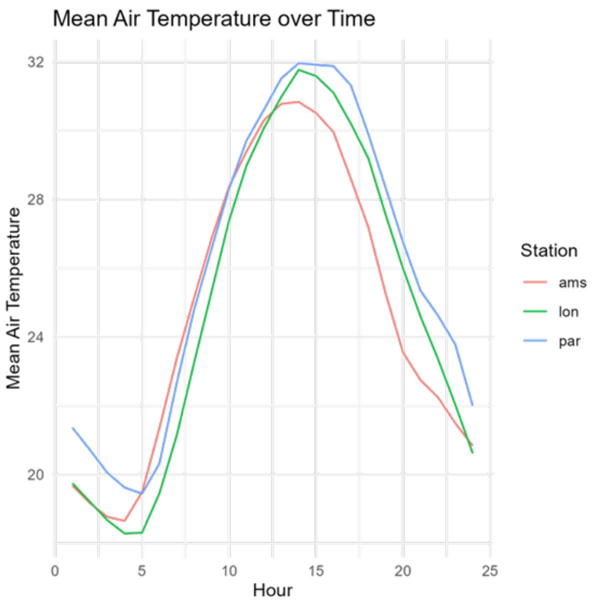
[a] *Landscape Architecture and Spatial Planning Group, Department of Environmental Sciences, Wageningen University & Research, the Netherlands*
[b] *Foster + Partners, London, United Kingdom*

Amount and distribution scenarios

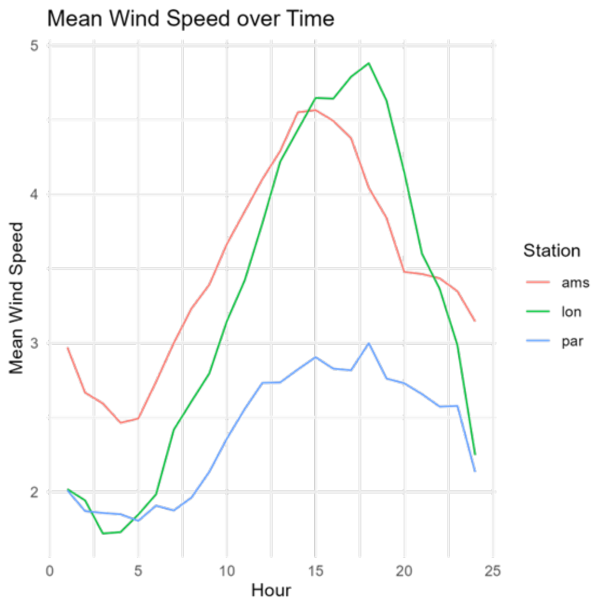


		S1	S2	S3	S4	S5
		Big trees in main and secondary streets	Big trees in secondary streets	Big trees in main streets	Small trees in main and secondary streets	Big trees in main and secondary high radiated side
Mainly wide streets with N-S and E-W orientations	T1					
Mainly narrow streets with N-S and E-W orientations	T2					
Mainly narrow streets with NE-SW and NW-SE orientations	T3					
Mainly wide streets with four orientations divided by 45°	T4					

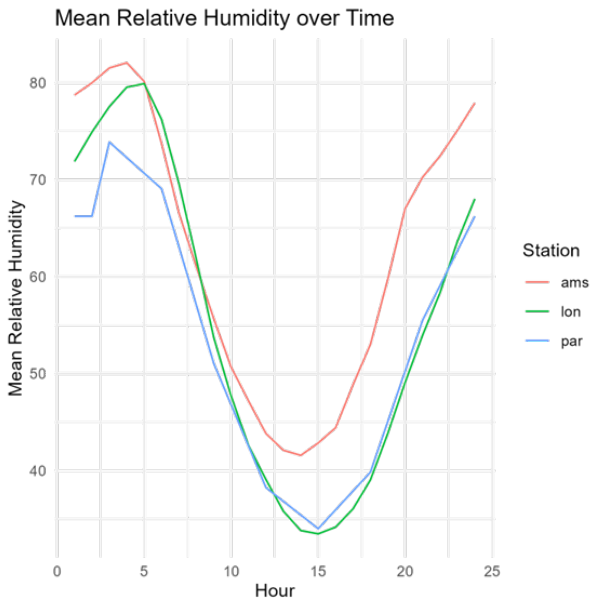
Simulation input: generalised weather data



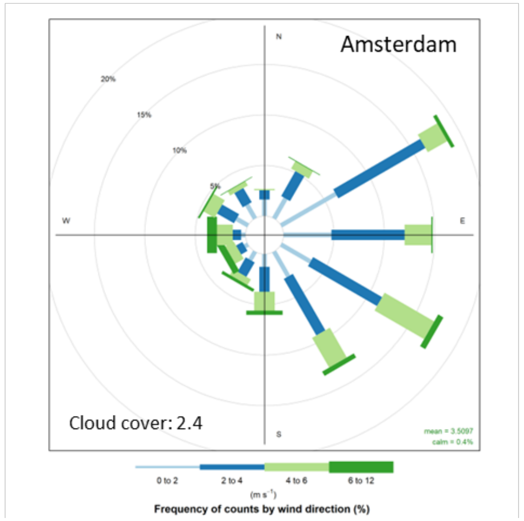
Mean Air Temperature over Time



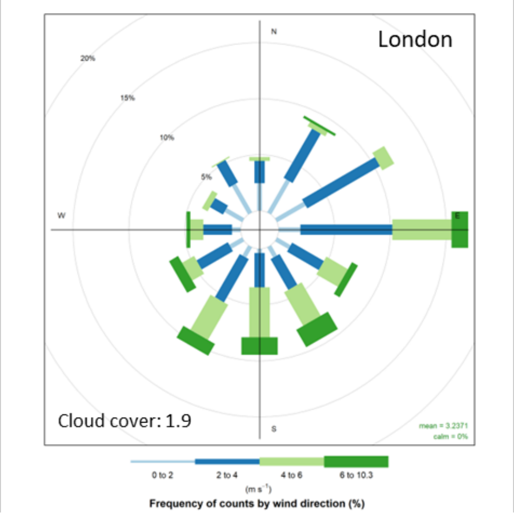
Mean Wind Speed over Time



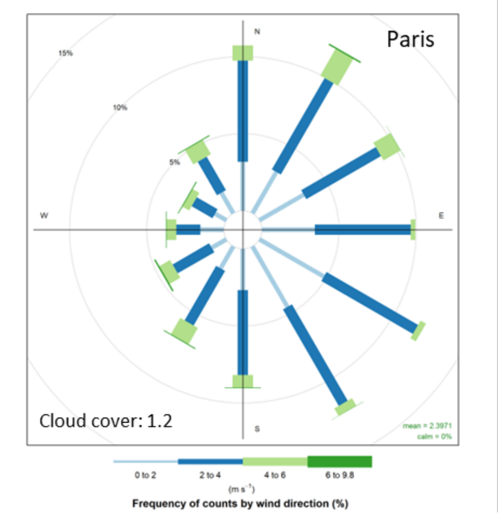
Mean Relative Humidity over Time



Cloud cover: 2.4



Cloud cover: 1.9



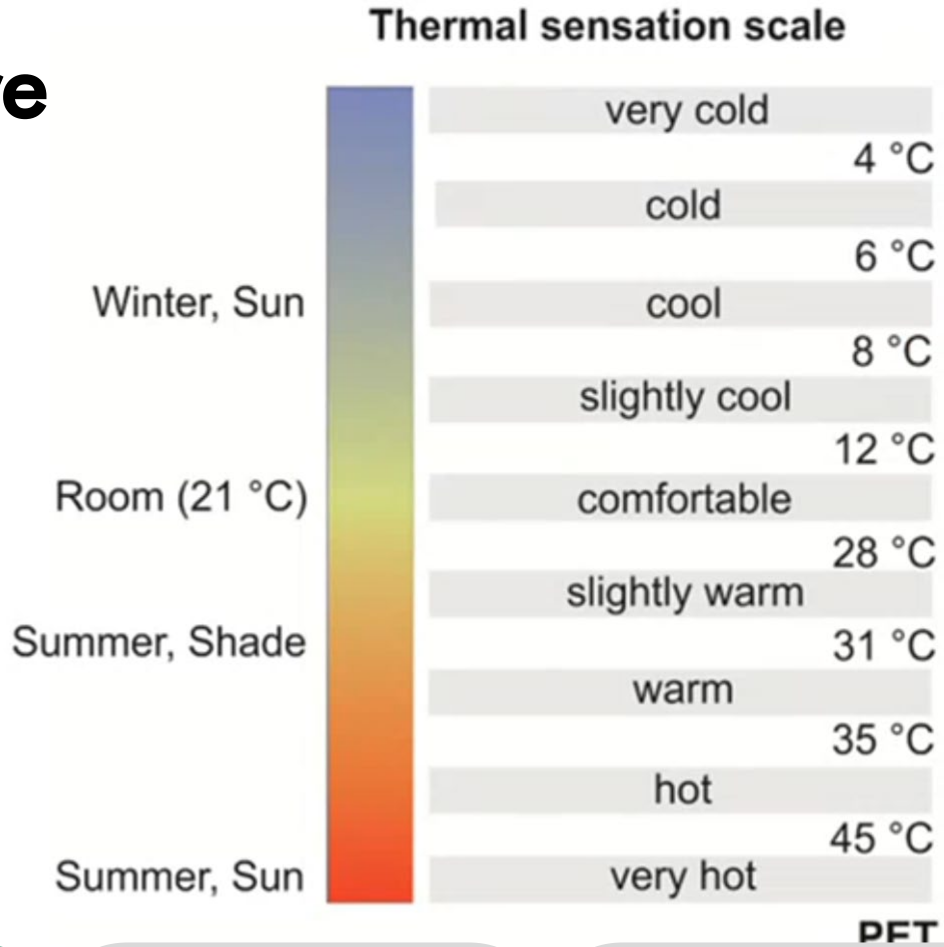
Cloud cover: 1.2

Heatwave days of the past 20 years were extracted and analysed to develop a generalised weather data.

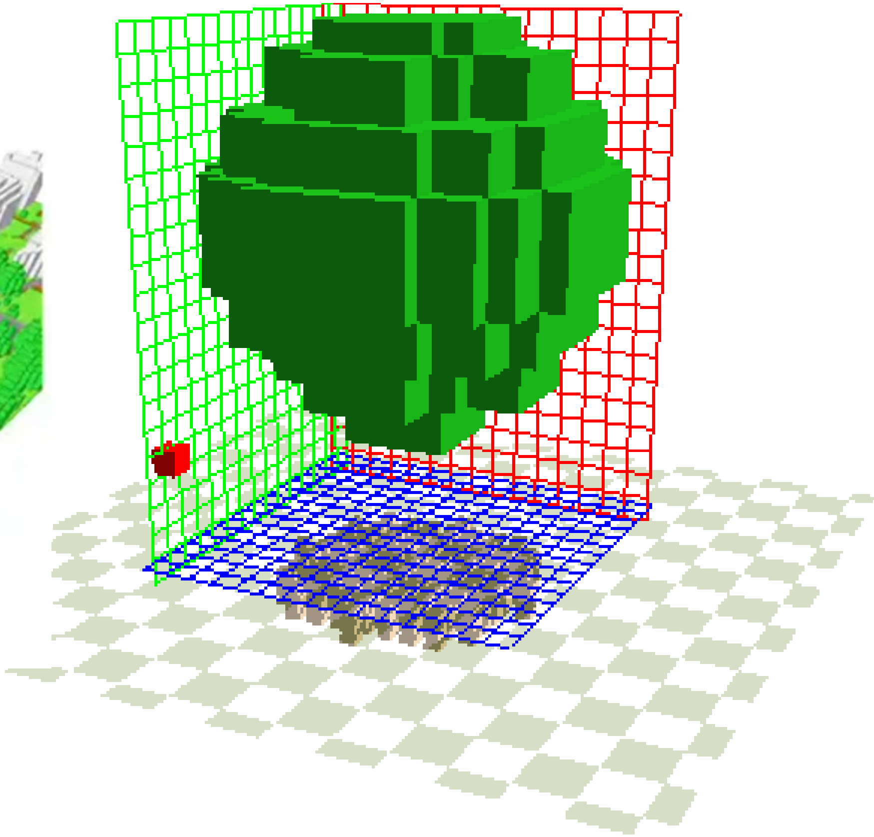
Thermal sensation index

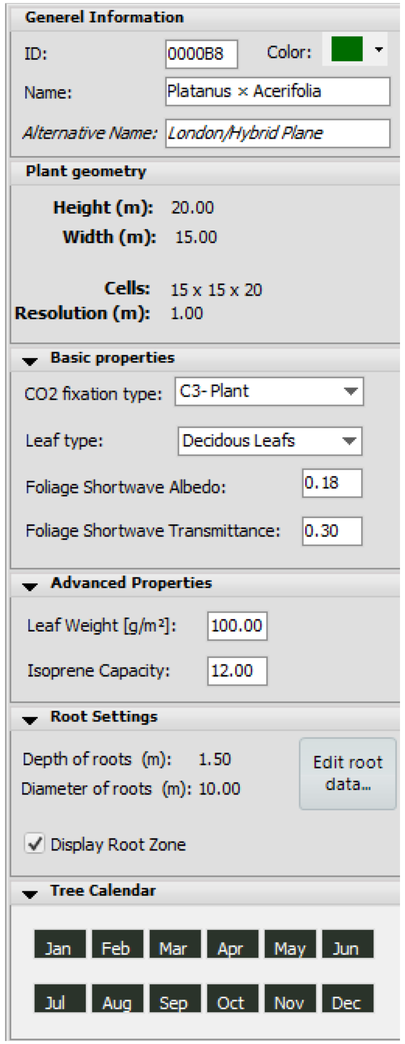
PET –
Physiological Equivalent Temperature

- Global radiation
- Wind speed
- Air temperature
- Relative humidity
- Mean radiant temperature
- Metabolic rate
- Clothing



Simulation methods: ENVI- met





Generel Information

ID: 0000B8 Color: 🟩

Name: Platanus × Acerifolia

Alternative Name: *London/Hybrid Plane*

Plant geometry

Height (m): 20.00

Width (m): 15.00

Cells: 15 x 15 x 20

Resolution (m): 1.00

Basic properties

CO2 fixation type: C3- Plant

Leaf type: Decidous Leafs

Foliage Shortwave Albedo: 0.18

Foliage Shortwave Transmittance: 0.30

Advanced Properties

Leaf Weight [g/m²]: 100.00

Isoprene Capacity: 12.00

Root Settings

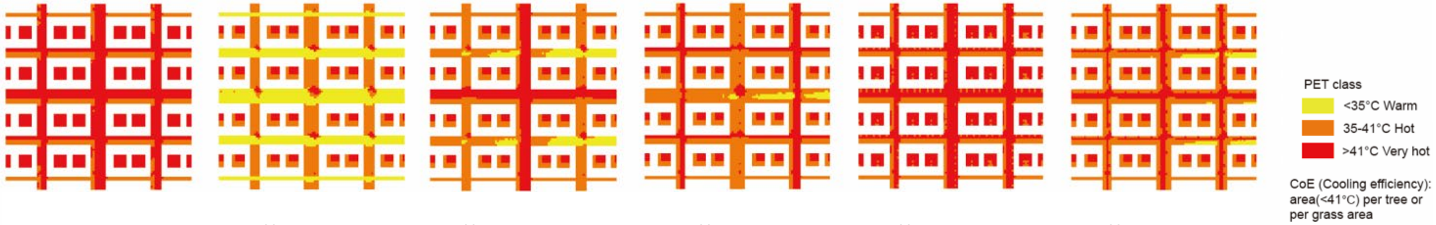
Depth of roots (m): 1.50

Diameter of roots (m): 10.00

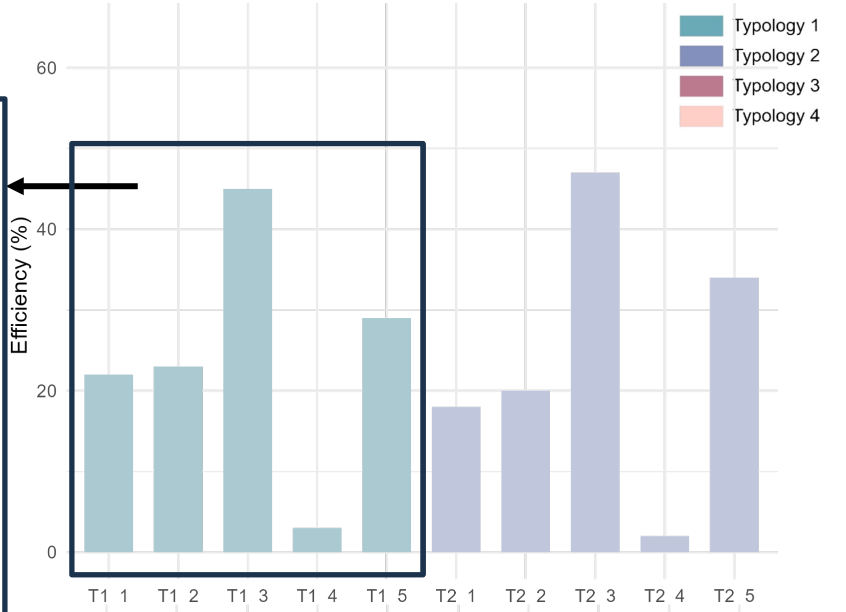
☑ Display Root Zone

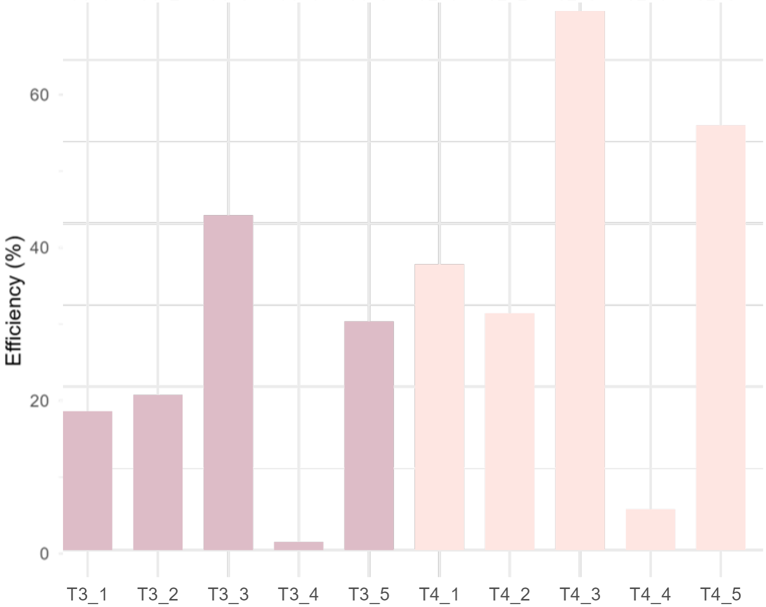
Tree Calendar

Preliminary results: neighbourhood scale



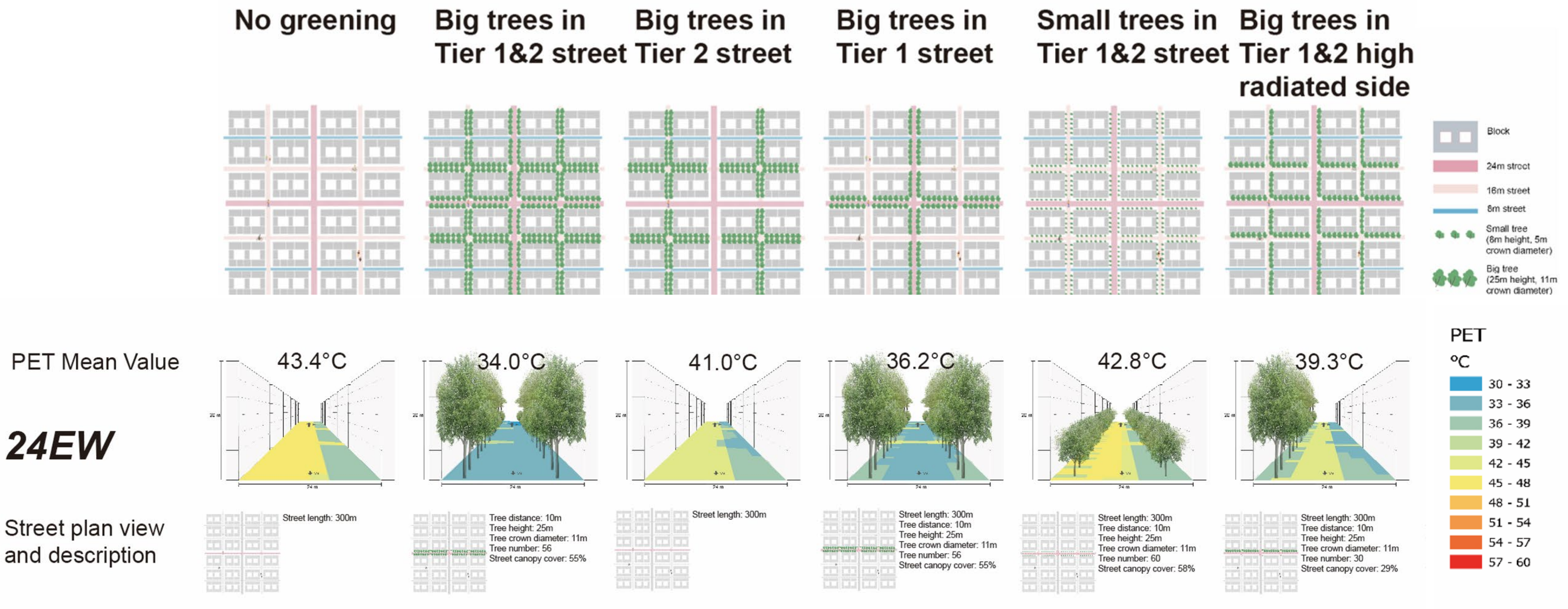
	No greening	Big trees in Tier 1&2 street	Big trees in Tier 2 street	Big trees in Tier 1 street	Small trees in Tier 1&2 street	Big trees in Tier 1&2 high radiated side
Neighbourhood plan view and description		Number: 276 Canopy: 30%	Number: 184 Canopy: 20%	Number: 92 Canopy: 10%	Number: 276 Canopy: 2%	Number: 138 Canopy: 15%
Average PET	45.4°C	36.9°C	40.6°C	41.4°C	44.4°C	40.8°C
Neighbourhood PET mean value and description		Efficiency per tree: 22%	Efficiency per tree: 23%	Efficiency per tree: 45%	Efficiency per tree: 3%	Efficiency per tree: 29%





Efficiency: planting two rows of big trees on the main streets >
one row on the high radiated side of main and secondary streets >
two rows on secondary streets / two rows on main and secondary streets

Preliminary results: street scale



	No greening	Big trees in Tier 1&2 street	Big trees in Tier 2 street	Big trees in Tier 1 street	Small trees in Tier 1&2 street	Big trees in Tier 1&2 high radiated side
PET Mean Value	43.4°C	34.0°C	41.0°C	36.2°C	42.8°C	39.3°C
Street plan view and description	Street length: 300m	Tree distance: 10m Tree height: 25m Tree crown diameter: 11m Tree number: 56 Street canopy cover: 55%	Street length: 300m	Street length: 300m Tree distance: 10m Tree height: 25m Tree crown diameter: 11m Tree number: 56 Street canopy cover: 55%	Street length: 300m Tree distance: 10m Tree height: 25m Tree crown diameter: 11m Tree number: 60 Street canopy cover: 58%	Street length: 300m Tree distance: 10m Tree height: 25m Tree crown diameter: 11m Tree number: 30 Street canopy cover: 29%

For streets with the same planting conditions and street profiles, if the surrounding streets are covered by street trees, it can result in 2 °C cooling in thermal sensation.

Designer assessment

They are aesthetically pleasant, considering:
- *Openness in the street*
- *Visibility from home*

They are compatible with other infrastructure, including:
- *Vehicle*
- *Cycling*
- *Walking*

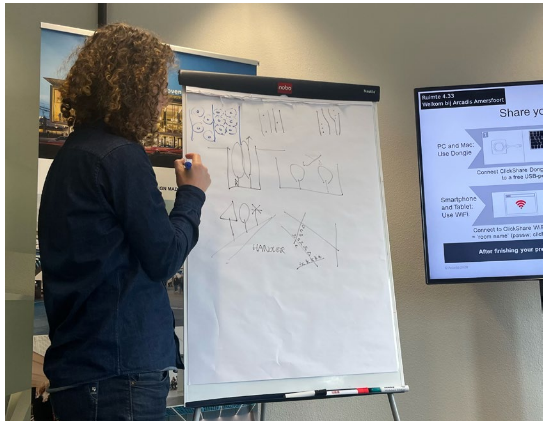
They are costly

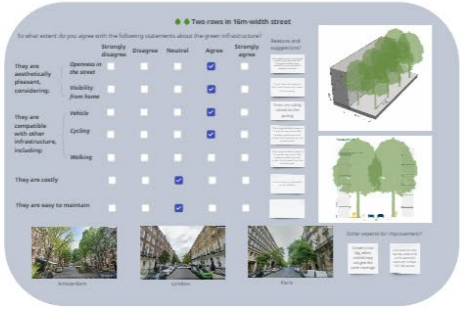
They are easy to maintain


Two rows in 24m-width street


One row in 24m-width street


Grass in 24m-width street

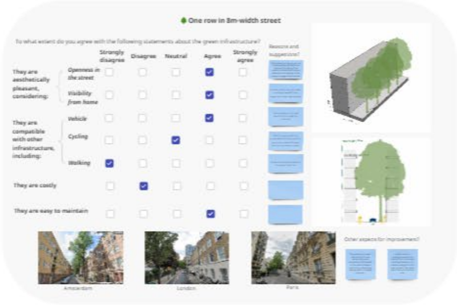



Two rows in 16m-width street


One row in 16m-width street


Grass in 16m-width street


Two rows in 8m-width street

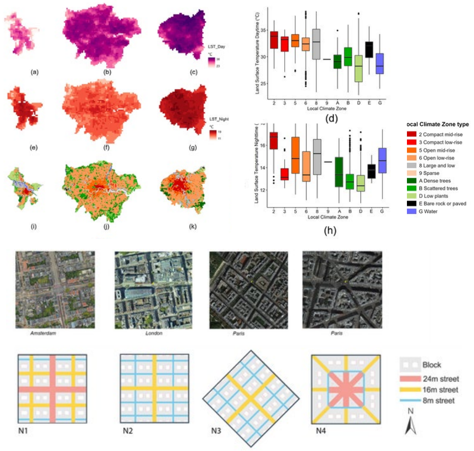

One row in 8m-width street


Grass in 8m-width street

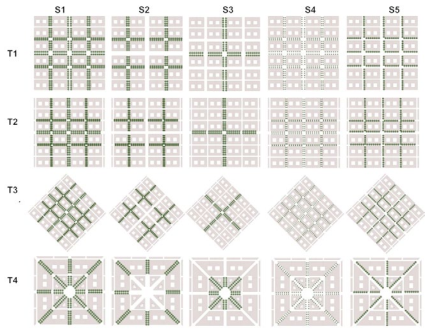
1. Typology – 2. Scenario – 3. Simulation – **4. Designer** – 5. Guidelines

Conclusion

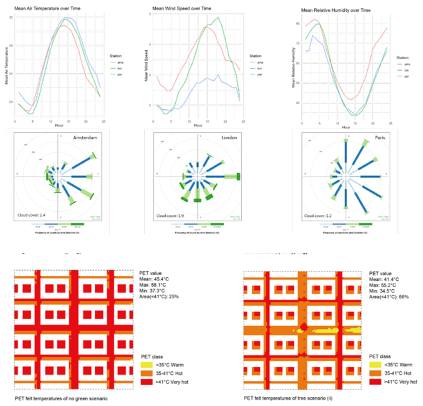
1. Typology



2. Scenario

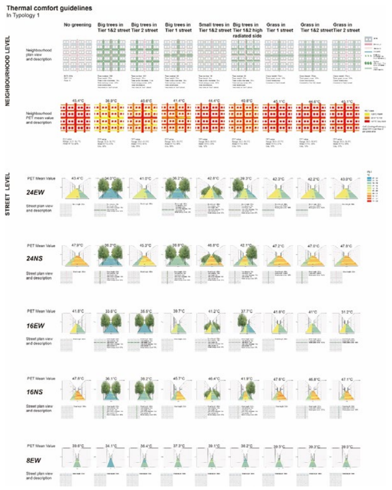


3. Simulation



4. Designer

5. Guidelines



- A methodological framework is developed to generate design guidelines from a large number of real-world neighbourhoods.

- Different design aspects were considered for possible street tree scenarios.

- Guidelines are proposed to inform practitioners of effective small green space design at the neighbourhood scale.

Thank you

Collaborators

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2023

World Forum on Urban Forests

2nd World Forum on Urban Forests

Washington DC, 2023

Session 1.3 In the Cool of the Day:

Urban Tree Canopy Reduction of Solar Ultraviolet Radiation: Mechanism and Assessment

Presented by

Yadong Qi[1], Vanessa Ferchaud[1], Wei Gao[2], Meng Wang[1], Eman El Dakkak[1], Kit Chin[1], and Gordon Heisler[3]

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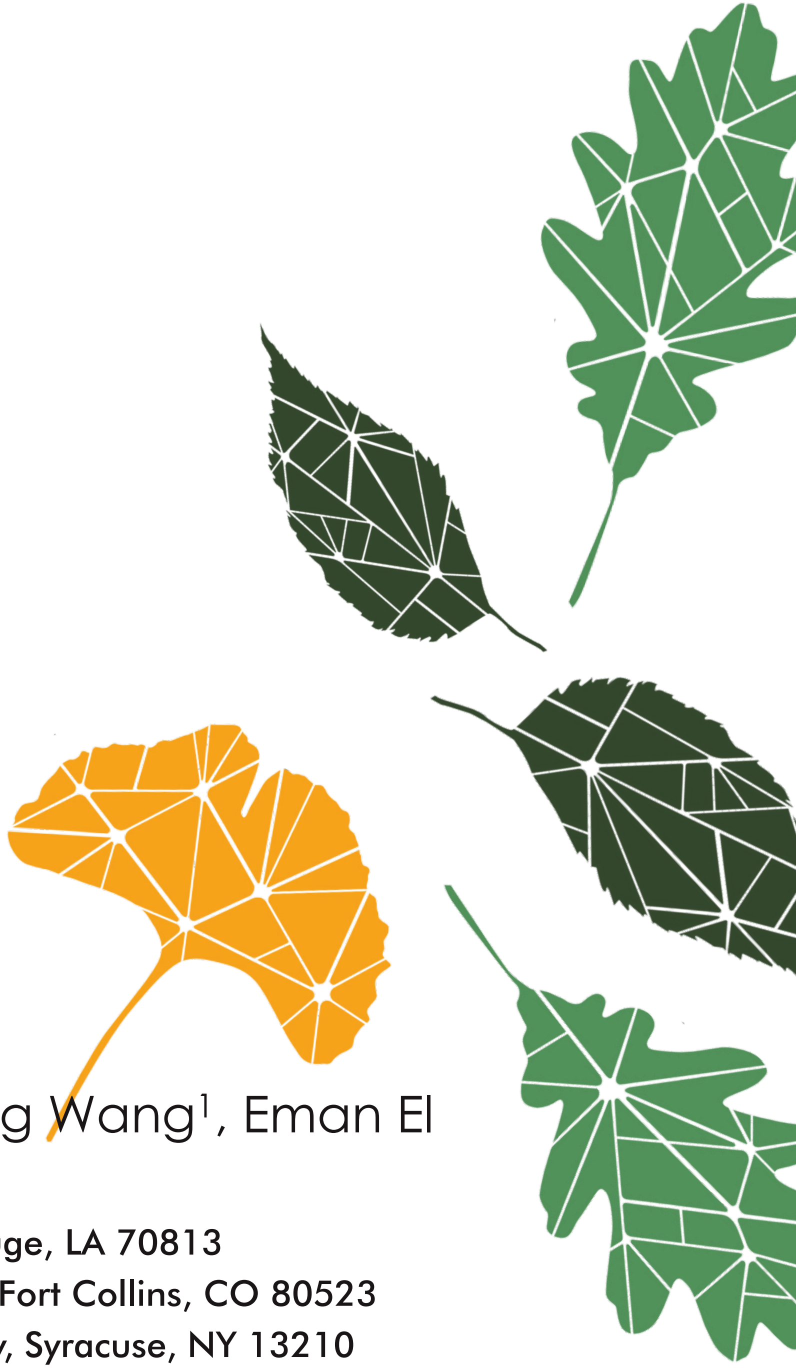
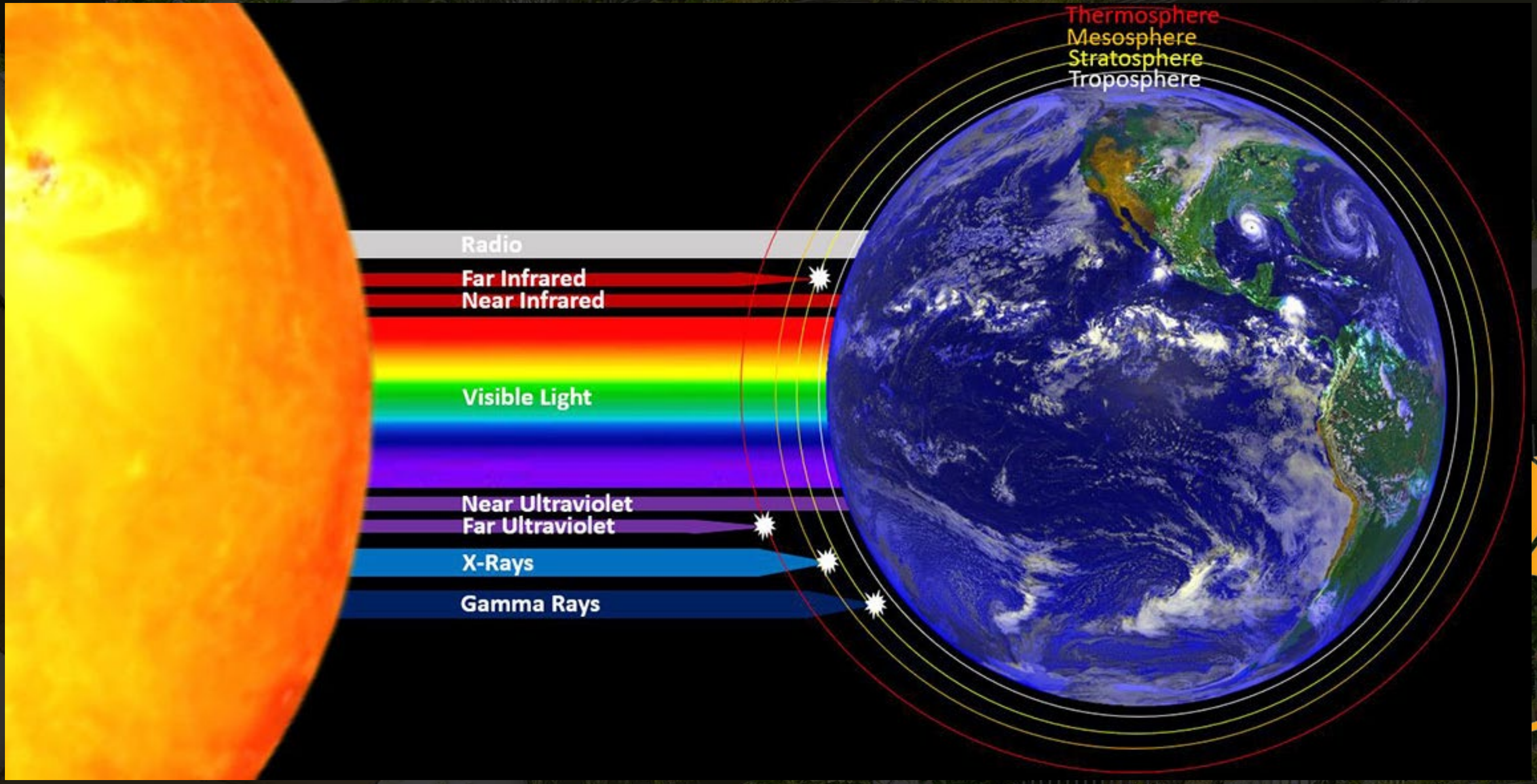
[2]USDA UV-B Monitoring and Research Program, Colorado State University, Fort Collins, CO 80523

[3]USDA Forest Service, SUNY College of Environmental Science and Forestry, Syracuse, NY 13210

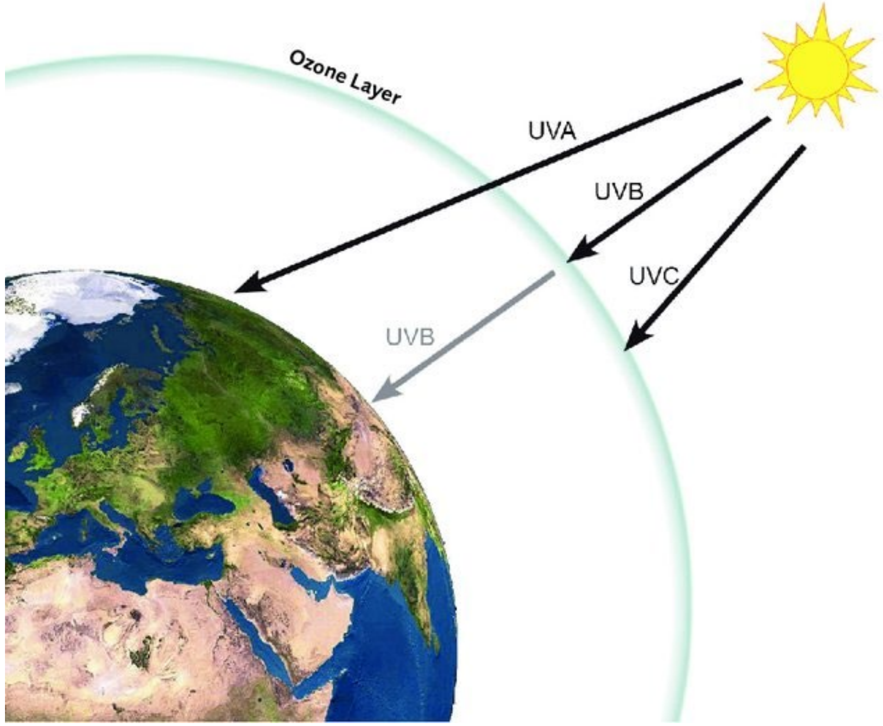


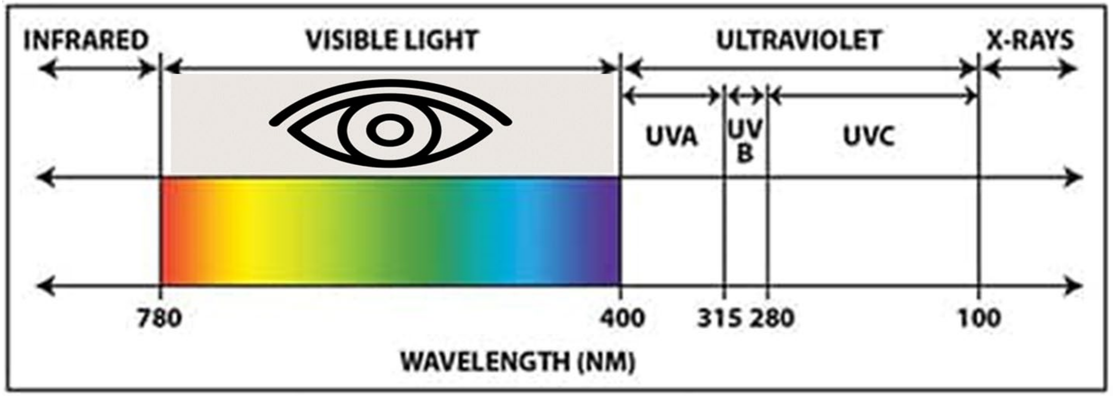
Solar radiation is continually bombarding our planet with both life-giving light as well as harmful radiation.



Absorption of solar radiation in the atmosphere.
Courtesy of Geoengieering.global. Images of the Sun and Earth courtesy of NASA.

Ultraviolet radiation is made up of three types of rays – UVA, UVB, and UVC.





The UV wavelengths are those immediately below what the human eye can see. (Image courtesy of W.S. Badger Company, Inc.)

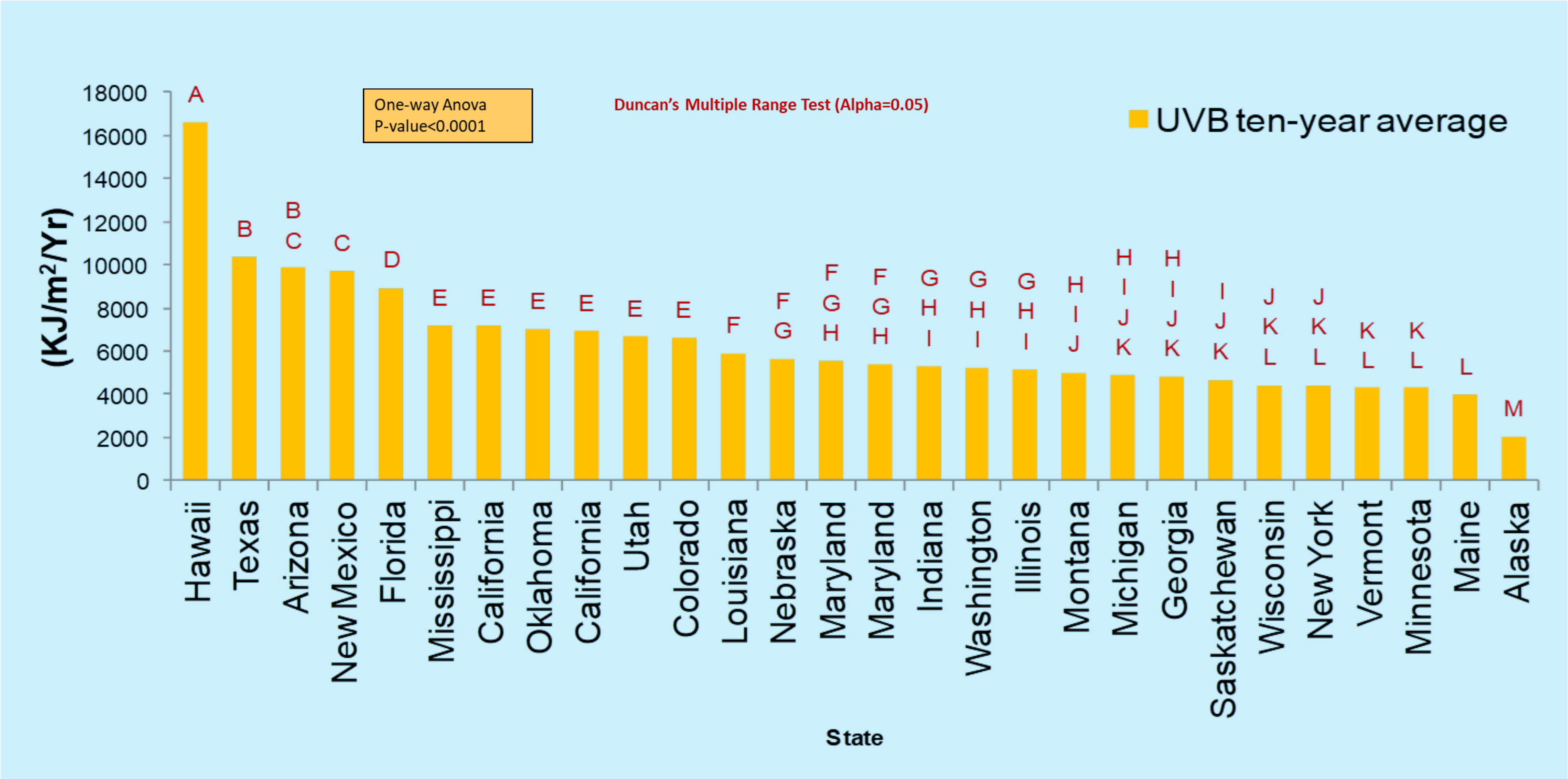
Although ultraviolet C is the most dangerous type of ultraviolet light in terms of its potential to harm life on earth, it cannot penetrate earth's protective ozone layer. Therefore, it poses no threat to human, animal or plant life on earth.

Ultraviolet A and B, on the other hand, can penetrate the ozone layer to reach the surface of the planet.

About 95% of the UV rays from the sun that reach the ground are UVA rays, with the remaining 5% being UVB rays.

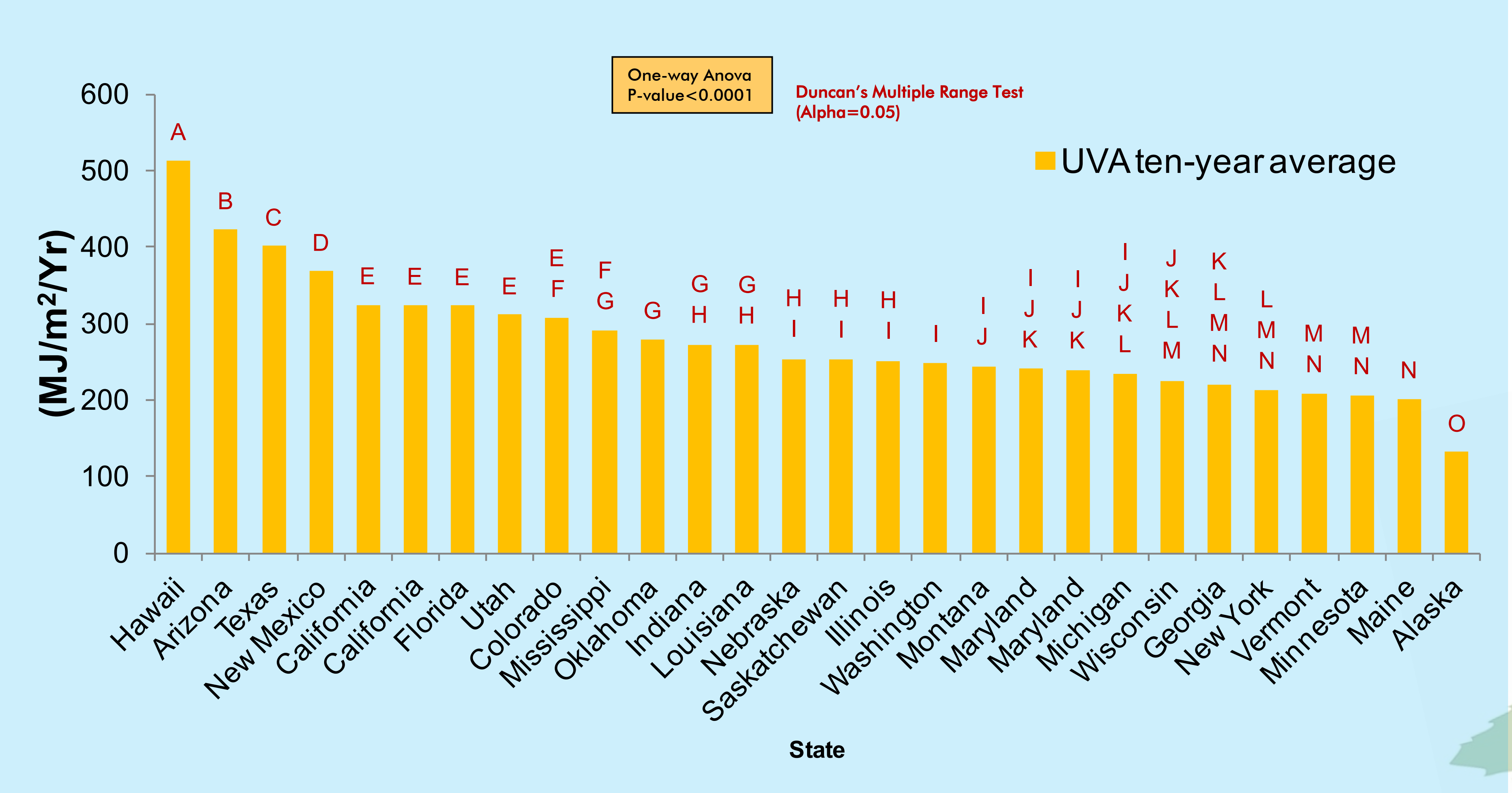
Annual UVB Total in USA

Spatial Change of Ten-year Average of UV-B Radiation in 27 States (2002-2011)



Annual UVA Total in USA

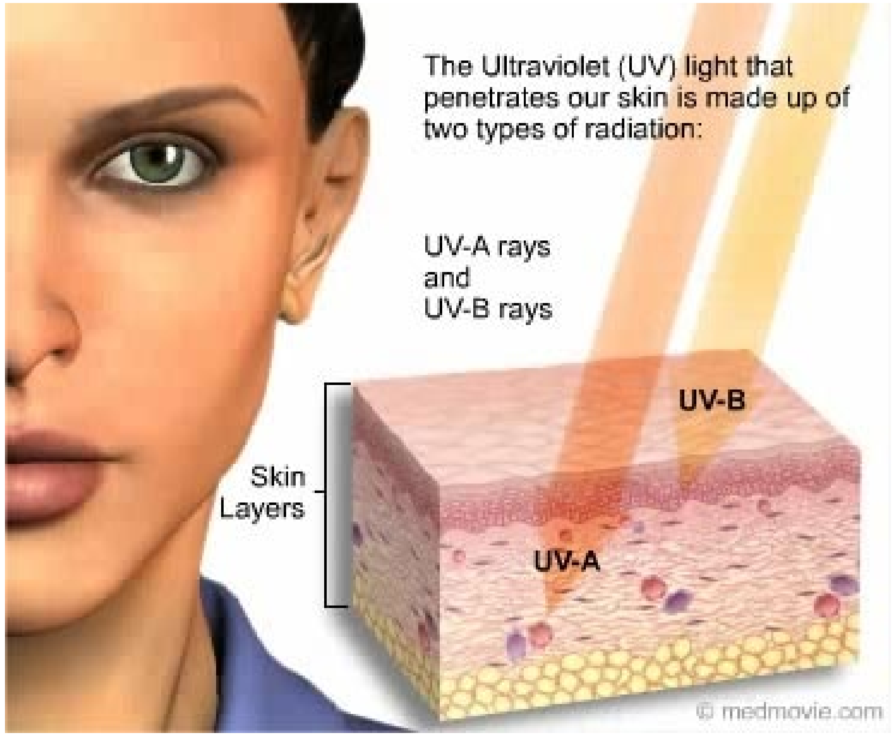
Spatial Change of Ten-year Average of UV-B Radiation in 27 States (2002-2011)



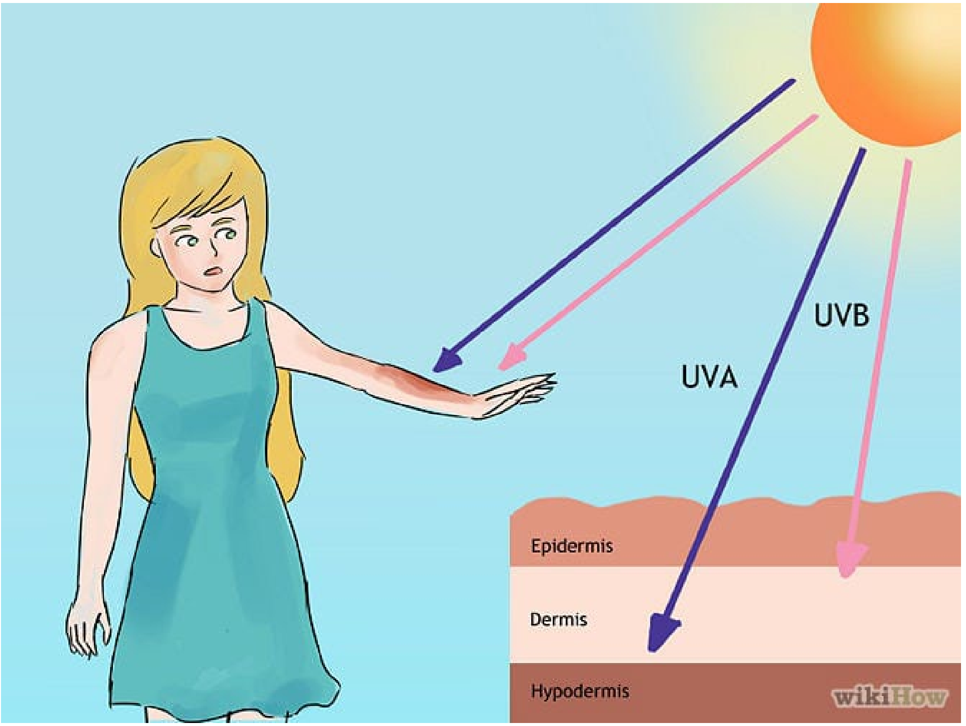
One-way Anova
P-value<0.0001

Duncan's Multiple Range Test
(Alpha=0.05)

UV Impact on Human

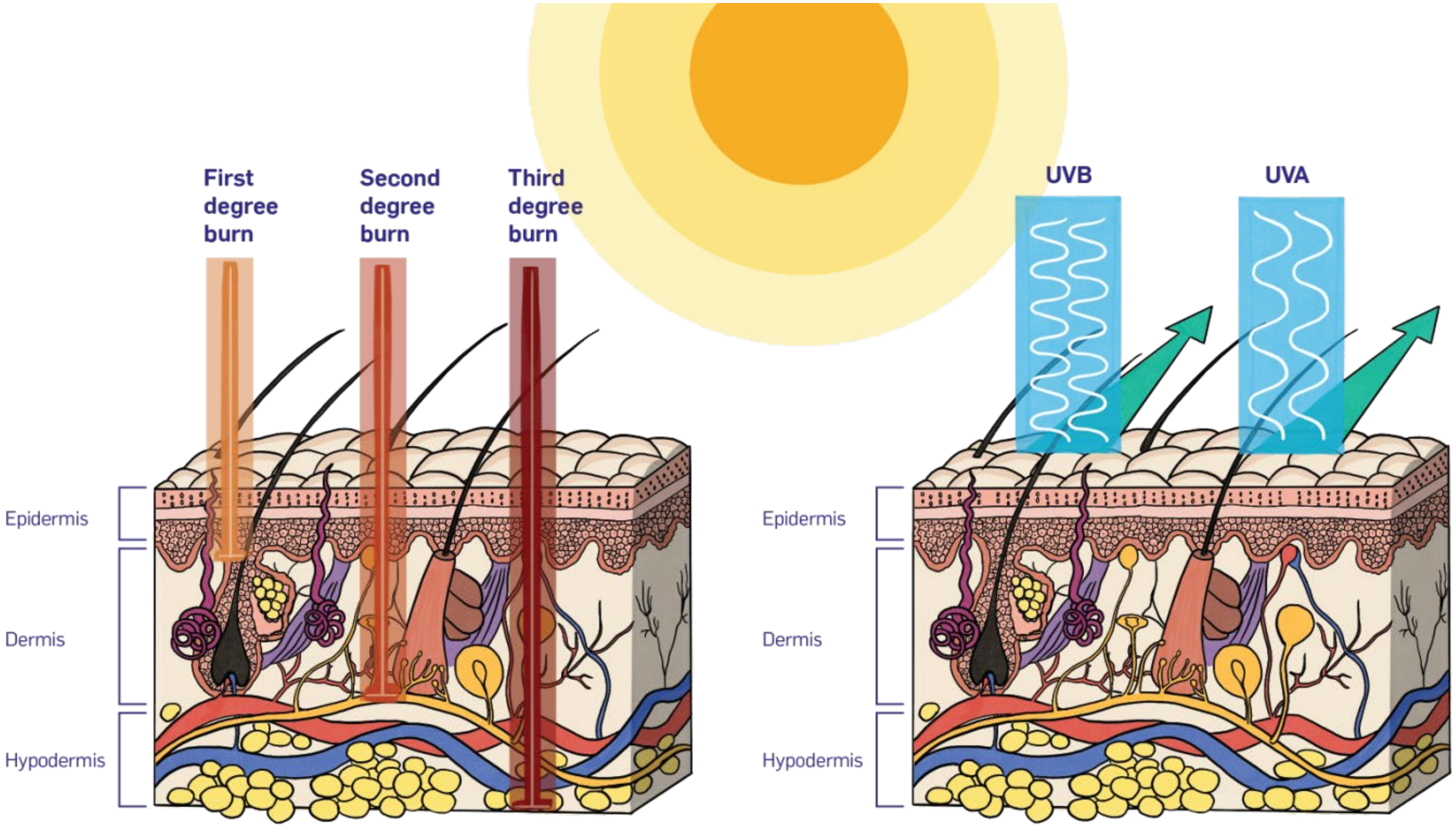


The Ultraviolet (UV) light that penetrates our skin is made up of two types of radiation:



- Suntans, freckling and sunburns are familiar effects of over-exposure to ultraviolet rays, along with a higher risk of skin cancer
- Most skin cancers in the US are a result of exposure to the UV rays in sunlight. Both basal cell and squamous cell cancers (the most common types of skin cancer) tend to be found on sun-exposed parts of the body, and their occurrence is typically related to lifetime sun exposure.

Protect Your Skin From The Sun



https://mscan.org.au/learning-hub/skin-cancer/skin-cancer-prevention/

How About Trees?

How do they protect themselves from Sun Burn?

Picture of a Parking lot nearby the Waco Convention Center taken by Dr. Yadong Qi on 9/27/2022

UV-B Radiation and Urban Forest

- Forests account for 80% of the global net primary production. Urban forest is a vital component of urban infrastructure, providing enormous ecological, environmental, and social economic benefits to urbanites.
- Ozone depletion in the upper atmosphere has resulted in a major concern of effects of the enhanced UV-B on living organisms and ecosystems for more than four decades.
- Nearly two-thirds of 400 plant species/cultivars tested, mainly annual crops, appear to be UV-B sensitive. Relatively little information exists on how forest tree species interact with UV radiation.
- With the future uncertainty of ozone recovery and global climate change, there is a critical need for systematic evaluation of UV-B impacts on forest/tree species and urban forests.
- Little study has been done prior to our research pertaining to how diverse urban tree species tolerant UV radiation and how much UV radiation urban tree canopy intercept/reduce.

Research Question # 1

How do diverse urban trees interact and cope with the harmful UV radiation?

- **Leaf optical properties – Biophysical Mechanism**
  - ✓ UV Reflectance
  - ✓ UV Transmittance
  - ✓ UV Absorbance
  - ✓ UV penetration depth into leaf tissue

- **Leaf UV absorbing compounds**
- **(mainly phenolic acids and flavonoids) – Biochemical Mechanism**
  - ✓ Quantification
  - ✓ Identification
  - ✓ Visualization
  - ✓ Localization

- **Leaf morphology and Anatomy features**
  - ✓ SEM
  - ✓ Light Microscopy

- **UV-induced DNA Damage & Repair – Genetic Mechanism**
  - ✓ CPDs (Cyclobutane pyrimidine dimers)
  - ✓ 6,4-PPs (6,4-Photoproducts)
  - ✓ 8-OxodG (8-Hydroxy-7,8-Dihydro-2′-Deoxyguanosine)
  - ✓ Repair proteins (Photolyases and Photoreceptors UVR-2 and UVR-8)

Research Question # 2

How do tree canopies influence the ground level UV radiation distribution?

Tree canopy level study - live oak (Quercus virginiana)

◆ **Tree Canopy Interception of UV Radiation**

UV Multi-Filter Rotating Shadow Band Radiometer (UV-MFRSR)

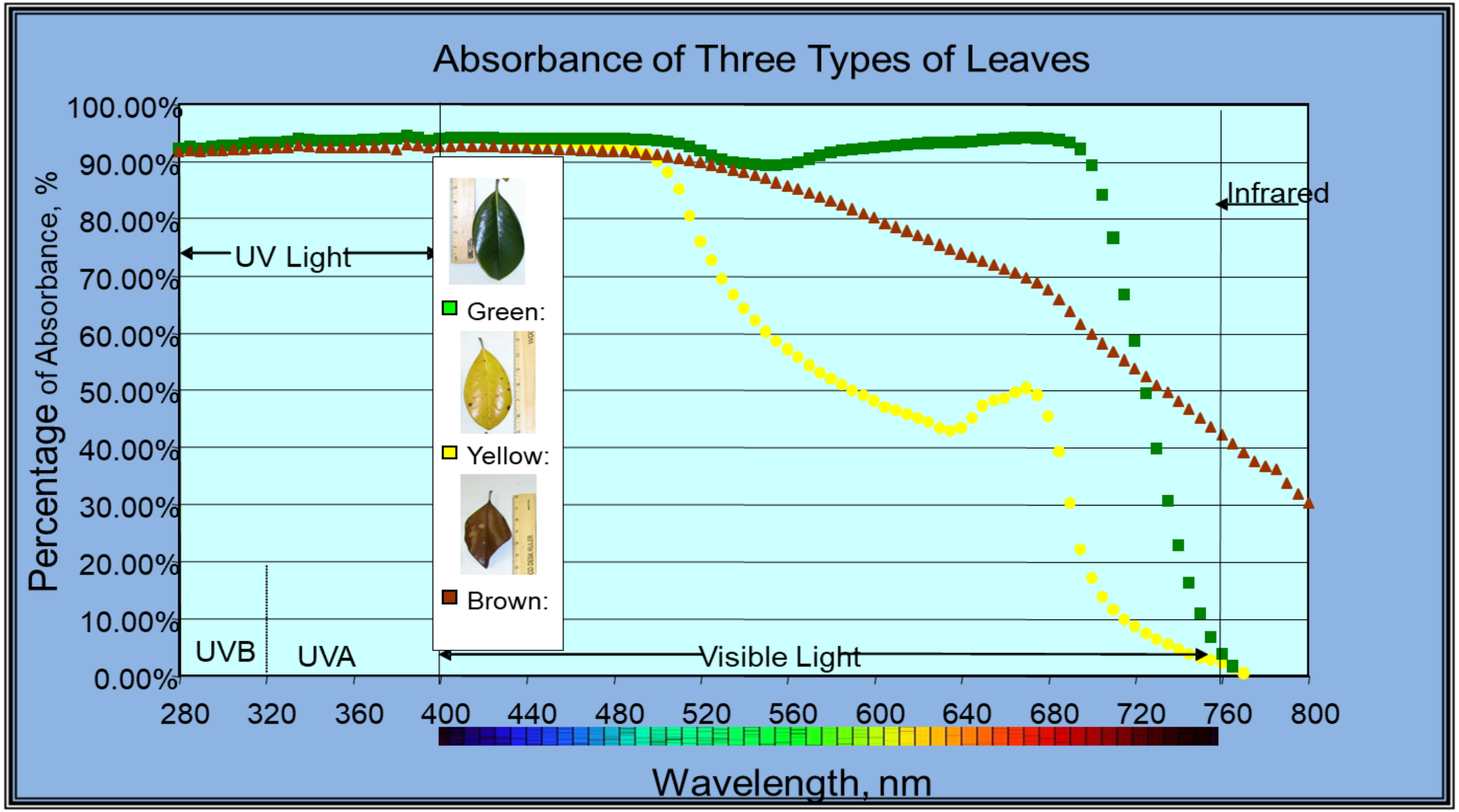
- **Direct, Diffused, and Total Horizontal Radiation of**
- **UV-B: at 300, 305, 311nm**
- **UV-A: at 317, 325, 332, 368 nm**

****

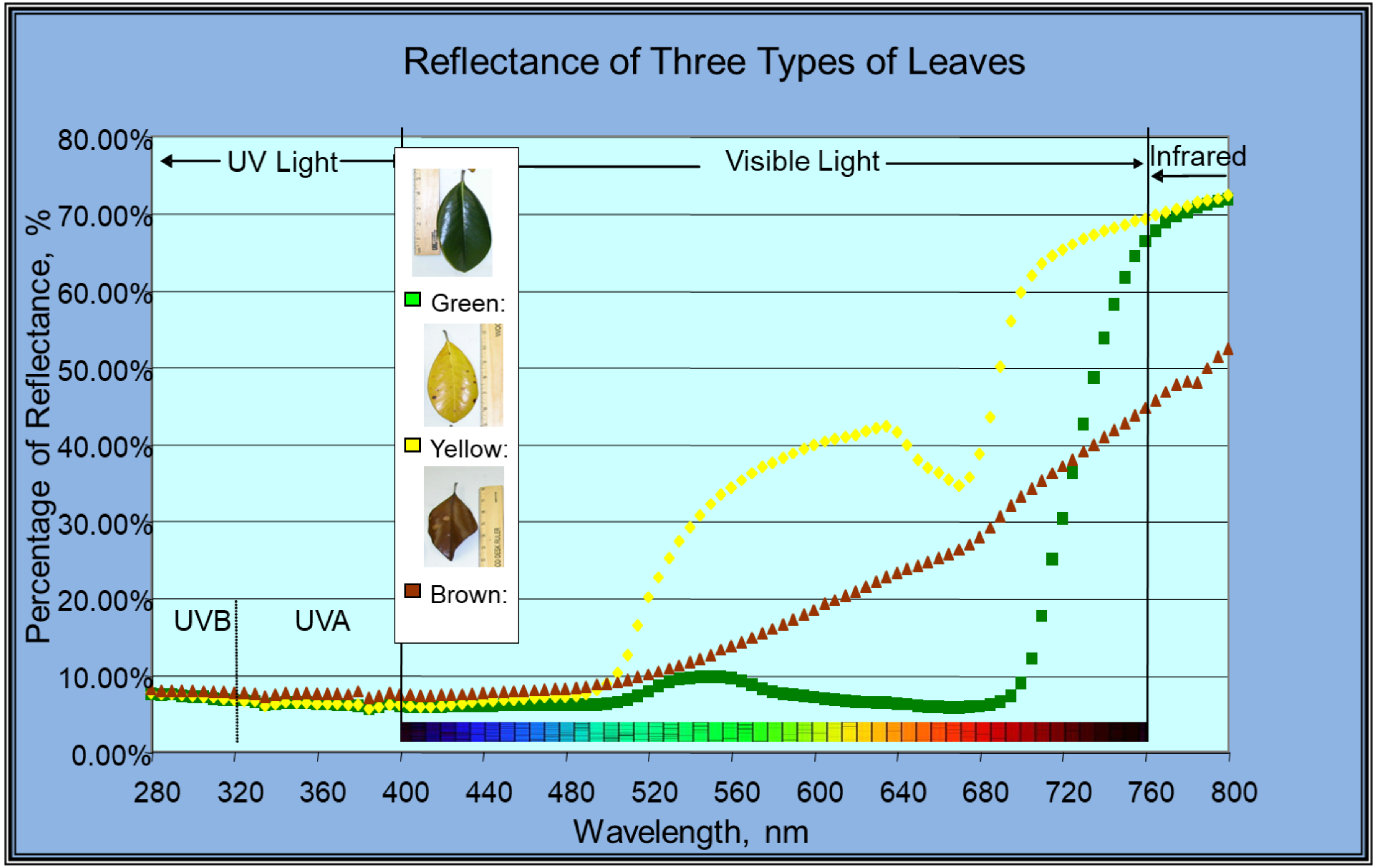
Data Collection:

- **Above-canopy: USDA UVBMRP Baton Rouge Monitoring Benhur Site Open Station**
- **Below-canopy: A mobile UV monitoring instrument system on SU campus**

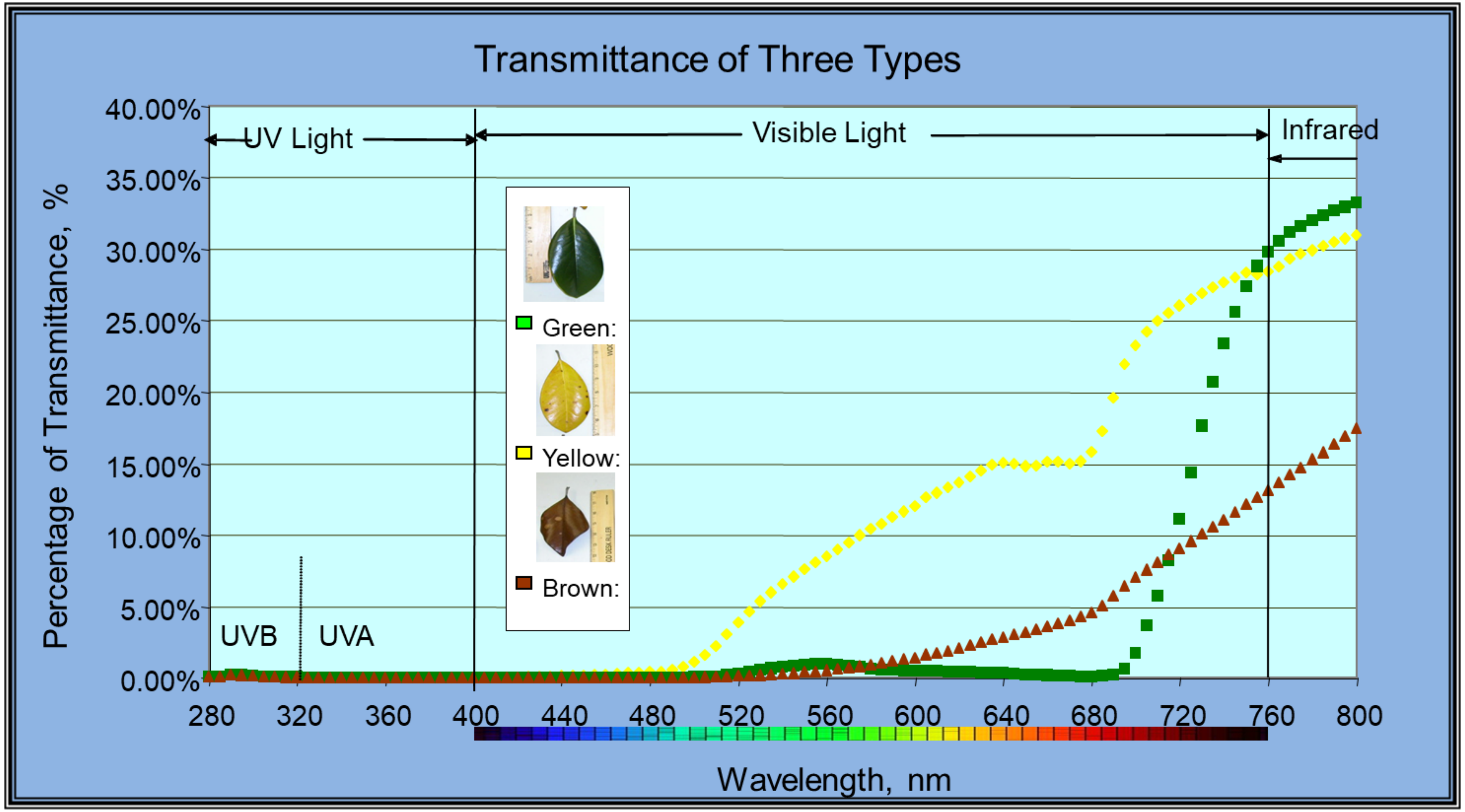
How Do Leaves Absorb UV and Visible Light?



How Do Leaves Reflect UV and Visible Light?



How Do Leaves Transmit UV and Visible Light?



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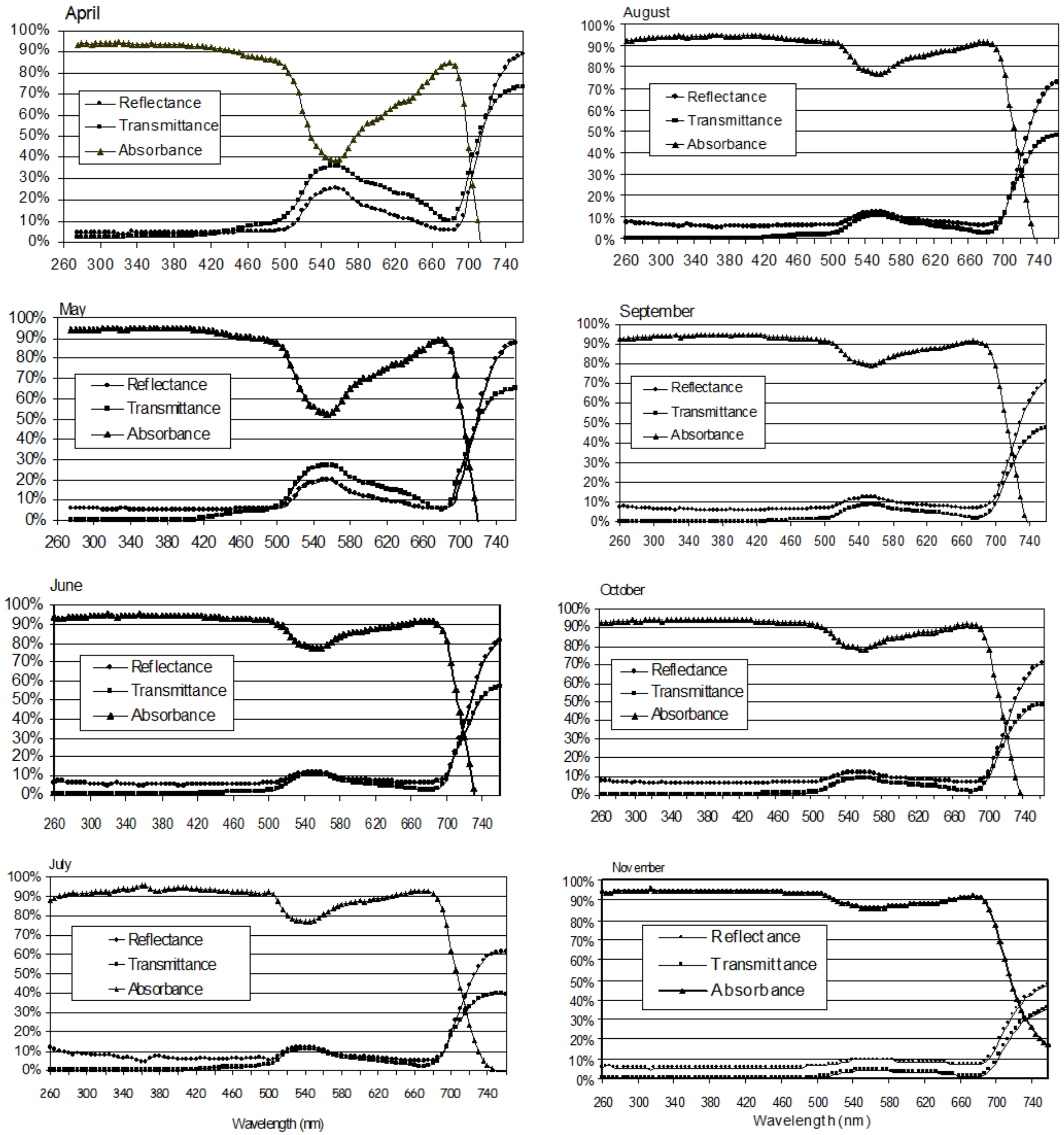
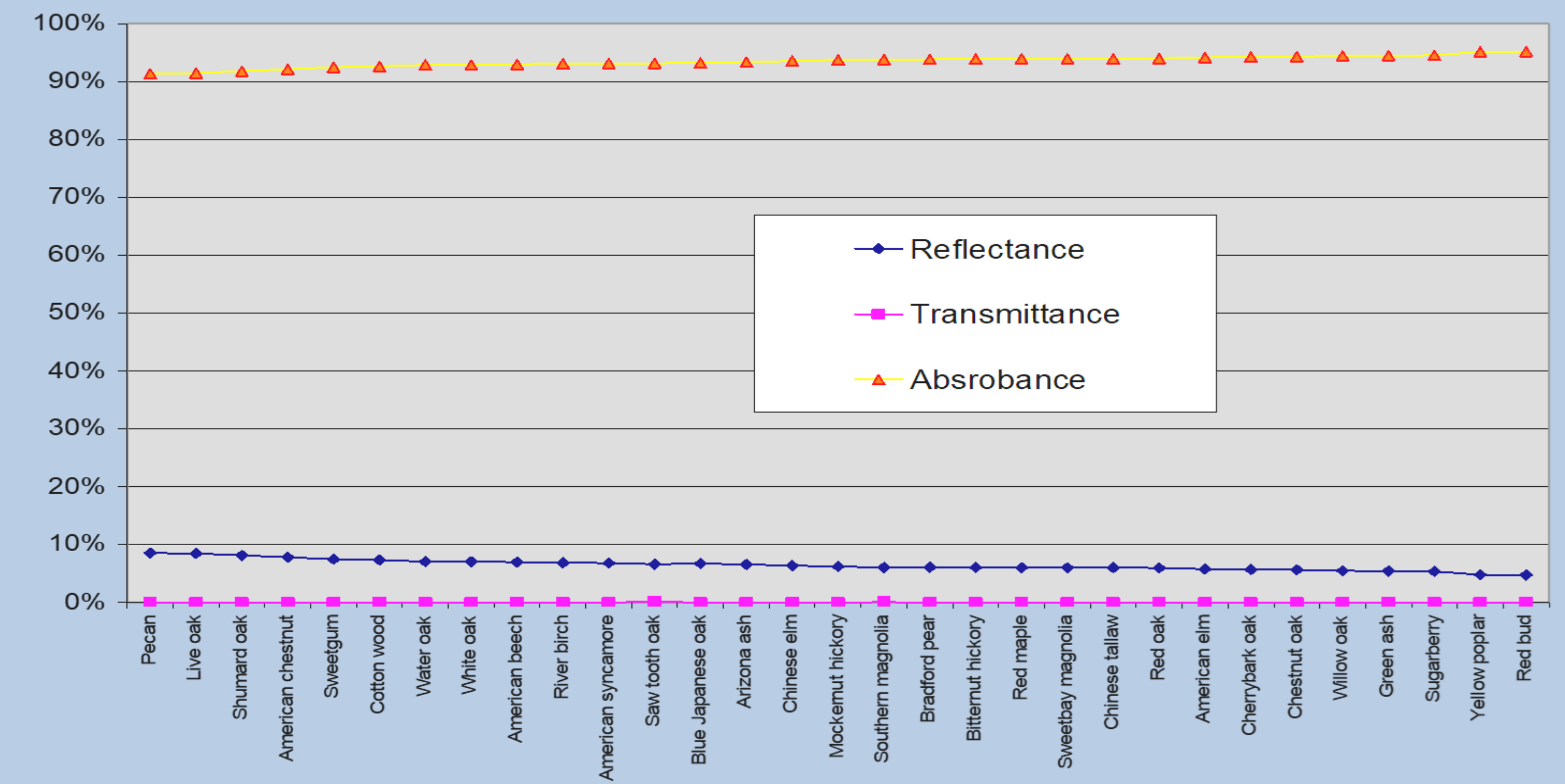
How Do Leaf Optical Properties Change in a Growing Season?



Leaf spectral reflectance, transmittance, and absorbance to UV/Visible light during a growing season from April to November) in leaves of pecan (Qi et al., 2003)

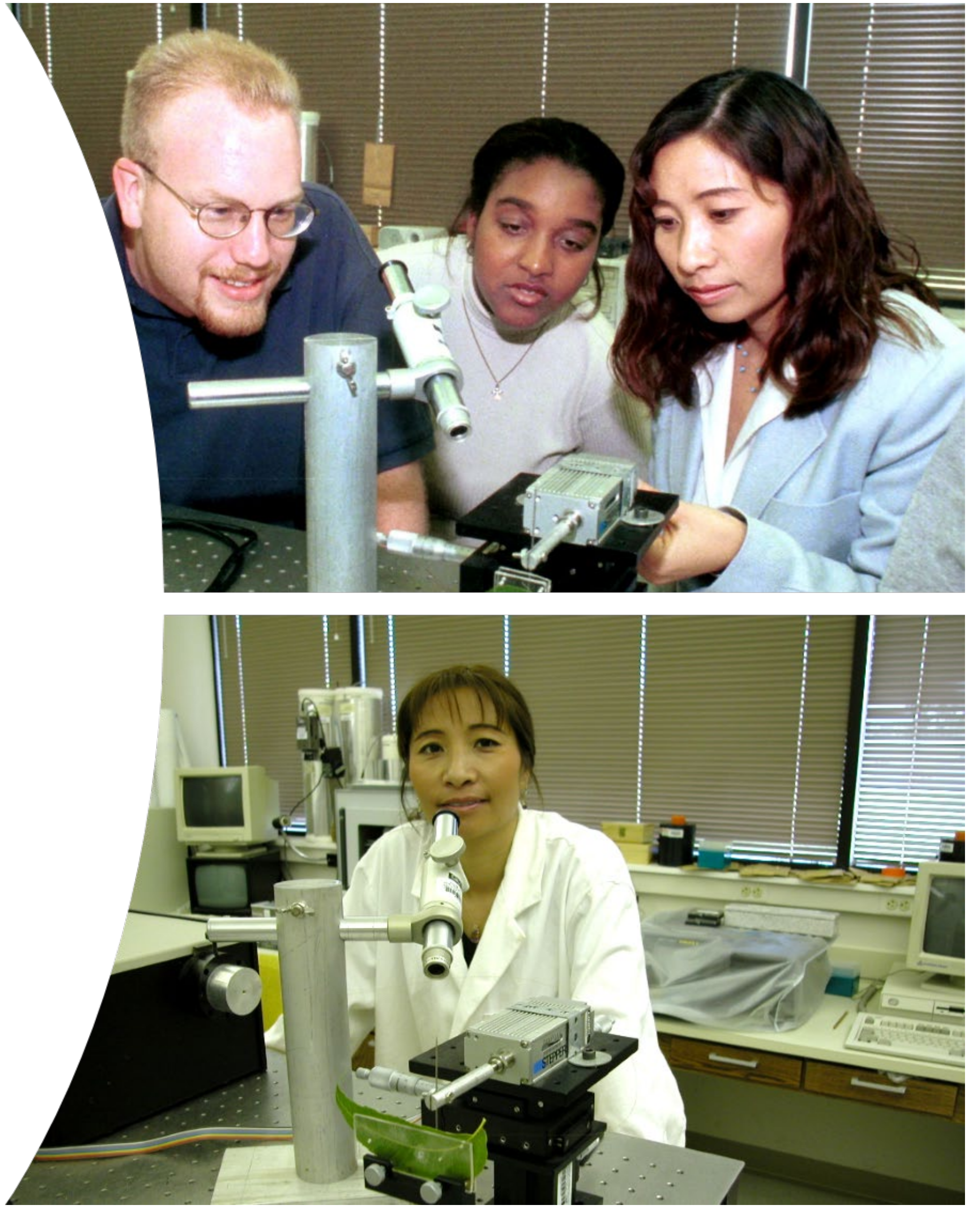
How Do Leaf UVB Optical Property Change With Diverse Broadleaf Tree Species ?



Leaf reflectance, transmittance, and absorbance to 300 nm UV-B radiation on a whole leaf basis in 31 broadleaf tree species. The measurements were made on the mature leaves collected in August in Baton Rouge, LA. The species are ranked based on the reflectance from the highest to the lowest (Qi et al, 2010)

How Deep Can UV & Visible Lights Penetrate into Leaf Tissues?

- Depth of UV/Visible light penetration into leaf tissues measured by a fiber optic microprobe system modified based on Vogelmann et al.(1989, 1991) and Qi et al. (2003, 2010).



Measuring Depths of Light Penetration into Leaf Tissue – A Pecan Leaf Model

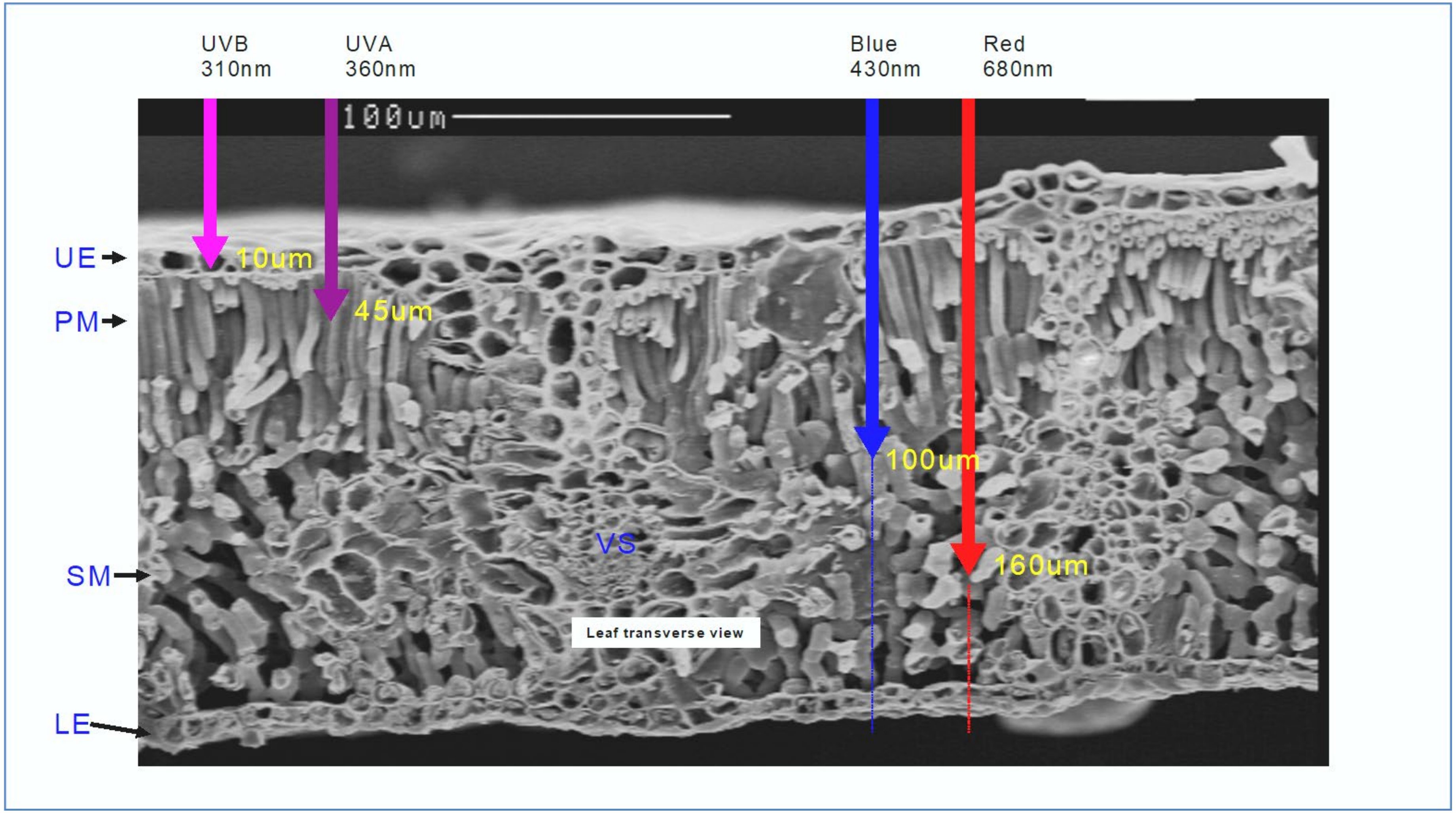
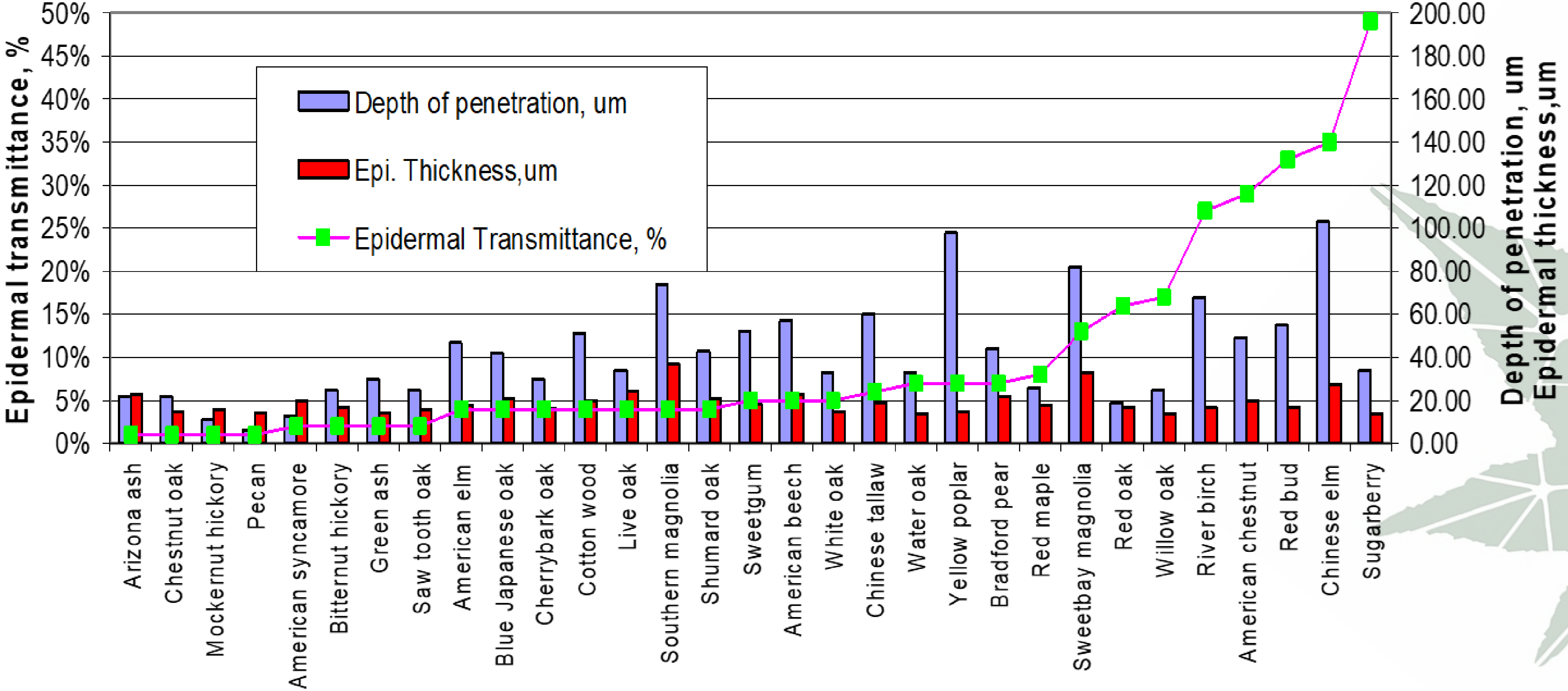


Illustration of the depths of the different light penetration into leaf tissues in pecan.
UE: upper epidermis, PM: palisade mesophyll, SM: sponge mesophyll, LE: lower epidermis, VS: vascular system.
The downward arrows show the relative positions of depths of light penetration at different wavelengths. (Qi et al, 2003, 2010)

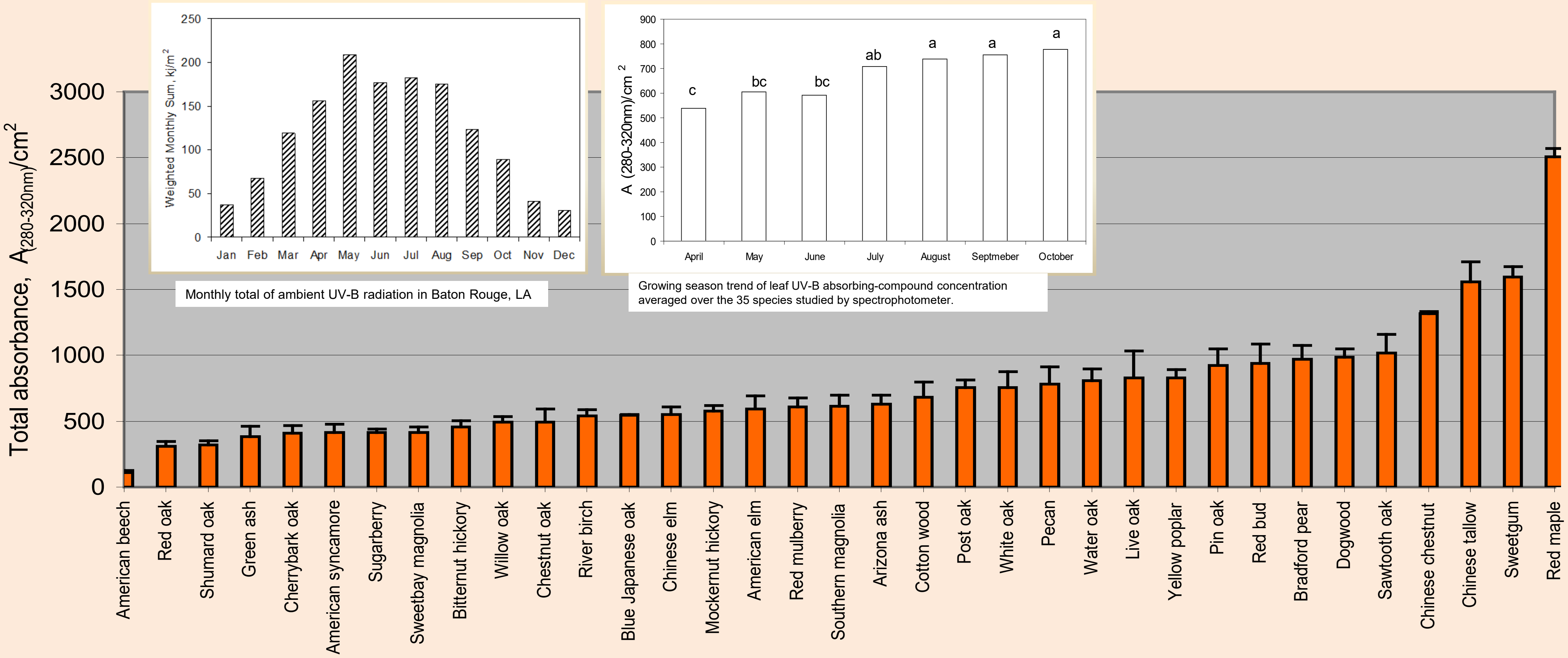
Comparison of the Depths of UV-B Light Penetration into Leaves of 31 Southern Tree Species



Comparisons of upper epidermal transmittance to 310 nm UV-B radiation, depth of 310 nm penetration into leaves, and epidermal thickness among the selected broadleaf tree species. Note: the species were ranked based on the epidermal transmittance from the lowest to the highest. In all cases, mature leaves were measured, and light was illuminated toward the upper leaf surfaces in the light penetration study (Qi et al., 2010)

Measuring Total UV-B Absorbing Compounds Content

Comparison of UV-B absorbing compound contents among 35 Southern Tree Species

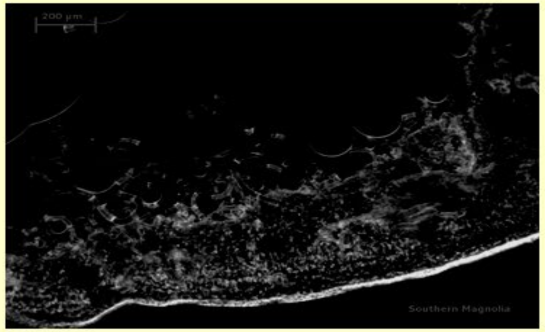


Monthly total of ambient UV-B radiation in Baton Rouge, LA

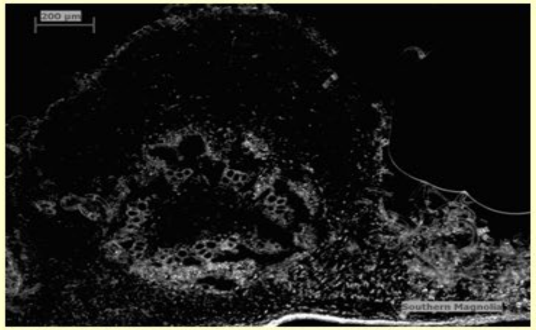
Growing season trend of leaf UV-B absorbing-compound concentration averaged over the 35 species studied by spectrophotometer.

Comparisons of UV-B absorbing-compound concentrations in mature leaves among 35 broadleaf tree species grown in Baton Rouge, LA. The value for each species was the mean over four-month measurements from July to Oct with four samples per month from sun-exposed leaves. The error bar indicates +1SE.

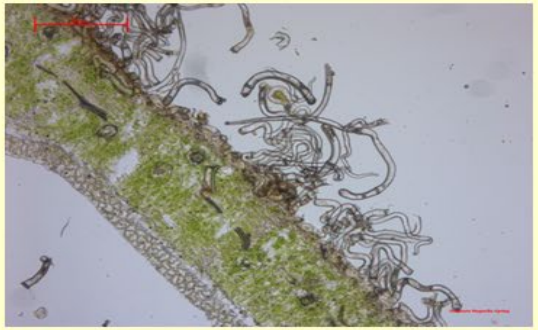
Visualization and Localization of Leaf UV Absorbing Compounds in Southern Magnolia Young and Mature Leaves



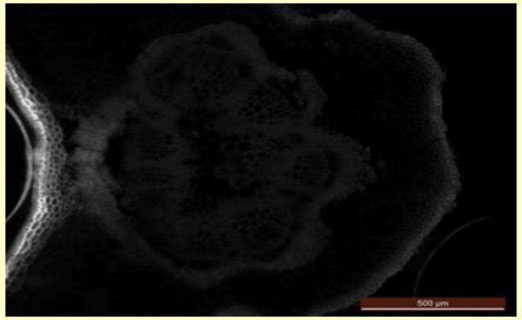
a. Southern magnolia young leaf (collected in April) cross-section using NA-stain with monochrome camera via GFP cube.



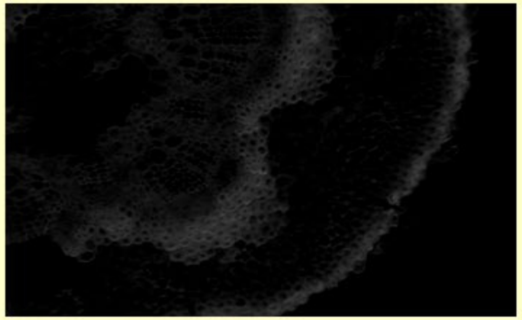
b. Southern magnolia young leaf petiole cross-section using GFP-NA-stain with monochrome camera.



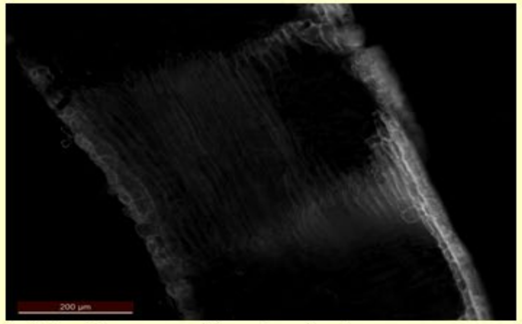
c. Southern magnolia young leaf cross-section taken with bright-field color camera. With no stain.



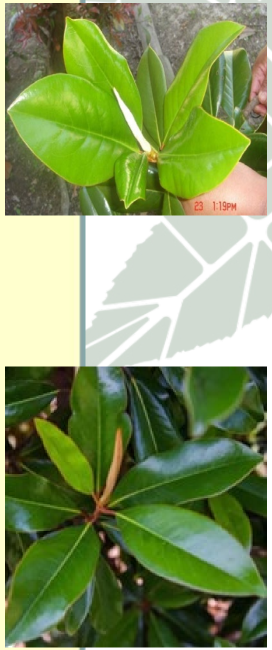
d. Southern magnolia mature leaf (collected in August) petiole cross-section using GFP-NA-stain taken with monochrome camera.



e. Southern magnolia mature petiole cross-section taken with NA stain.

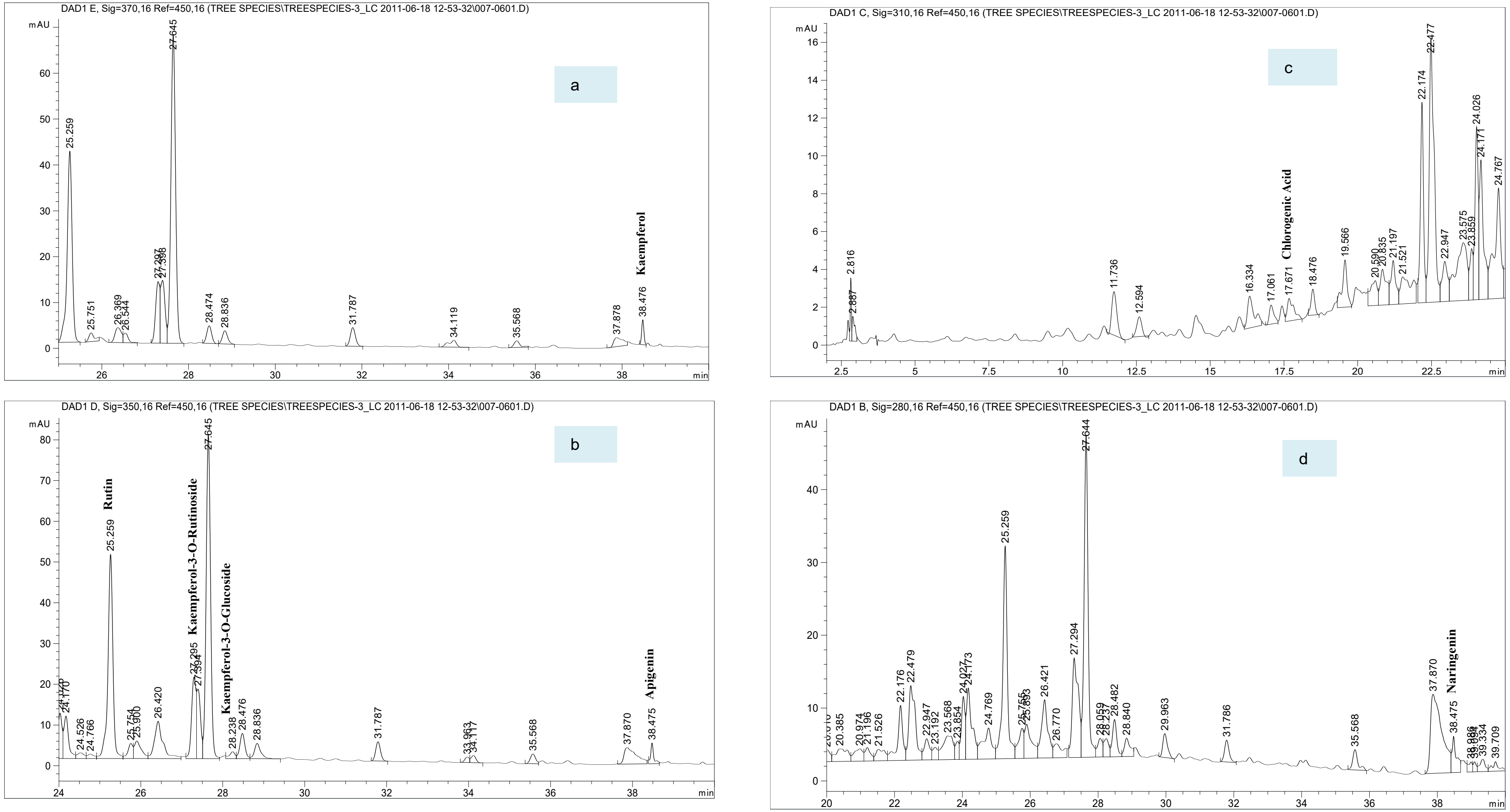


f. Southern magnolia mature leaf cross-section taken using GFP-NA-stain taken with monochrome camera.



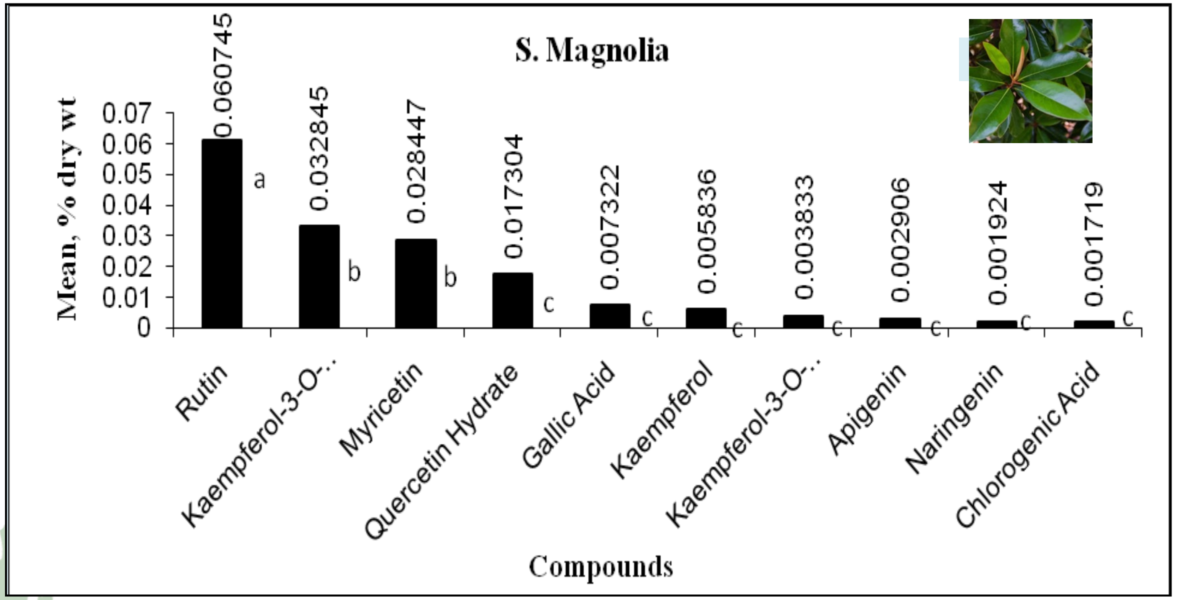
The NA-stained young Southern magnolia leaves show that the cellular and wall-bound UV absorbing-compounds were rendered highly visible under monochrome camera via green fluorescent protein (GFP) cube (a and b). The UV absorbing-compounds were present primarily in upper and lower epidermis, palisade tissues, and trichomes in leaf cross-section (a), in epidermal layers and vascular bundle in the petiole (b), as compared to a bright field color image of the leaf cross-section without NA-stain (c). Similar to the young leaves, the NA-stained mature leaves show that the absorbing-compounds were present primarily in leaf epidermal layers and vascular bundle in the petiole (d and e), and in the transfusion tissue, epidermal layers, and trichomes in the leaf cross-section (f). (Ferchaud and Qi, 2021)

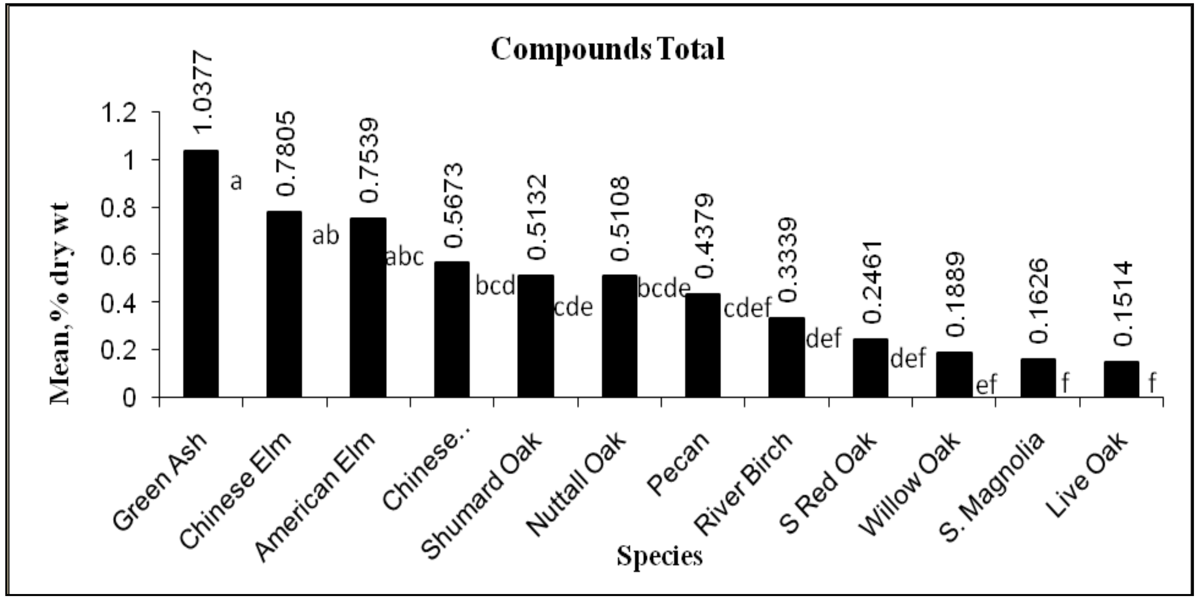
HPLC Quantification of Ten Most Common UV Absorbing Compounds in Mature Leaves of Southern Magnolia



Ten UV absorbing compounds were identified with HPLC and external standards in four wavelengths, 280nm (d), 310nm (c), 350nm (b), 370nm (a) in Southern magnolia leaves.

HPLC Quantification of Ten Most Common UV Absorbing Compounds in Mature Leaves of 12 Tree Species



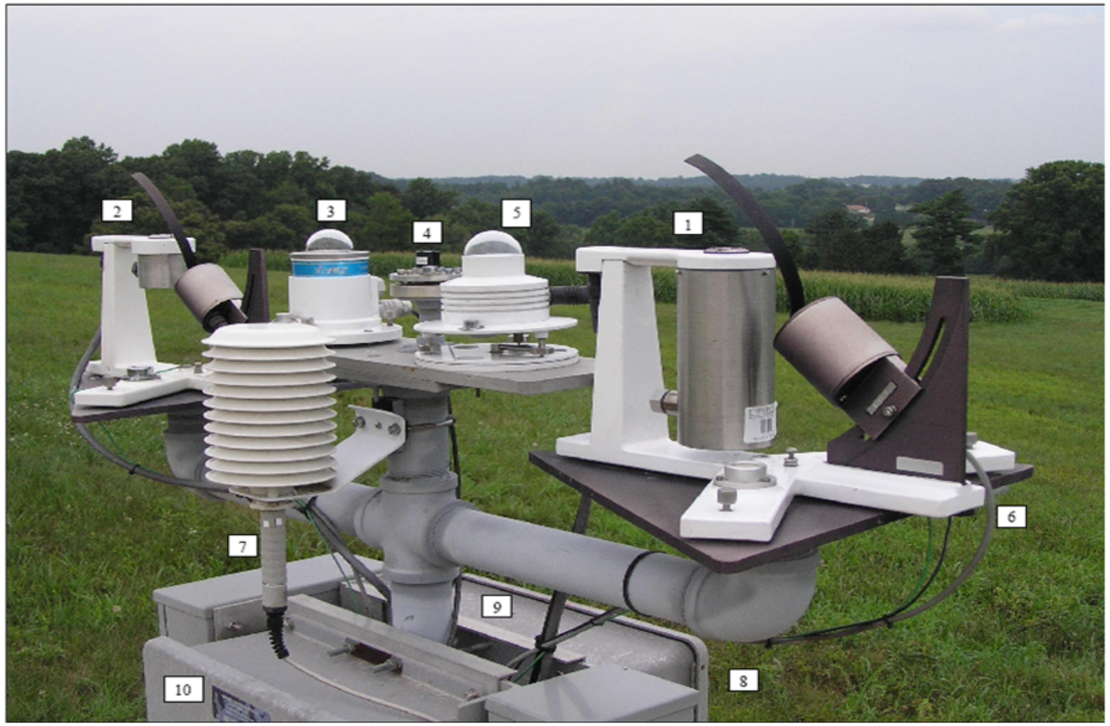


The quantification shows that rutin as the most dominant compound, followed by kaempferol-3-o-rutinoside and myricetin. Naringenin and chlorogenic acid showed trance amount on the dry weight basis (left) in mature magnolia leaves, and a comparison of all total 10 compounds combined indicated there are significant differences among the 12 tree species studied (right).

Standard Solar UV Radiation Monitoring Station in the USDA-UVB Monitoring Network

UVMRP Station Instruments

1. UVB Multi-Filter Rotating Shadowband Radiometer (UVMFRSR)
2. Visible Multi-Filter Rotating Shadowband Radiometer (vis-MFRSR)
3. UVB-1 Radiometer (Broadband)
4. Photosynthetically Active Radiation (PAR or Quantum Sensor)
5. UVA-1 Radiometer (Broadband)
6. Downward LiCor Photometric Sensor
7. Air Temperature (AT)
7. Relative Humidity (RH)
8. Pressure (inside datalogger enclosure)
9. UVMFRSR Datalogger
10. Vis-MFRSR Datalogger



The standard UVB radiation monitoring station configuration in USDA UVB Monitoring and Research Program (UVMRP) at Colorado State University (Image from UVMRP).

UV Monitoring Stations Above and Below Tree Canopy

Open Space Monitoring Station at LSU Benhur Farm, Baton Rouge, LA, as the Control Station Serving for Above Tree Canopy Monitoring (10 miles from SU campus)

Measurements

The UV-MFRSR sensor was put under a live oak canopy in the middle of its drip line radius in each of four directions (north, south, east and west) randomly in continuous sunny days from 10:00 a.m. to 4:30 p.m. daily at 3-min intervals.

A total of 48 days were monitored from Feb to June.

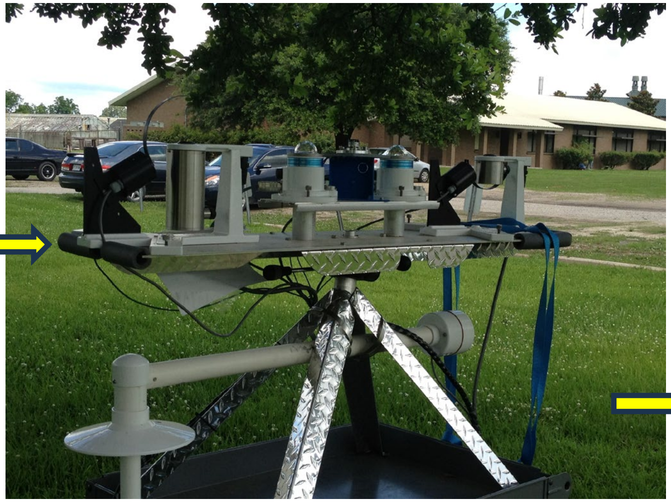
Data Format

Three-minute recordings (W/m^2s)

- For each wavelength (300, 305, 311, 317, 325, 332, 368nm)
- For UV-A range (317 + 325 + 332 + 368nm)
- For UV-B range (300 + 305 + 311nm)
- Canopy reduction = (Above-canopy recording) – (Below-canopy recording)
- Reduction percentage = (Canopy reduction irradiance) / (above-canopy UV recording) X 100%

Canopy reduction daily doses (J/m^2) = sum {(Canopy reduction)×180s)}
(10:00 a.m. – 4:00 p.m.)

UV Mobile Station at SU Campus built for Below Tree Canopy UV Monitoring



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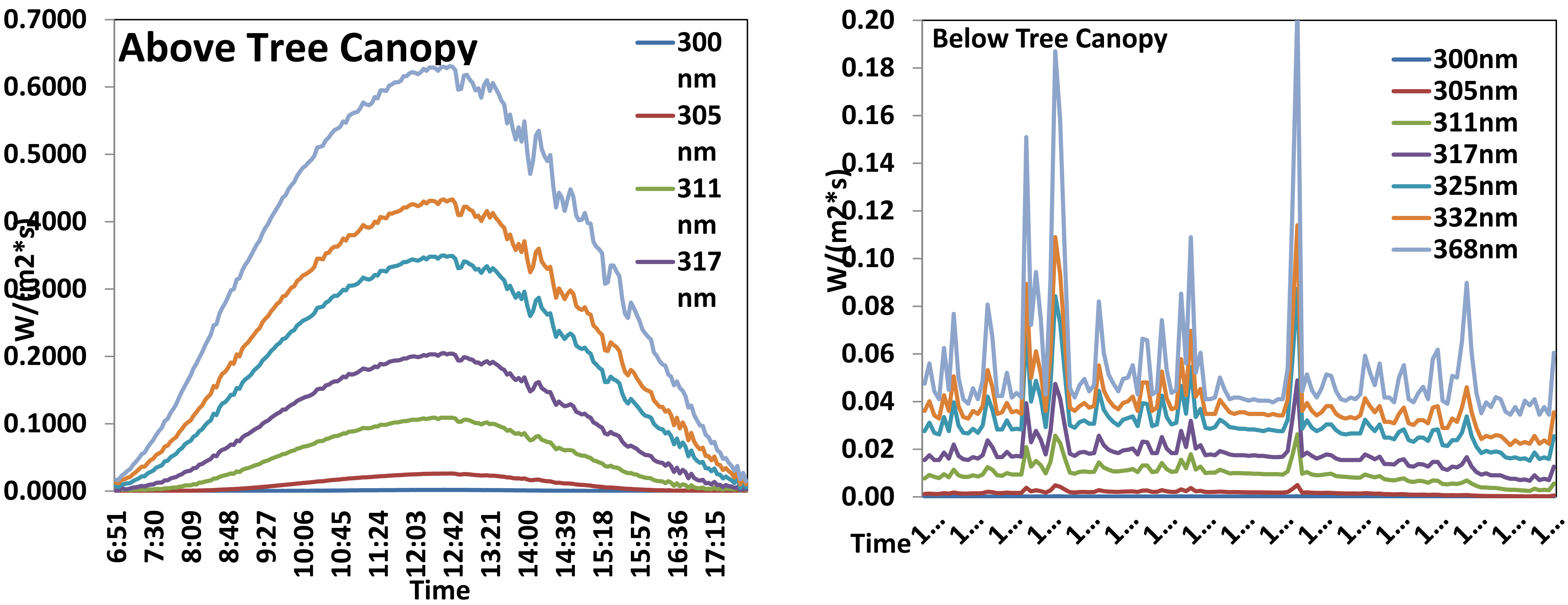
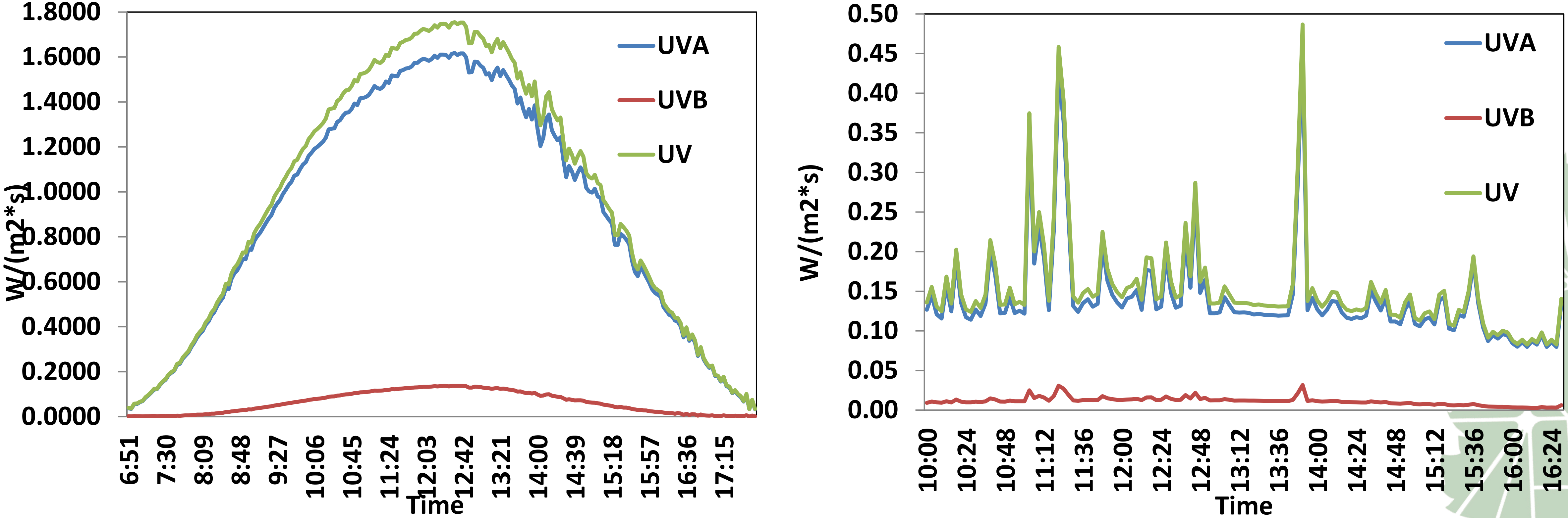
Urban Tree Canopy Effects on Daily Trends of Solar UV Radiation at 7 UV Wavelengths



Daily trends of UV radiation above and below the canopy of a live oak at 300nm, 305nm, 311nm, 317nm, 325nm, 332nm, 368nm, in east quadrant measured on Feb. 15, 2013. Tree number: 1; LAI: 3.60; DLA: 105.6 m^2; Height: 9.1 m, and DBH: 67 cm

Urban Tree Canopy Effects on Daily Trends of Solar UVA, UVB, and Total UV Radiation



Daily trends of UVA, UVB, and total UV radiation above and below the canopy of a live oak in east quadrant measured on Feb. 15, 2013. Tree number: 1; LAI: 3.60; DLA: 105.6 m^2; Height: 9.1 m, and DBH: 67 cm

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UV above and below tree canopy during a clear sky day, LAI = 0.69

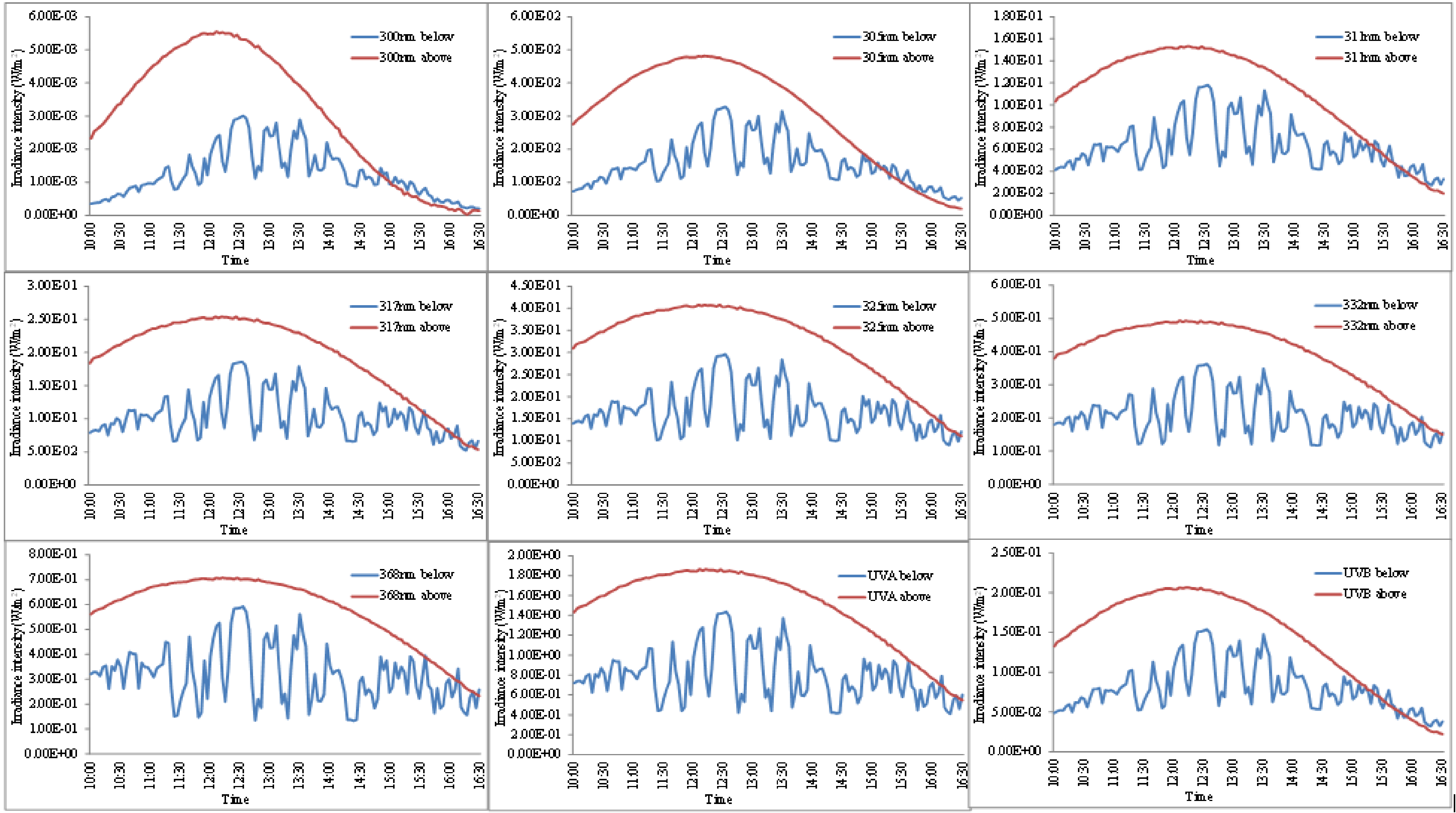

Figure 61. UV radiation above and below the canopy of a live oak at 300nm, 305nm, 311nm, 317nm, 325nm, 332nm, 368nm, UVA (sum of the last 4 wavelengths) and UVB (sum of the first 3 wavelengths) in south quadrant measured in Mar. 12, 2013. Tree number: 3; LAI: 0.69; DLA: 88.3 m²; Height: 8.5 m, and DBH: 53.9 cm

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UV above and below tree canopy during a clear sky day, LAI =1.31

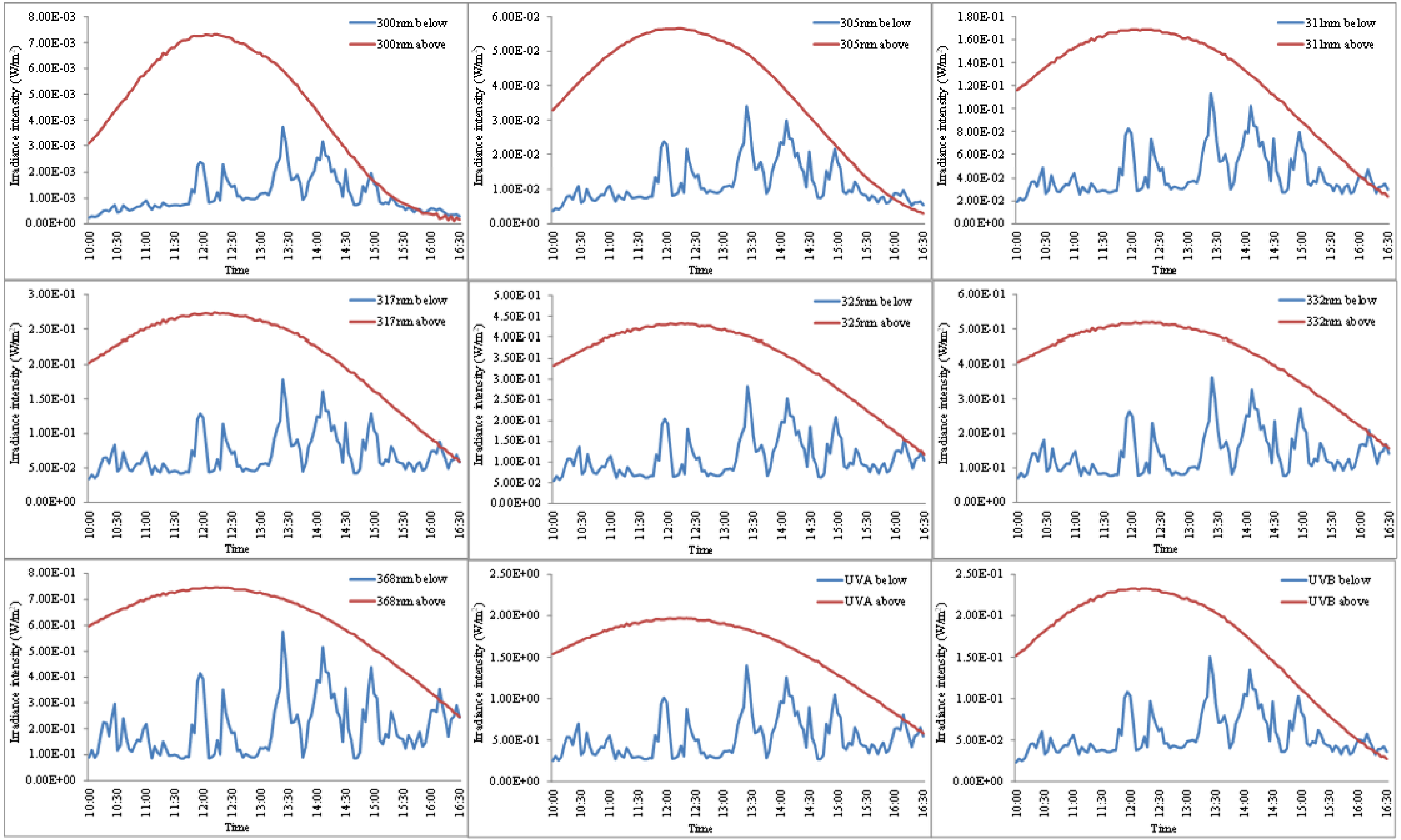


Figure 67. UV radiation above and below the canopy of a live oak at 300nm, 305nm, 311nm, 317nm, 325nm, 332nm, 368nm, UVA (sum of the last 4 wavelengths) and UVB (sum of the first 3 wavelengths) in south quadrant measured in Mar. 25, 2013. Tree number: 2; LAI: 1.31; DLA: 95.5 m²; Height: 9.5 m, and DBH: 55.7 cm

UV above and below tree canopy during a clear sky day, LAI =2.48

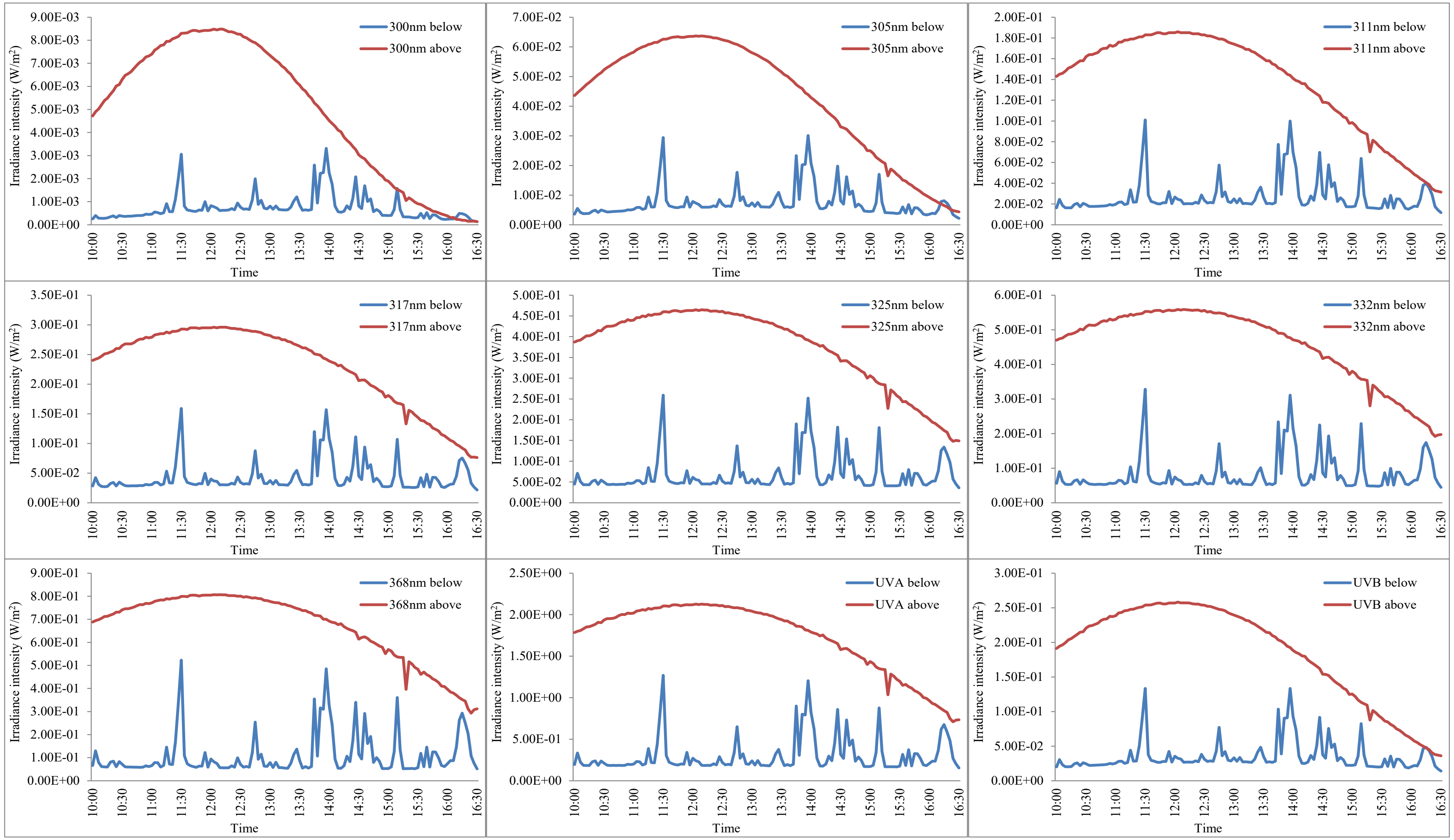


Figure 79. UV radiation above and below the canopy of a live oak at 300nm, 305nm, 311nm, 317nm, 325nm, 332nm, 368nm, UVA (sum of the last 4 wavelengths) and UVB (sum of the first 3 wavelengths) in east quadrant measured on May 6, 2013. Tree number: 3; LAI: 2.48; DLA: 88.3 m^2; Height: 8.5 m, and DBH: 53.9 cm

UV above and below tree canopy during a clear sky day, LAI =3.61

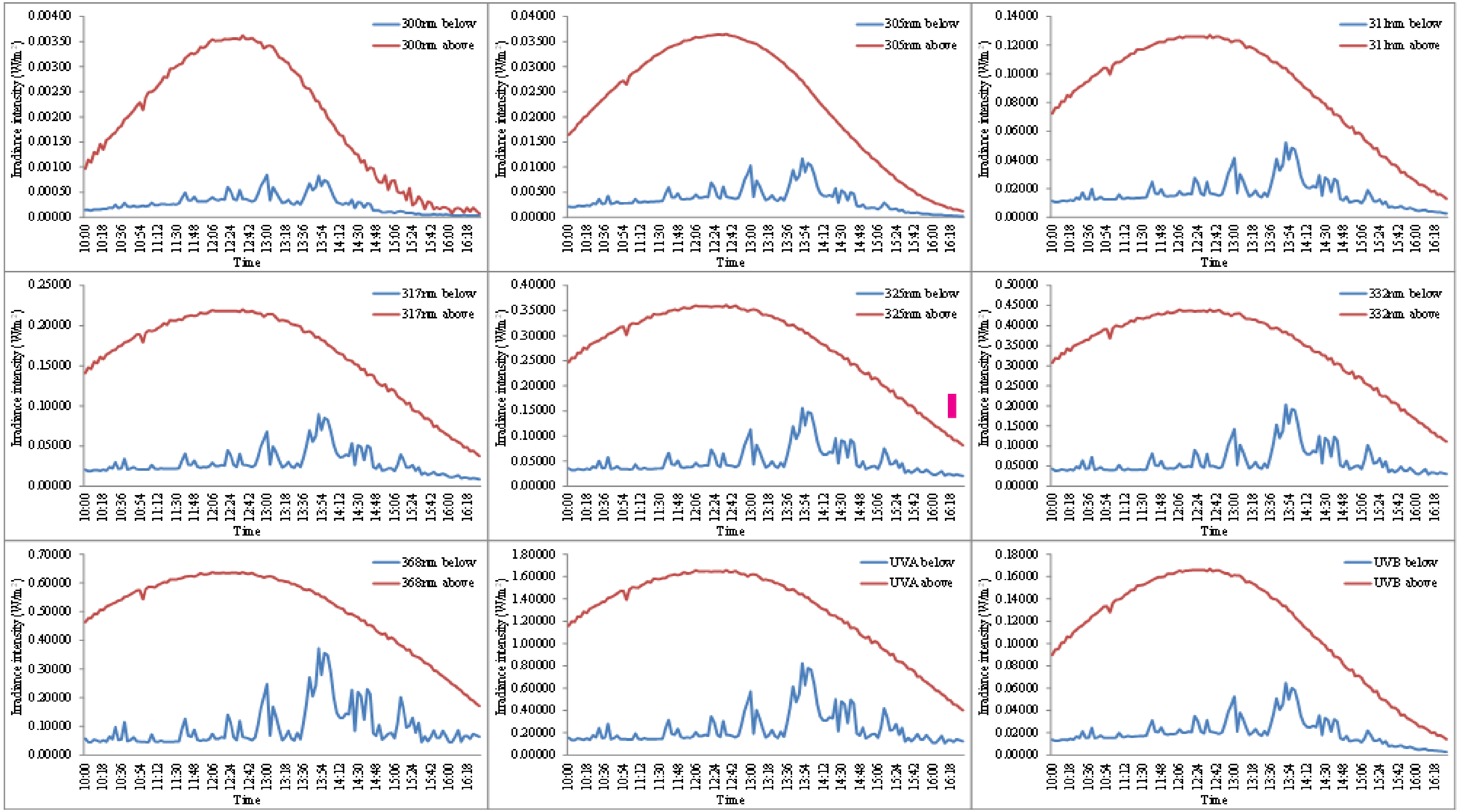


Figure 51. UV radiation above and below the canopy of a live oak at 300nm, 305nm, 311nm, 317nm, 325nm, 332nm, 368nm, UVA (sum of the last 4 wavelengths) and UVB (sum of the first 3 wavelengths) in west quadrant measured in Feb. 14, 2013. Tree number: 1; LAI: 3.61; DLA: 105.6 m²; Height: 9.1 m, and DBH: 67 cm

UV above and below tree canopy during a clear sky day, LAI =3.76

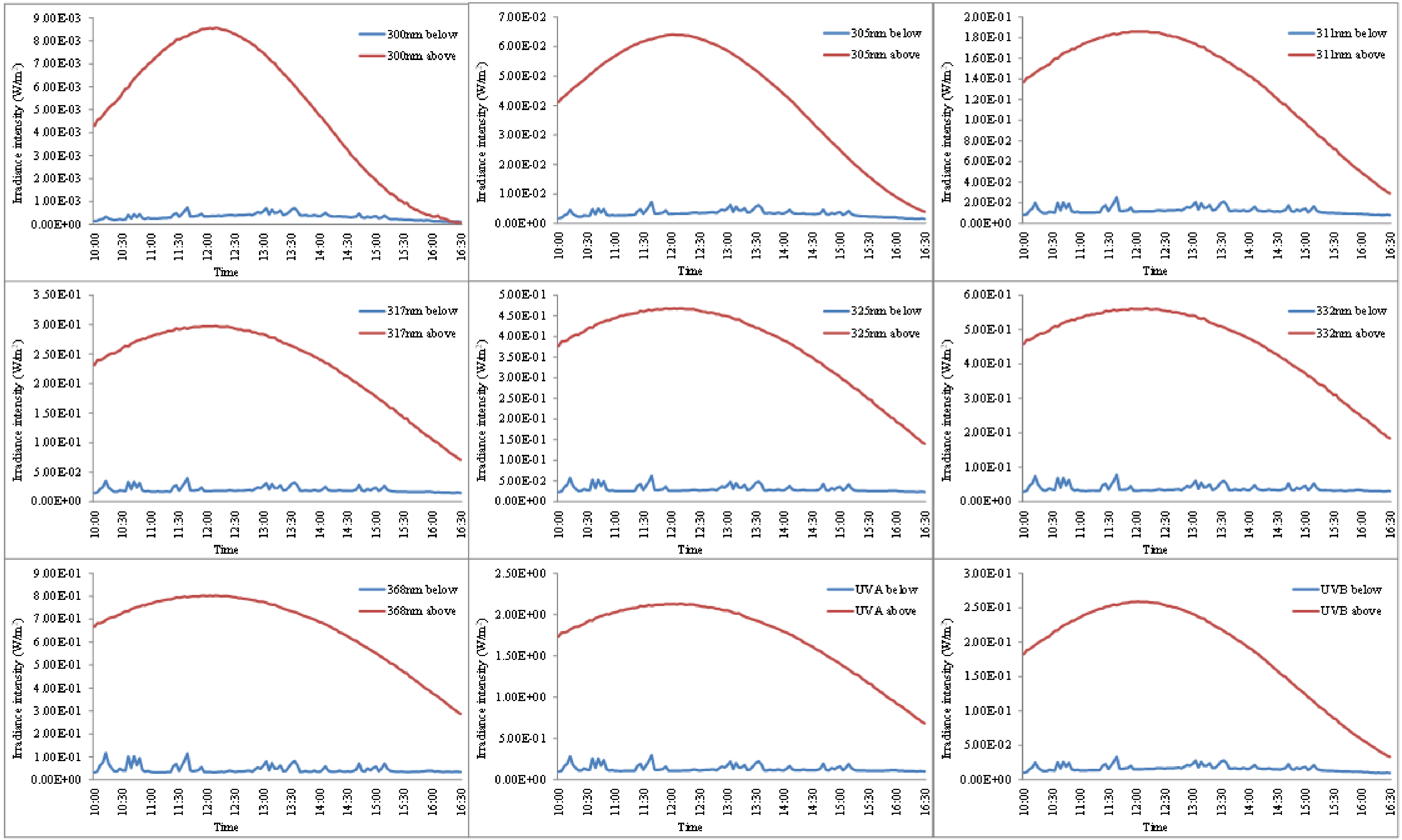


Figure 75. UV radiation above and below the canopy of a live oak at 300nm, 305nm, 311nm, 317nm, 325nm, 332nm, 368nm, UVA (sum of the last 4 wavelengths) and UVB (sum of the first 3 wavelengths) in north quadrant measured in Apr. 21, 2013. Tree number: 1; LAI: 3.76; DLA: 105.6 m^2; Height: 9.1 m, and DBH: 67 cm

UV above and below tree canopy during a partially cloudy day, LAI = 3.05

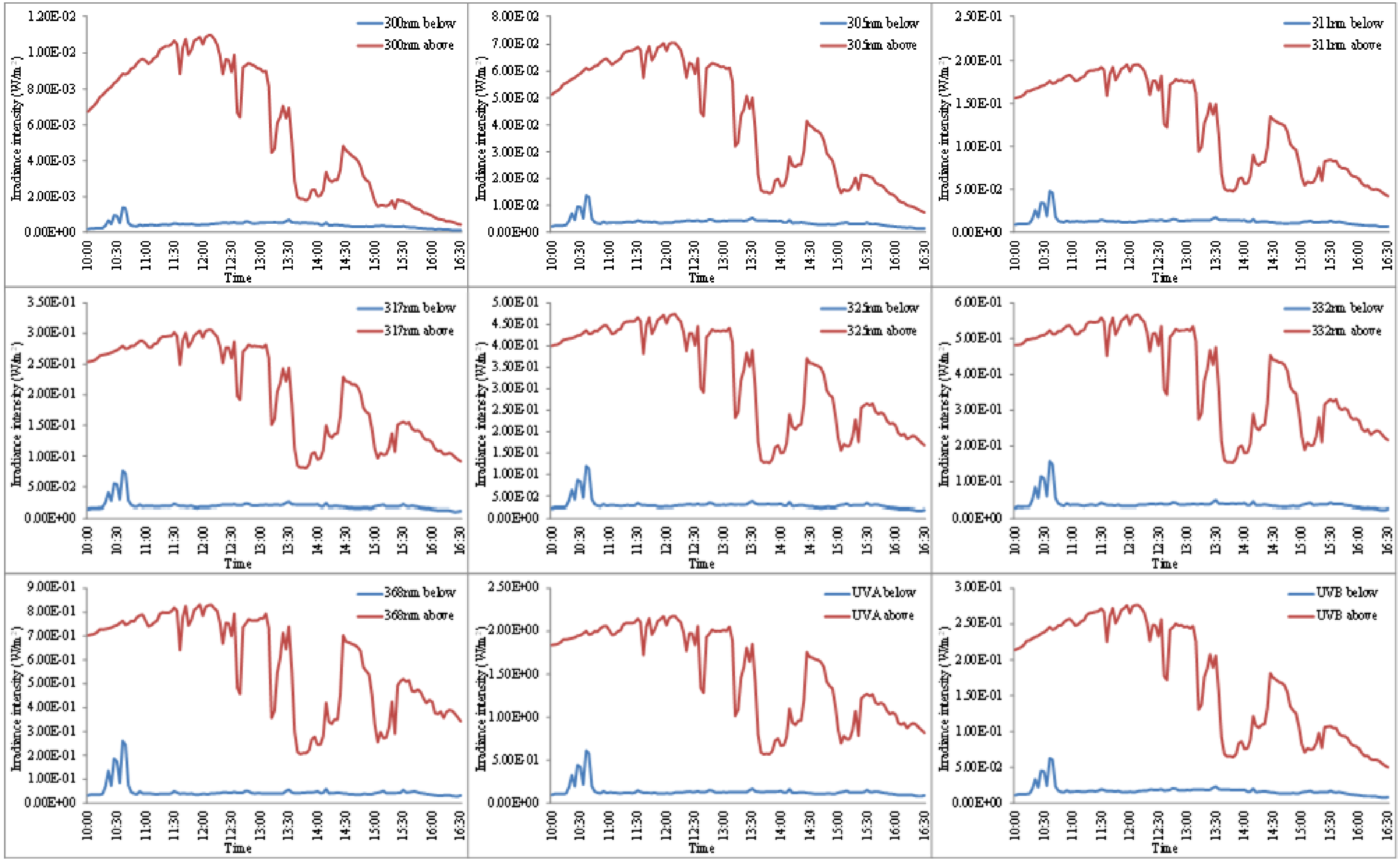
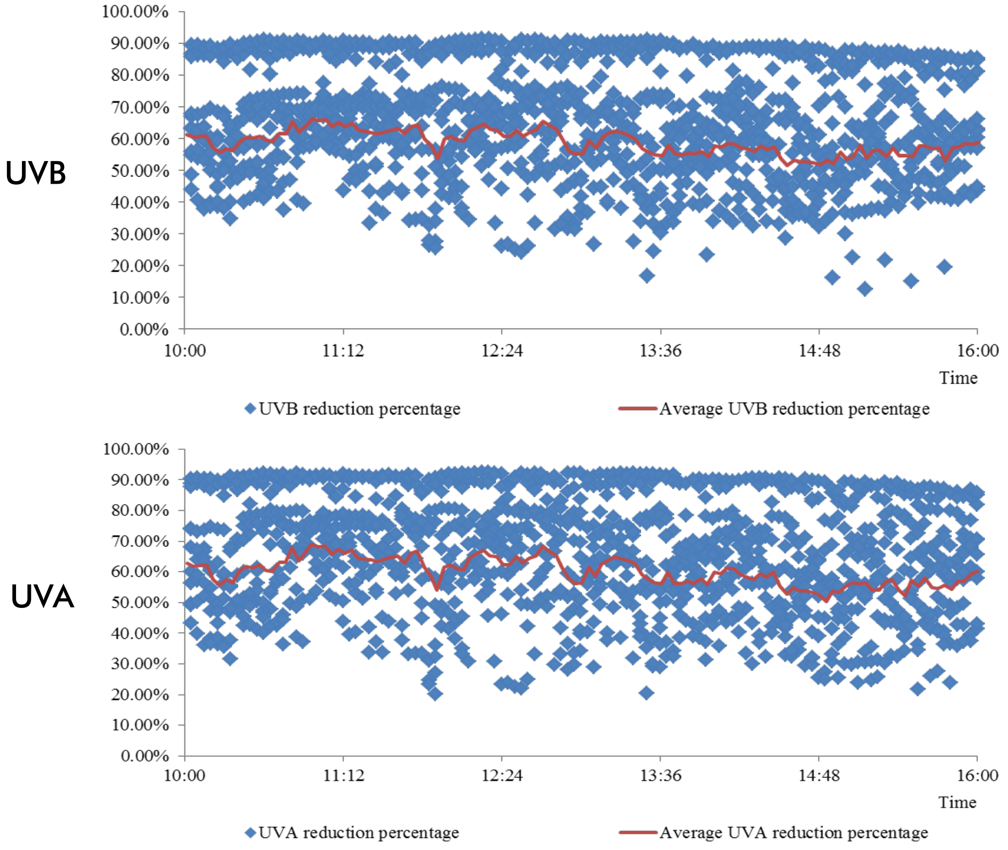


Figure 93. UV radiation above and below the canopy of a live oak at 300nm, 305nm, 311nm, 317nm, 325nm, 332nm, 368nm, UVA (sum of the last 4 wavelengths) and UVB (sum of the first 3 wavelengths) in west quadrant measured in Jun. 6, 2013. Tree number: 3; LAI: 3.05; DLA: 88.3 m²; Height: 8.5 m, and DBH: 53.9 cm

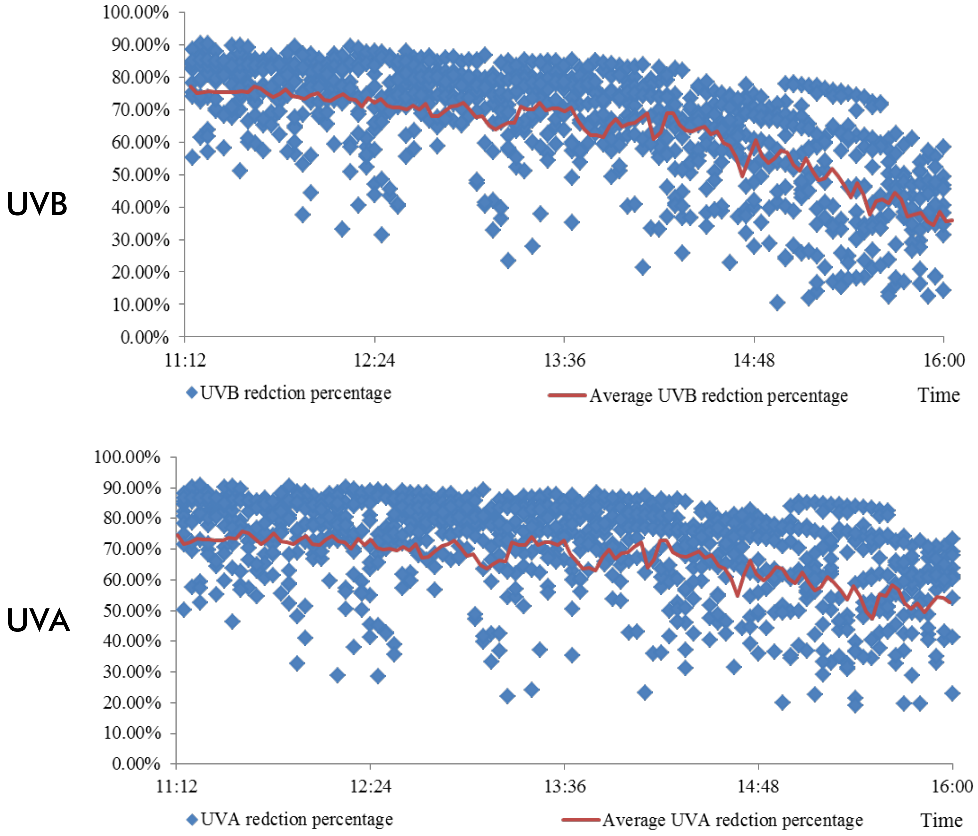
Urban Tree Canopy Reduction % of Solar UVB & UVA Radiation

Feb-March – 60%



UVA and UVB reduction percentages by tree canopy based on three live oak trees monitored for 12 days from 02/14/2013 to 03/12/2013, LAI: 0.52-3.61

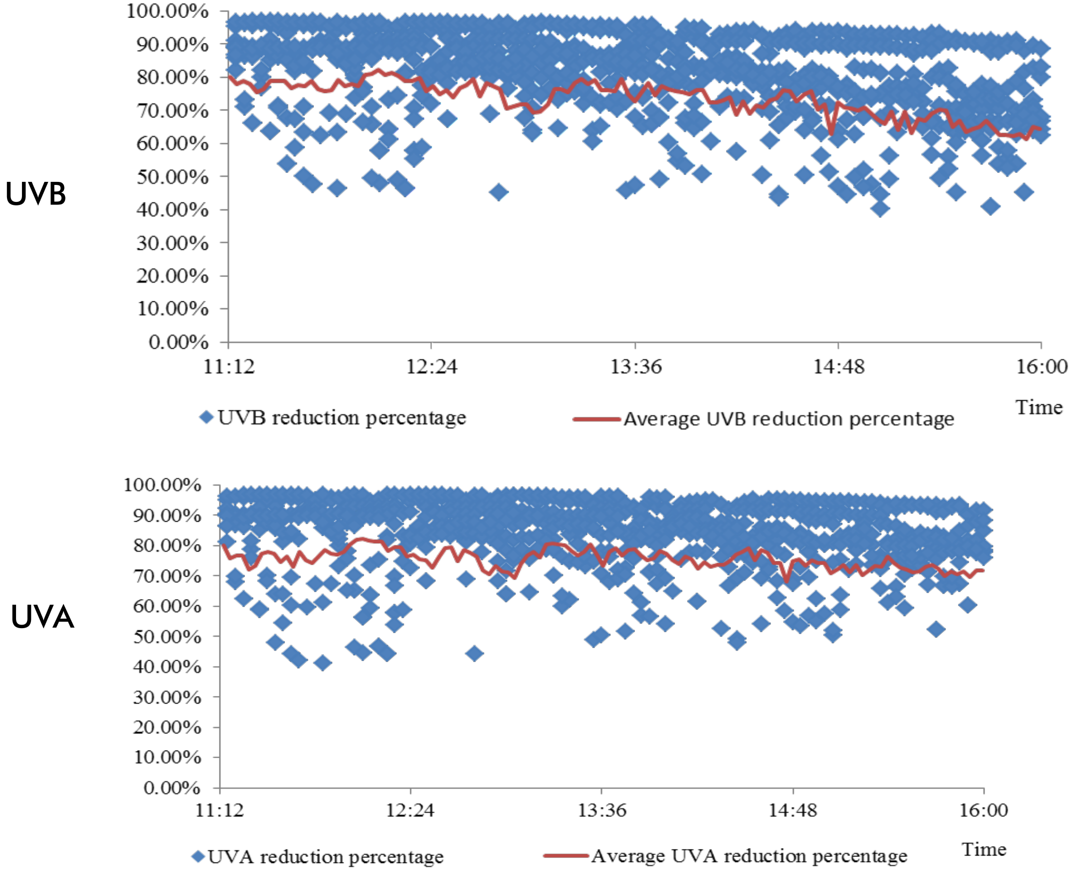
March to April – 70%



UV-A and UV-B reduction percentages for three live oak trees in each experimental day in series 2 from 03/13/2013 to 04/12/2013 LAI: 1.31-2.89

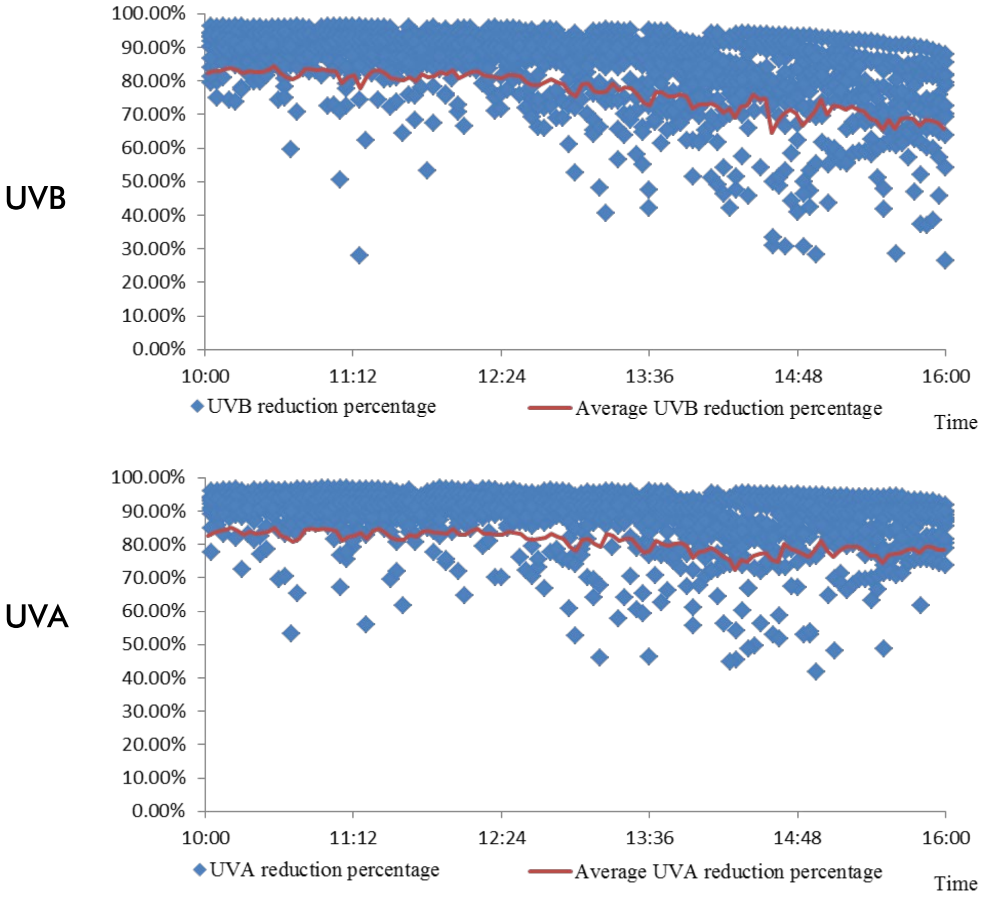
Urban Tree Canopy Reduction % of Solar UVB & UVA Radiation

April-May – 75%



UVA and UV-B reduction percentages for three live oak trees in each experimental day in series 3 from 04/13/2013 to 05/09/2013 LAI: 2.48-3.80

May - June – 80%



UVA and UVB reduction percentages by tree canopy based on three live oak trees monitored for 12 days from 05/12/2013 to 06/07/2013, LAI: 2.11-3.62

Urban Tree Canopy and UV Radiation Reduction

Results of regressions of daily canopy reduction of UV at different wavelengths against LAI for live oak trees

UV Wavelength	Variable	Parameter Estimate	Standard Error	t Value	Pr > |t|
300nm UVB	Intercept	0.51376	0.07496	6.85	<.0001
	LAI	0.03997	0.01938	2.06	0.0054
305nm UVB	Intercept	3.37193	0.46661	7.23	<.0001
	LAI	0.39218	0.12063	3.25	0.0003
311nm UVB	Intercept	9.27517	1.3126	7.07	<.0001
	LAI	1.44503	0.33934	4.26	<.0001
317nm UVA	Intercept	15.50361	2.05445	7.55	<.0001
	LAI	2.32382	0.53113	4.38	<.0001
325nm UVA	Intercept	24.59066	3.25783	7.55	<.0001
	LAI	3.70777	0.84224	4.4	<.0001
332nm UVA	Intercept	29.09118	3.87578	7.51	<.0001
	LAI	4.54166	1.00199	4.53	<.0001
368nm UVA	Intercept	41.78671	5.94611	7.03	<.0001
	LAI	6.84716	1.53723	4.45	<.0001

Linear regression indicated the significant positive relationship between UV canopy reduction and canopy leaf area index (LAI).

$Y = a + bx$, Y: canopy reduction UV daily dose (J/m2); X: leaf area index (LAI)

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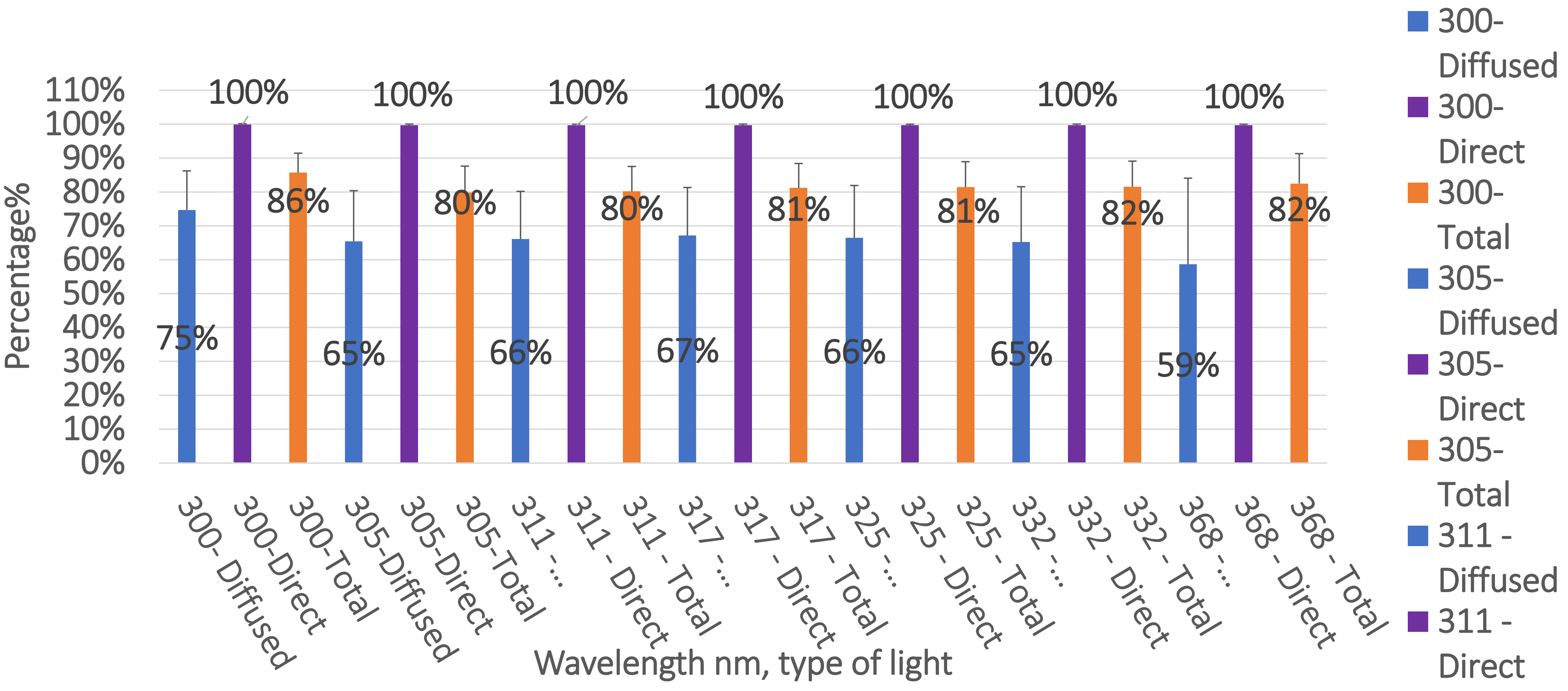
Average daily canopy reduction percentage

of diffused, direct, and total horizontal UV radiation at 7 specific UV wavelengths, based on 11 days' measurements combined in the Spring (April-May) 2018.



In summary

- Our leaf optical property study indicated that on a whole leaf basis, tree leaves absorb 91-95%, reflect 5-9%, and transmit very little (<1%) incident UV-B radiation. At the leaf tissue level, the upper leaf epidermis absorbs the most UV-B radiation.
- Out of 31 species studied we identified 23 broadleaf tree species that possess a strong epidermal UV-B screening function. The leaves of these species are capable of attenuating 92-99% of the UV-B through their upper epidermal layers.
- Total contents of UV absorbing compounds in 35 select tree species were quantified using UV-Visible spectrophotometer method in the ranges of 280-400nm. Significant variations exist among the species in total UVB absorbing compound contents. Synthesis of UV-B absorbing compounds helps trees mitigate the damaging effects of UV-B radiation.
- All the species studied exhibit cumulative increases in leaf thickness, UV-B absorbing compound concentration, and chlorophyll content during the growing season as solar UV-B radiation increases from April to August;
- We established a laboratory protocol to localize and visualize flavonoids and phenolic compounds in leaves of tree species using the chemical reagent, Naturstoffreagenz A (NA) (diphenylboric acid 2-aminoethylester) via fluorescence microscopy. The UV absorbing compounds were found mainly present in the leaf petiole epidermises, leaf lower and upper epidermises for all species, and in vascular bundles and palisade tissues of some species.
- We developed and established research protocols on identification and quantification of eight flavonoids and associated phenolic acids using HPLC assays. The amount of the identified compounds varied significantly with species. These compounds may play important roles in UV-B tolerance in these broadleaf trees.
- Our research indicated that urban tree (e.g., live oak) canopy can reduce (interception) up to 100% of direct solar UVA and UVB radiation, up to 75% diffuse and 86% total horizontal UV radiation. Tree canopy UV reduction power is significantly increased with increasing leaf area index.
- These results have implications in predicting urban forest effects on UV reduction and modeling urban forest effects for long-term sustainability of urban ecosystem.

Urban and Forestry Natural Resources

Southern University Agricultural Research & Extension Center

NIFA GRANTS

Colorado State University

Funding

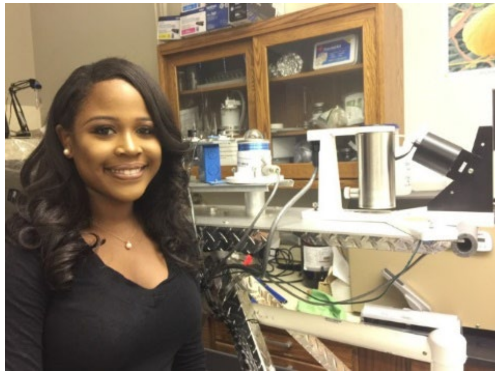
Funding for this research initiative : USDA-NIFA-Grant Awards #201438821-22415 (PD-Yadong Qi) #2010-38821-21608 (PD-Yadong Qi) and #98-38814-6386 (Pd-Yadong Qi).

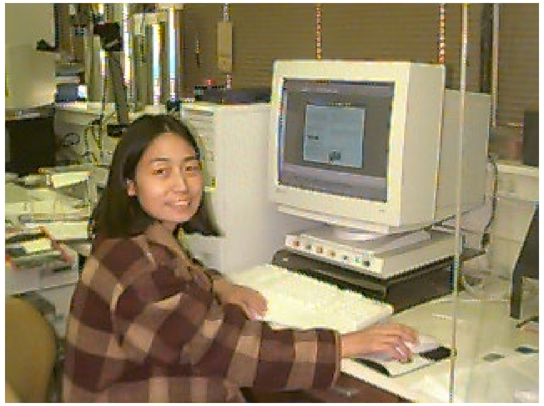
For more information:

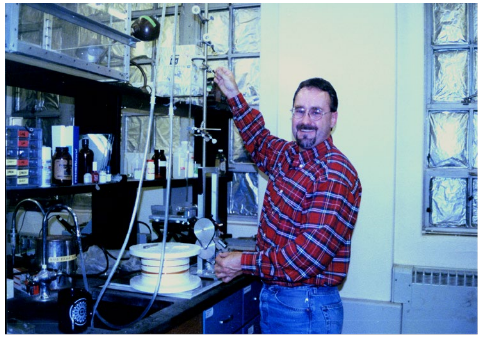
On going research includes

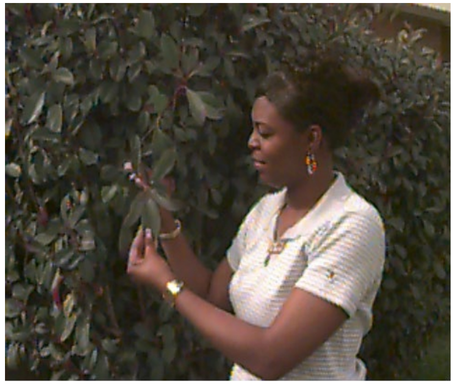
(1) “Genetic Approach to Assessing UV-B Tolerance in Selected Southern Broadleaf Trees” USDA-NIFA grant # 2023-38821-39967(PD-Yadong Qi)

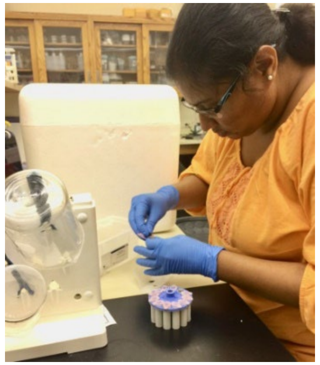
(2) Modeling tree canopy reduction of direct, diffused, and total UVA and UVB, and Visible radiation, to understand the insight of tree canopy interception of specific wavelengths of solar radiation.



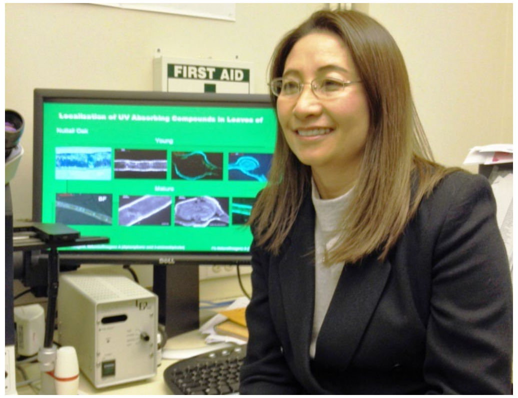


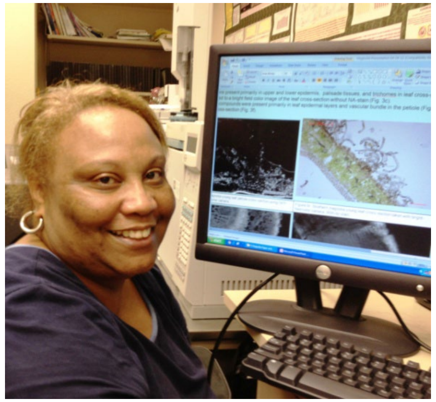


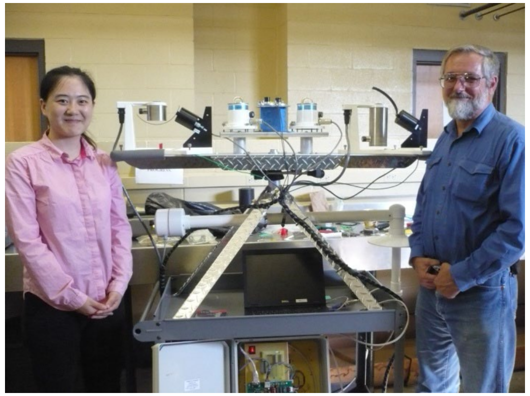


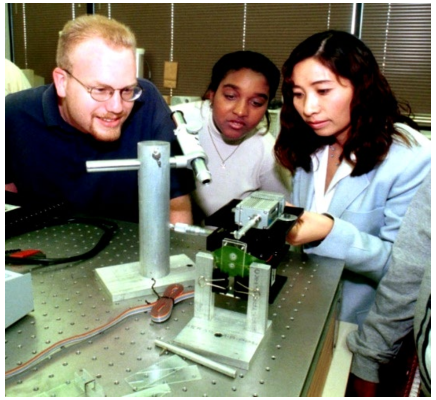


Funding for this research initiative was from the following USDA-NIFA-Grant Awards to Qi: No. 1998-38814-6386, No. 2010-38821-21608, No. 2014-38821-22415









Thank you

Yadong Qi, PhD., Professor

Dept of Urban Forestry, Environment, and Natural Resources

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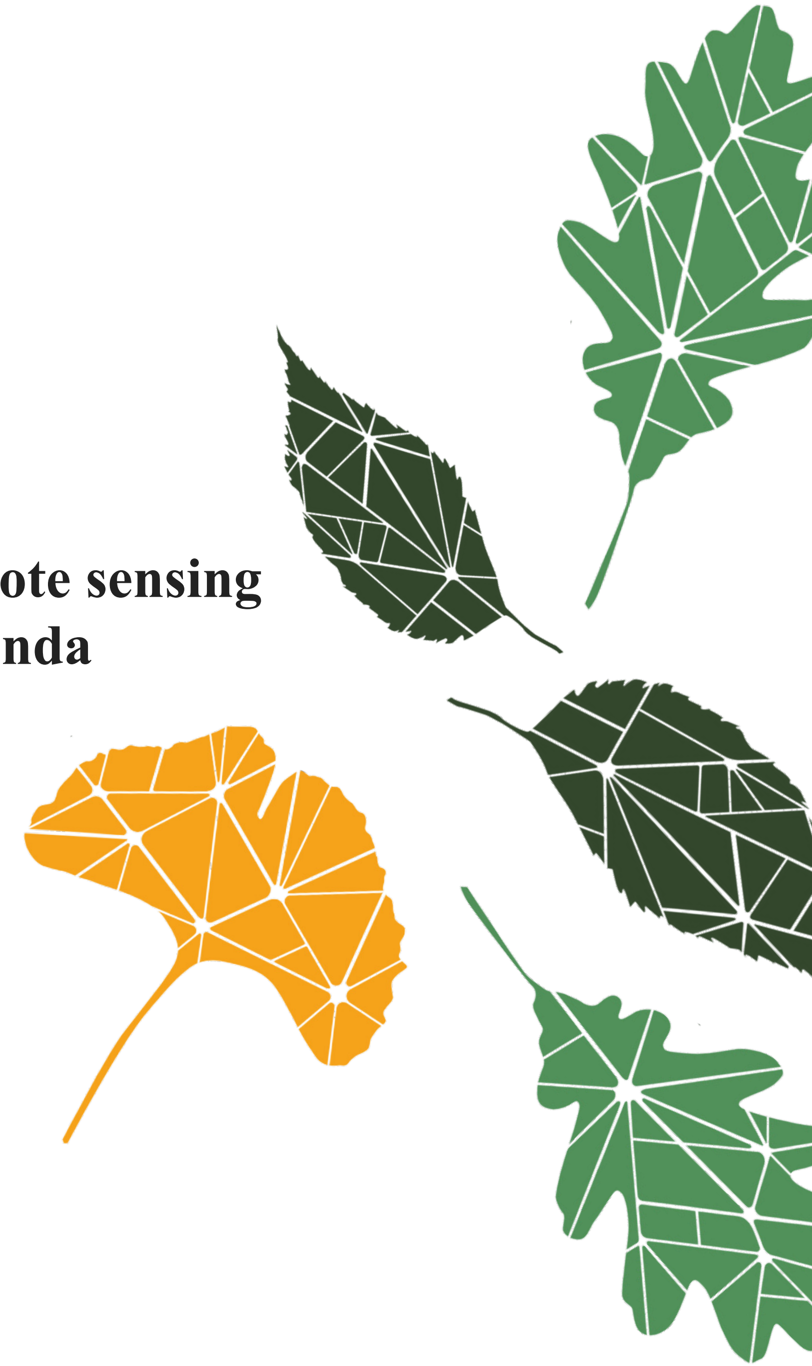
2nd World Forum on Urban Forests

2023

World Forum on Urban Forests

2nd World Forum on Urban Forests
Washington DC, 2023



Analysis of urban forest effects on urban microclimate using remote sensing technique: a case study of Nyarugenge Sector of Kigali City, Rwanda

Presented by

Hyacinthe NGWIJABAGABO
Assistant Lecturer
University of Rwanda, College of Science and Technology, School of Architecture and Built Environment (SABE)

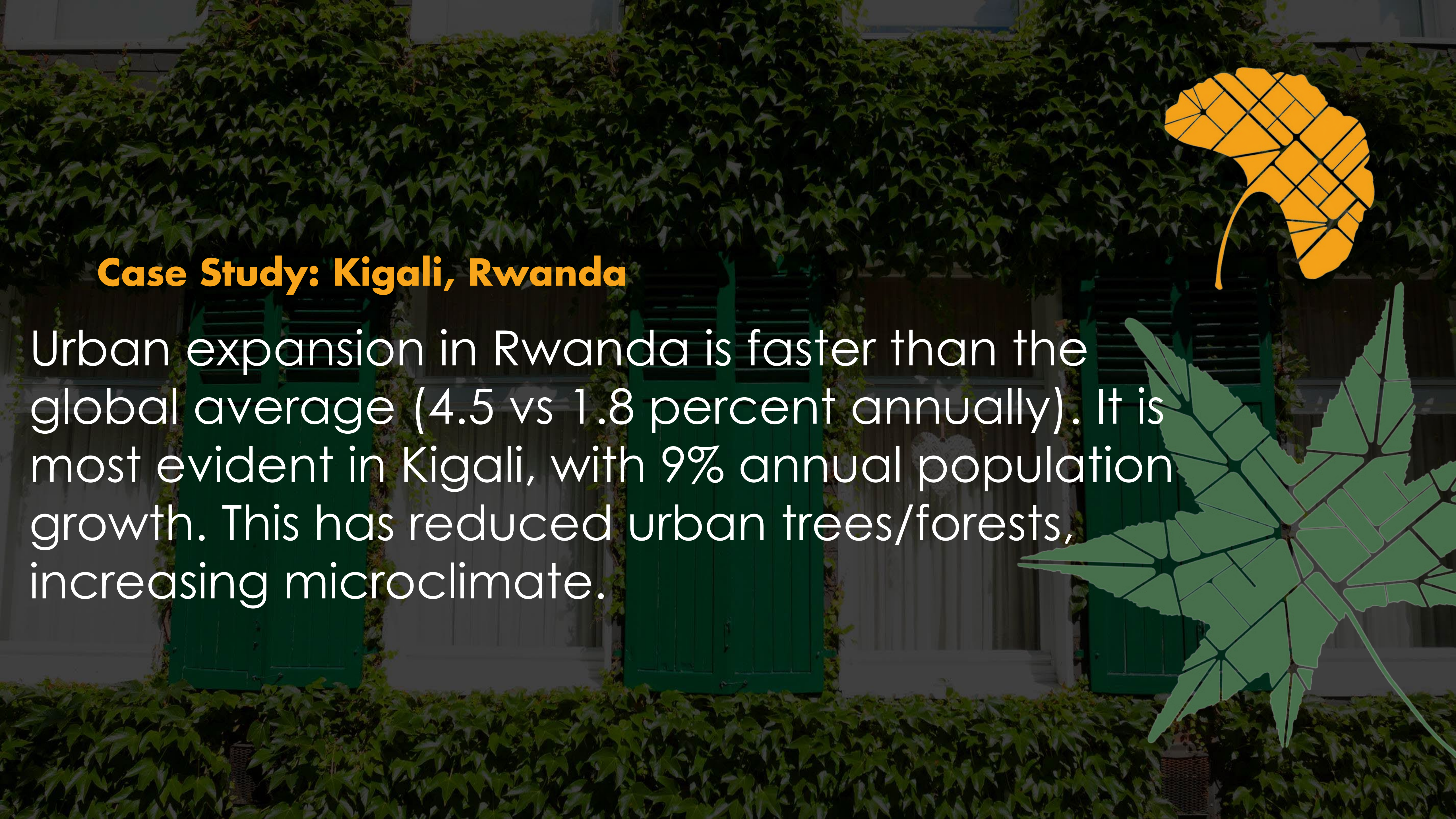
Urban microclimates

Urban microclimates have developed in urban settings due to densely populated areas, concrete zones, and anthropogenic activity.

In developing countries, cities have been growing rapidly with changes in land surface characteristics that exacerbate microclimate conditions, leading to discomfort and negative health effects.

The Importance of Urban Forests

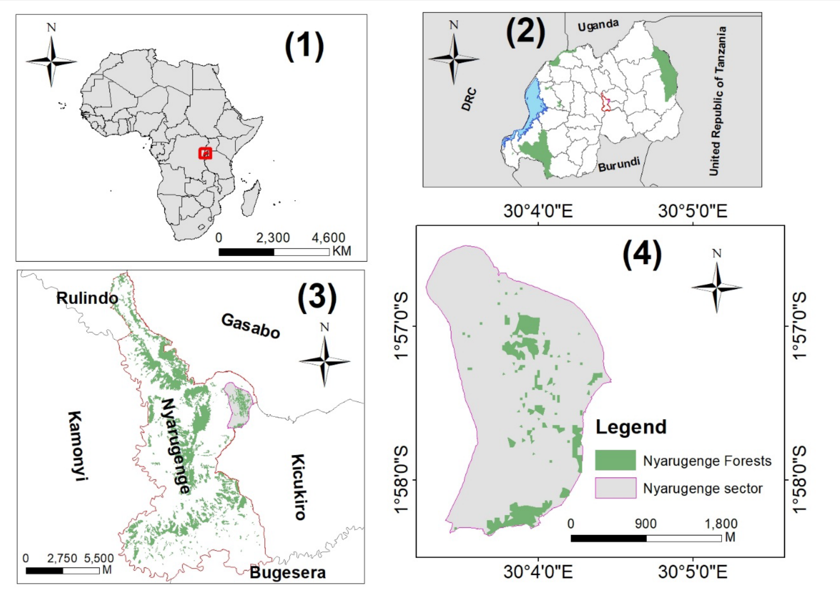
- Urban forests and trees bring down the temperature and cool down the urban climate of the surrounding land by blocking and absorbing solar radiation through their leaves.
- Urban forest-covered regions can reduce the surface temperature by more than 15 °C, and shade can lower the body temperature by 3 to 5 °C.



Case Study: Kigali, Rwanda

Urban expansion in Rwanda is faster than the global average (4.5 vs 1.8 percent annually). It is most evident in Kigali, with 9% annual population growth. This has reduced urban trees/forests, increasing microclimate.

Exploring Nyarugenge District: A Study of Kigali's Vibrant City Center



Nyarugenge Sector is one of 10 sectors that make up Nyarugenge District; it contains the city center of Kigali and most of the city's businesses. The sector has a population density of 4625 people per square kilometer.

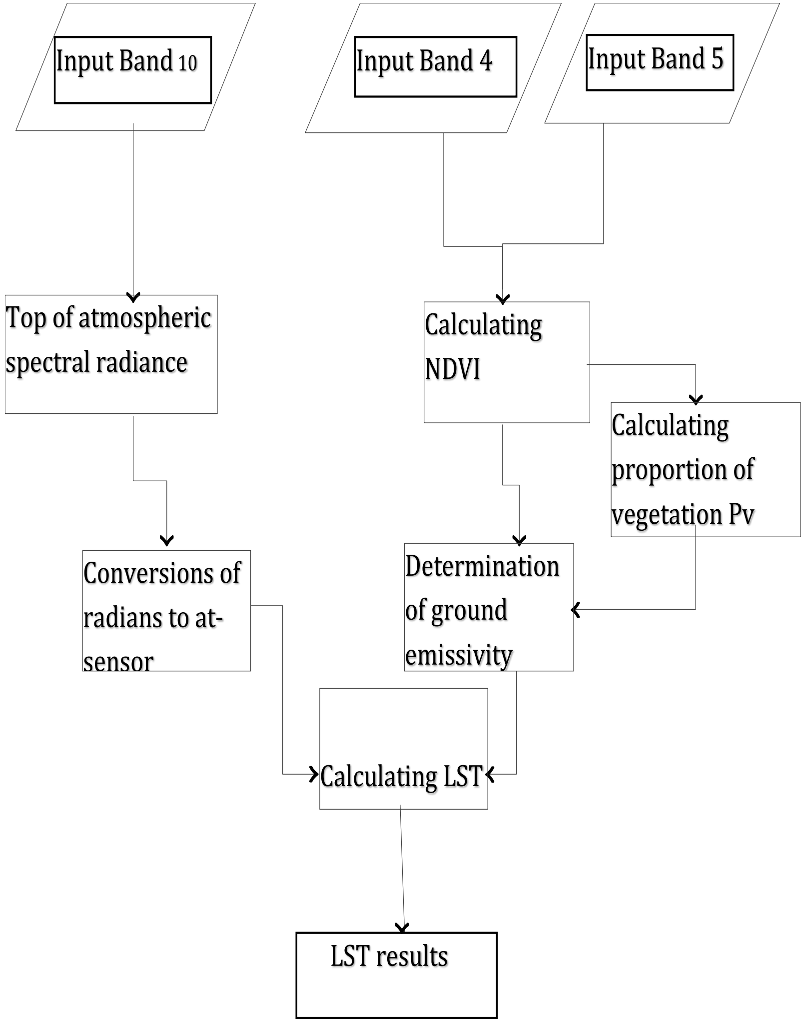
Methods and data

- A satellite image from the United States Geological Survey was used to analyze the Land Surface Temperature (LST) and Normalized Difference Vegetation Index (NDVI) of a cloud- free environment during late dry seasons.
- The image had a 30m resolution and the thermal channel was processed to retrieve the LST. The NDVI was calculated using visible and near infrared bands.
- To analyze the effects of forests on land surface temperature, a Landsat- 8 Thermal Infrared Sensor (TIRS) satellite image was used; along with Urban forest and administrative boundary shapefiles.
- The Normalized Difference Vegetation Index (NDVI) was then created to estimate LST and calculate vegetation masks of forests, and it was used in the NDVI- LST correlation analysis.
- To do this, the top of Atmospheric Spectral Radiance (TOA) was calculated using a radiance rescaling factor and thermal infrared digital numbers.

Forest and individual urban tree analysis

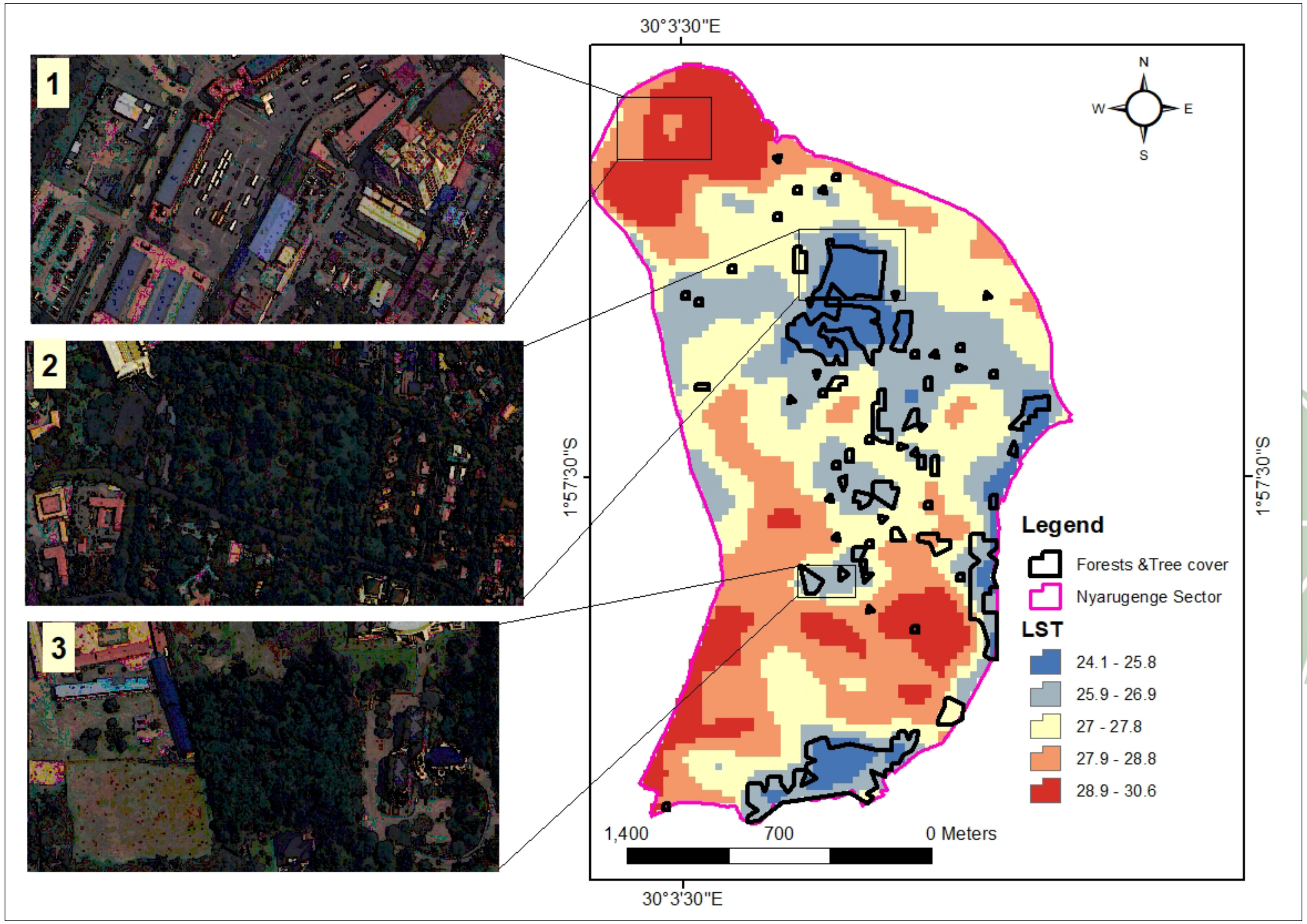
- For urban forest and individual urban trees assessments, an administrative boundary of urban forest was used, and the NDVI calculate in Equation ($\boldsymbol{NDVI = (Band\,5 - Band\,4)}$ / $\boldsymbol{(Band\,5 + Band\,4)}$) was used as an indicator to assess vegetation greenness and urban forest density. NDVI values were used to evaluate its correlation with urban land surface temperature.

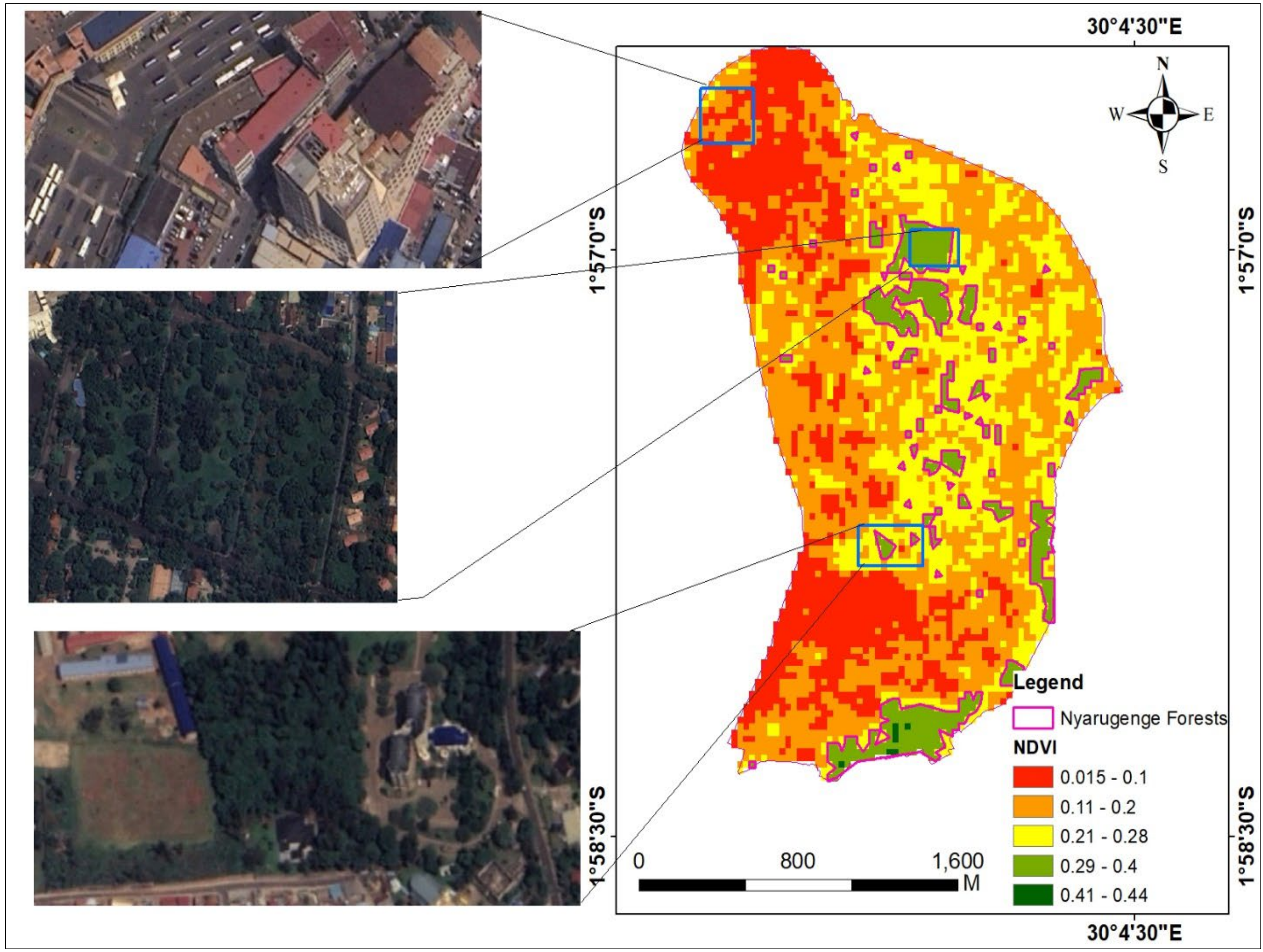
Land Surface Temperature retrieval approach

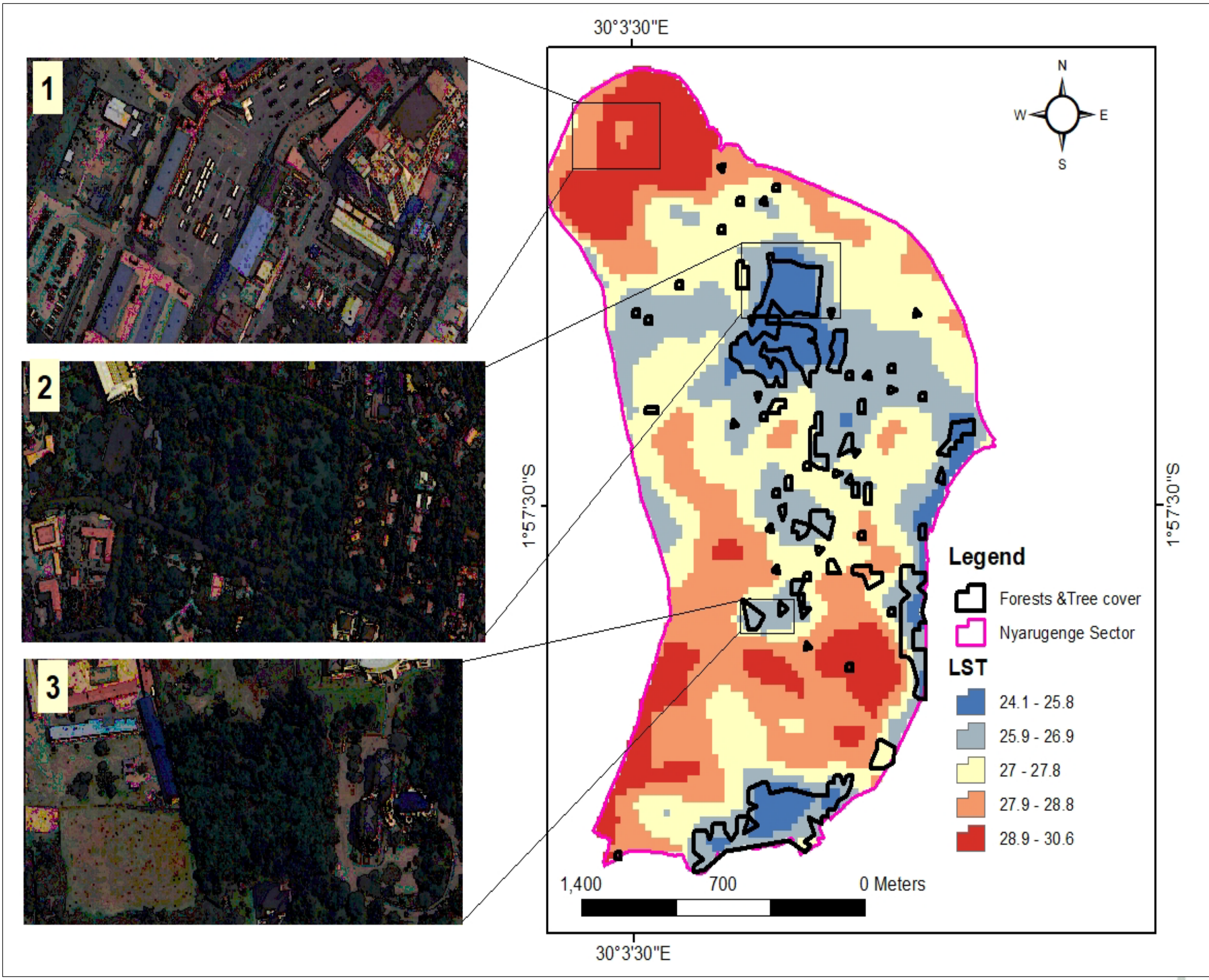


Results: Uncovering the Cooling Power of Urban Forests

- **The cooling effect of urban forests was examined by analyzing Land Surface Temperatures (LST) within the forests and their surrounding areas. Results range from 24.9- 30.6 C and show that the LST decreases from the core of the forest and increases with distance away.**




30°4'30"E
1°57'0"S
1°58'30"S
N
S
W
E
0
800
1,600
M
Legend
Nyarugenge Forests
NDVI
0.015 - 0.1
0.11 - 0.2
0.21 - 0.28
0.29 - 0.4
0.41 - 0.44


1
2
3
30°3'30"E
1°57'30"S
N
S
W
E
Legend
Forests &Tree cover
Nyarugenge Sector
LST
24.1 - 25.8
25.9 - 26.9
27 - 27.8
27.9 - 28.8
28.9 - 30.6
1,400
700
0 Meters

Conclusion

- This study used Landsat 8/TIRS to investigate the effect of forests and individual trees in urban areas on the urban microclimate.
- The results of the study showed a negative and linear correlation between NDVI (Normalized Difference Vegetation Index) and LST (Land Surface Temperature), meaning that areas far from forests or with less vegetation cover had higher LST.
- GIS and remote sensing techniques were found to be effective in analyzing the role of urban trees in regulating urban microclimate.
- The study also provides a decision- making tool and a scientific basis for preserving and expanding urban forests and green spaces to reduce the Urban Heat Island phenomenon.

Thank you

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2023

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2nd World Forum on Urban Forests
Washington DC, 2023

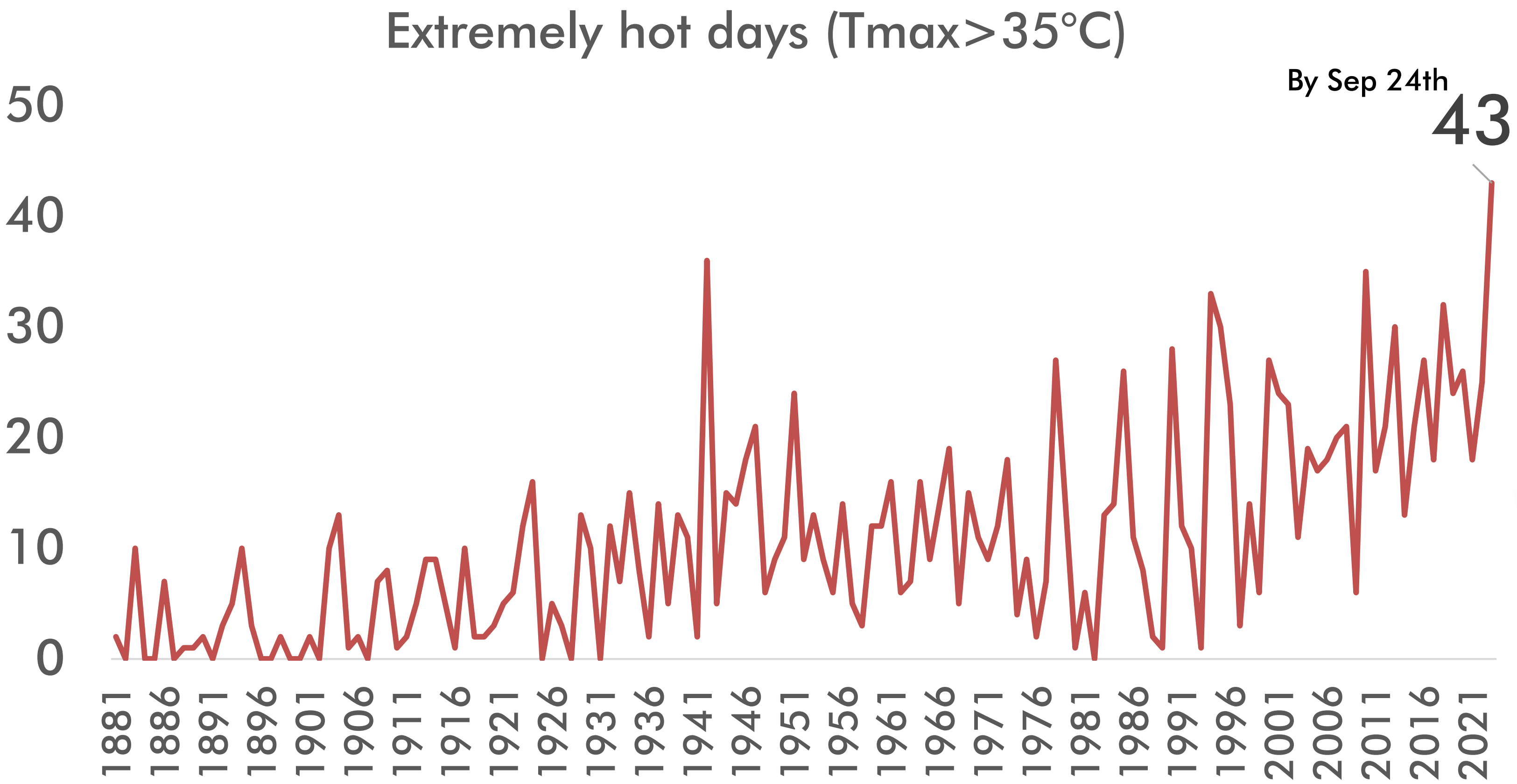
Quantifying the effect of tree volume on thermal comfort within urban parks using a 3D laser scanner

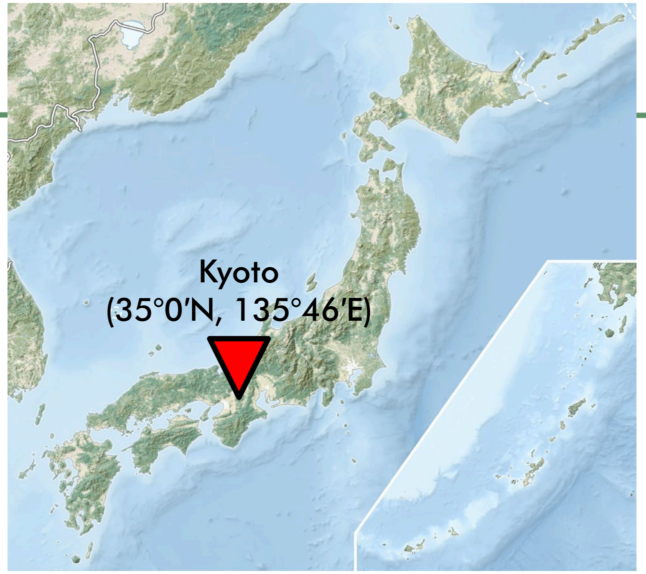
Presented by

Lihua Cui, Shozo Shibata
Kyoto University

Introduction

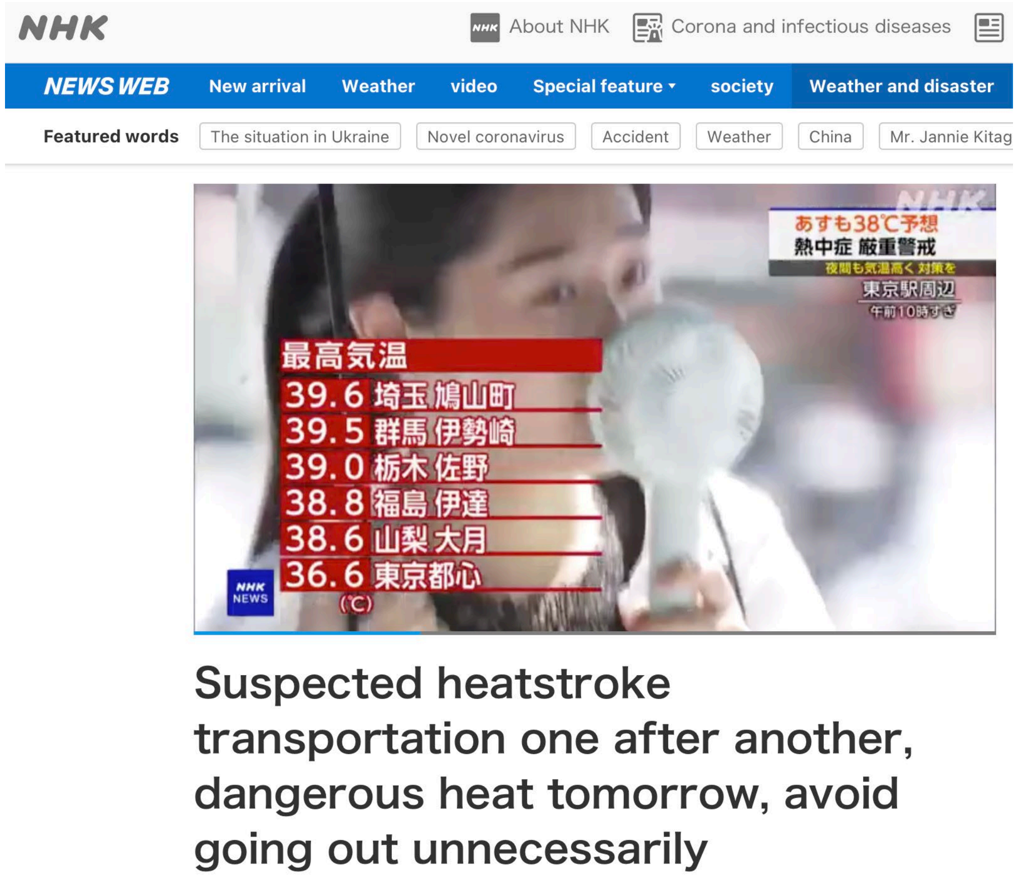
Extremely hot days in Kyoto, Japan





Climate: *Cfa*, warm temperate climate
Hot and humid summer

Current heatwave adaptation strategies



Suspected heatstroke transportation one after another, dangerous heat tomorrow, avoid going out unnecessarily

https://www3.nhk.or.jp/news/html/20230730/k10014147031000.html

- Avoid going out
- Drink water frequently
- Use air-conditioners

https://www3.nhk.or.jp/news/html/20230712/k10014126591000.html

The New York Times

The World Wants Air-Conditioning. That Could Warm the World.

Should we cool our rooms by heating the world?

https://www.nytimes.com/2018/05/15/climate/air-conditioning.html#:~:text=While%2090%20percent%20of%20American,Birol%2C%20executive%20director%20of%20the

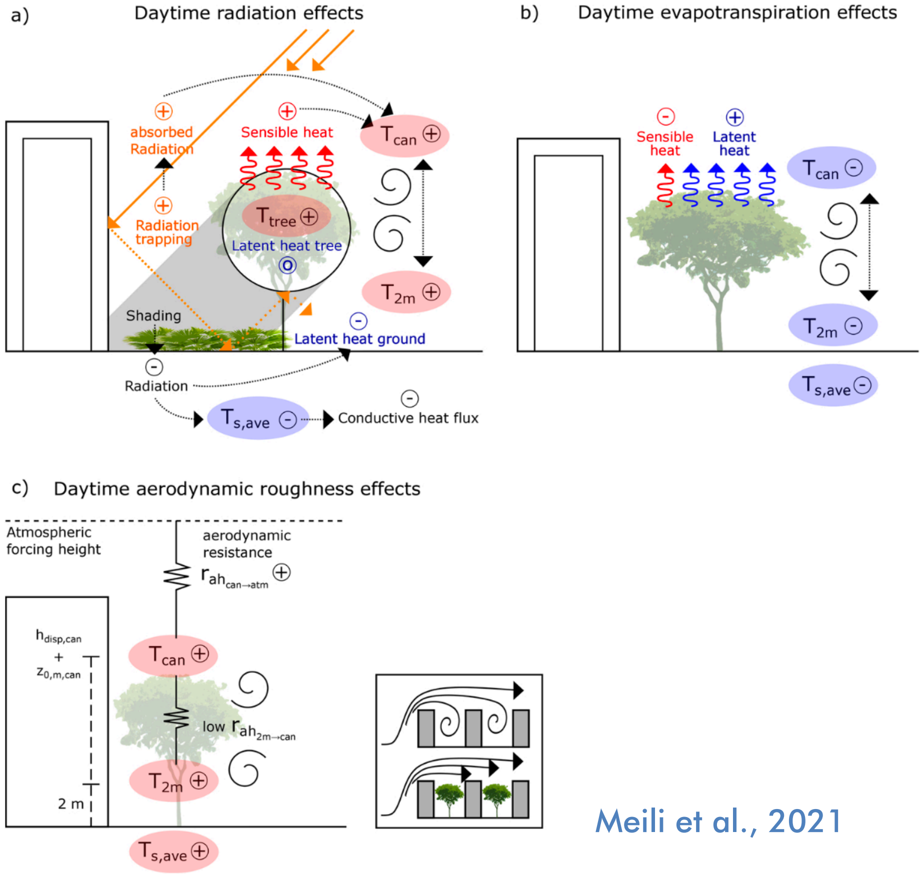
Urban green spaces modify surrounding microclimates and ameliorate heat stress (Shooshtarian et al., 2018; Jamei et al. 2016)

Green & blue interventions provide cooling effects:

- ❖ Trees
  (Lin, Matzarakis, and Hwang 2010; Cheung and Jim 2018; de Abreu-Harbich, Labaki, and Matzarakis 2015)
- ❖ Water bodies
  (Manteghi, Limit, and Remaz 2015; Nishimura et al. 1998)
- ❖ Shade provision
  (Makaremi et al. 2012; Lee et al. 2020; Lin, Matzarakis, and Hwang 2010; Kong et al. 2017)
- ❖ Wind corridors
  (Priyadarsini, Hien, and Wai David 2008; Memon, Leung, and Liu 2010)
- ❖ Green roofs and walls (Olivieri et al. 2013; Jim 2015)
- ❖ Technological modifications (e.g. misting station, reflective materials)
  (Yang, Wang, and Kaloush 2015; Black-Ingersoll et al. 2022)

Trees, the most important green intervention for summer thermal comfort

Tree effects on urban microclimates



Meili et al., 2021

The increase in tree canopy cover is associated with better summer thermal conditions.

(Aminipouri et al., 2019, Krayenhoff et al., 2021)

Tree canopy cover goal in London: 34% by 2065
in NYC: 30% by 2035

Burlington Green
Together we make a difference

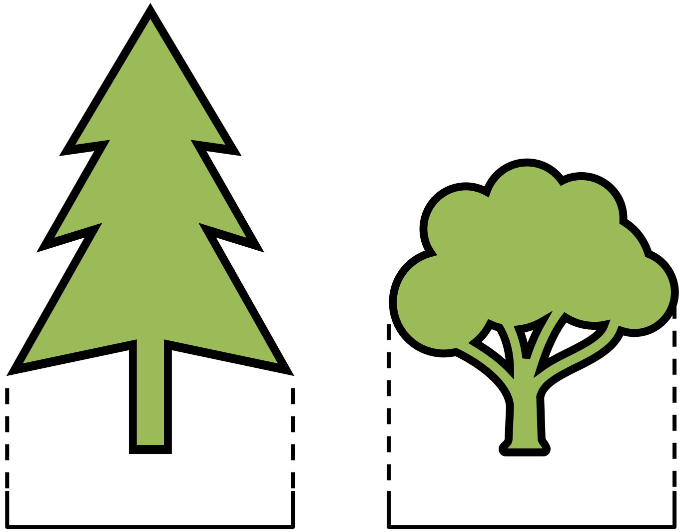
3 trees from every home

30 % tree canopy cover in every neighbourhood

300 meters from the nearest park or green space

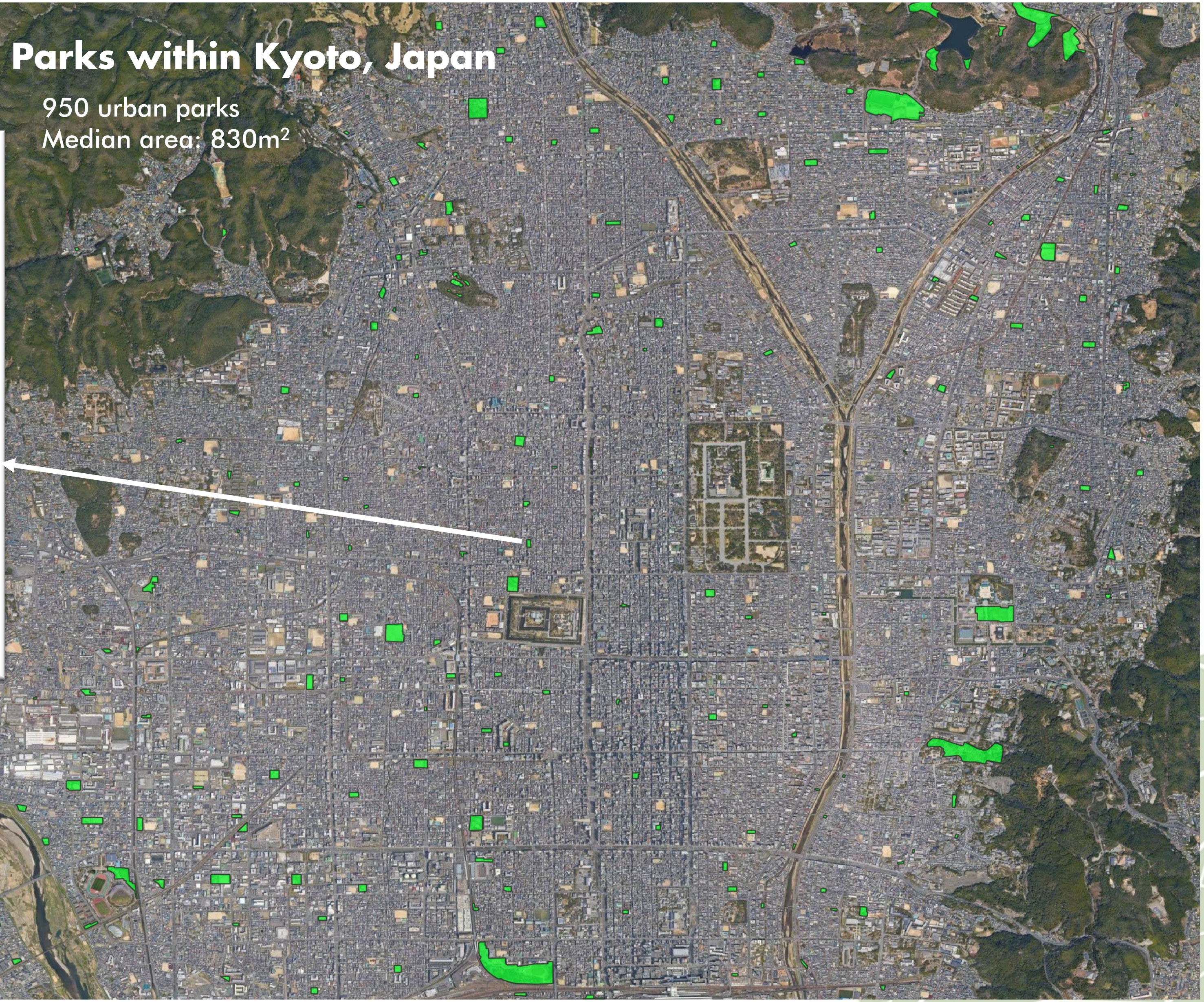
The 3-30-300 rule
(Konijnendijk, 2022)

What about tree canopy volume?



Hypothesis:

Trees' cooling effect is associated with their canopy volumes.



🟩 Urban Parks within Kyoto, Japan

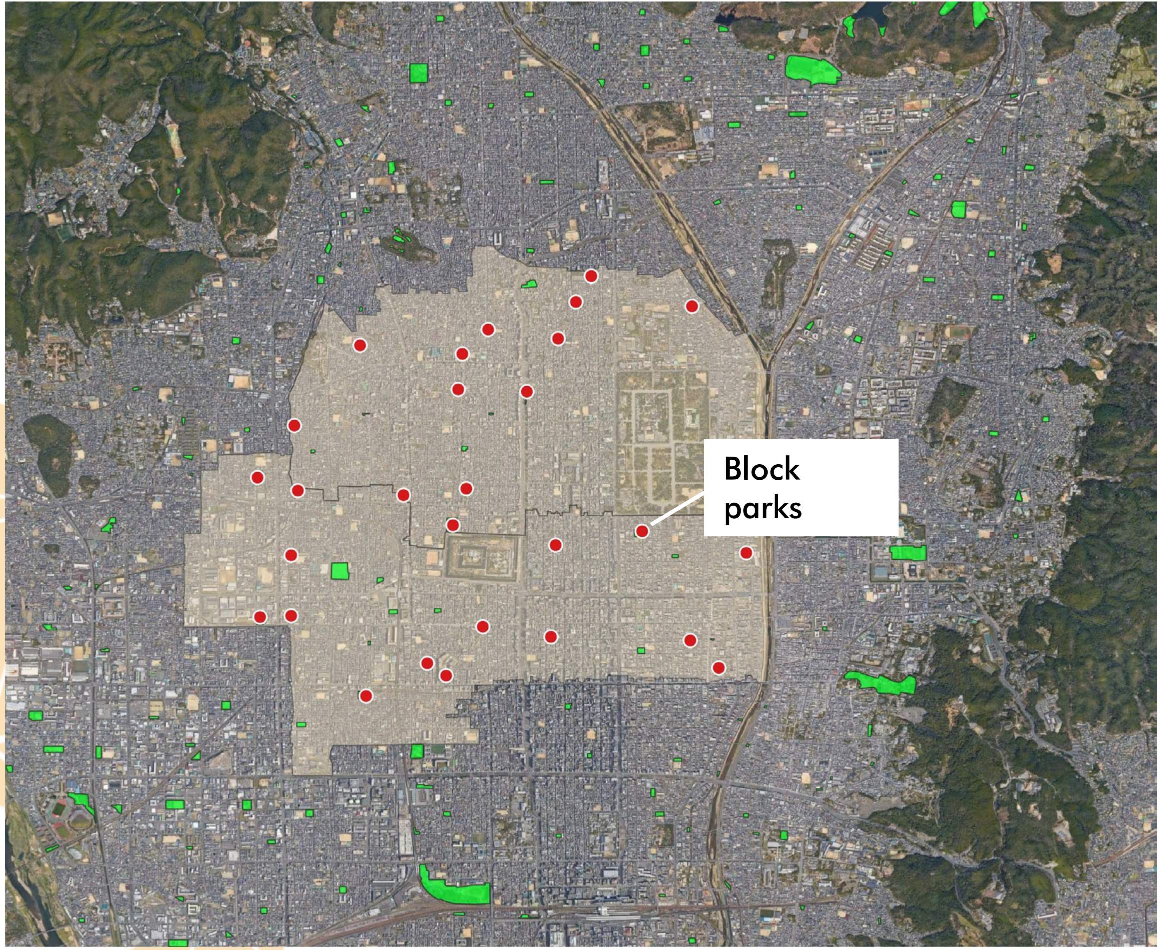
950 urban parks
Median area: 830m²

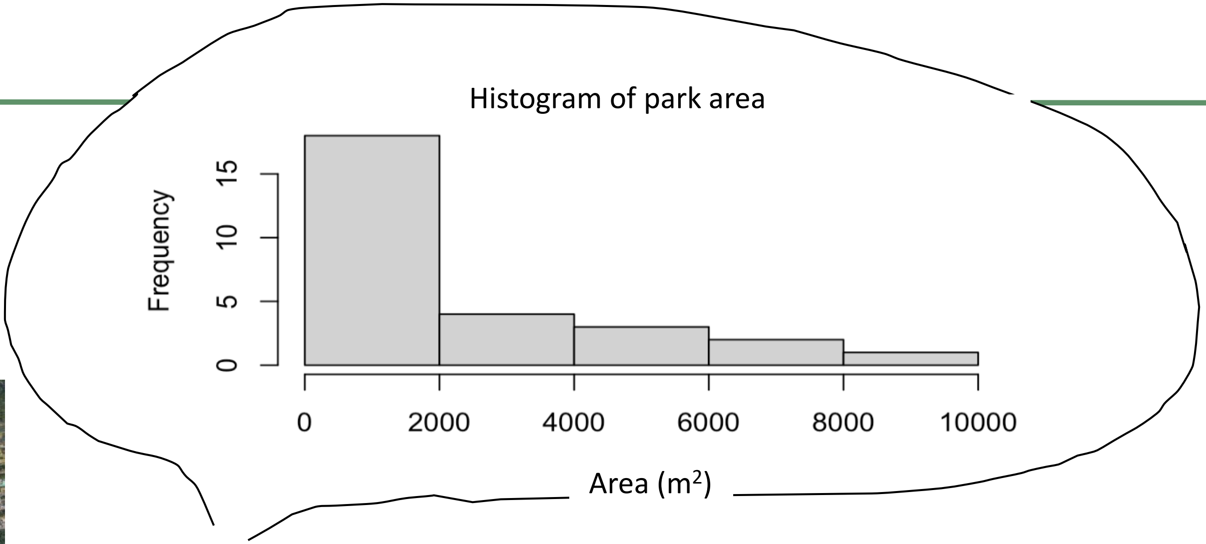
Would increasing tree canopy volume in urban parks improve the microclimate of urban parks and enhance thermal comfort within them?

Methods

Study sites

Population density: 12500 people / km^2





28 small block parks

116 resting areas (e.g. benches, pavilions)

Meteorological measurement:

July ~ September, 2021

9:00 ~ 17:00 in each park

Thermal comfort evaluation

Parameters:
- Air temperature (*Ta*)
- Globe temperature (*Tg*)
- Relative humidity (*RH*)
- Wind speed (*v*

$$MRT = \left[(Tg + 273.15)^4 + 0.678 \times 10^8 \times v^{0.019} \times (Tg - Ta)/\varepsilon D^{0.4}\right]^{0.25} - 273.15$$

(Ouyang et al., 2022)

$\varepsilon = 0.95$
$D = 0.025\text{m}$

RayMan model 1.2
(Matzarakis et al., 2007)

Kestrel 5400 Heat Stress Tracker

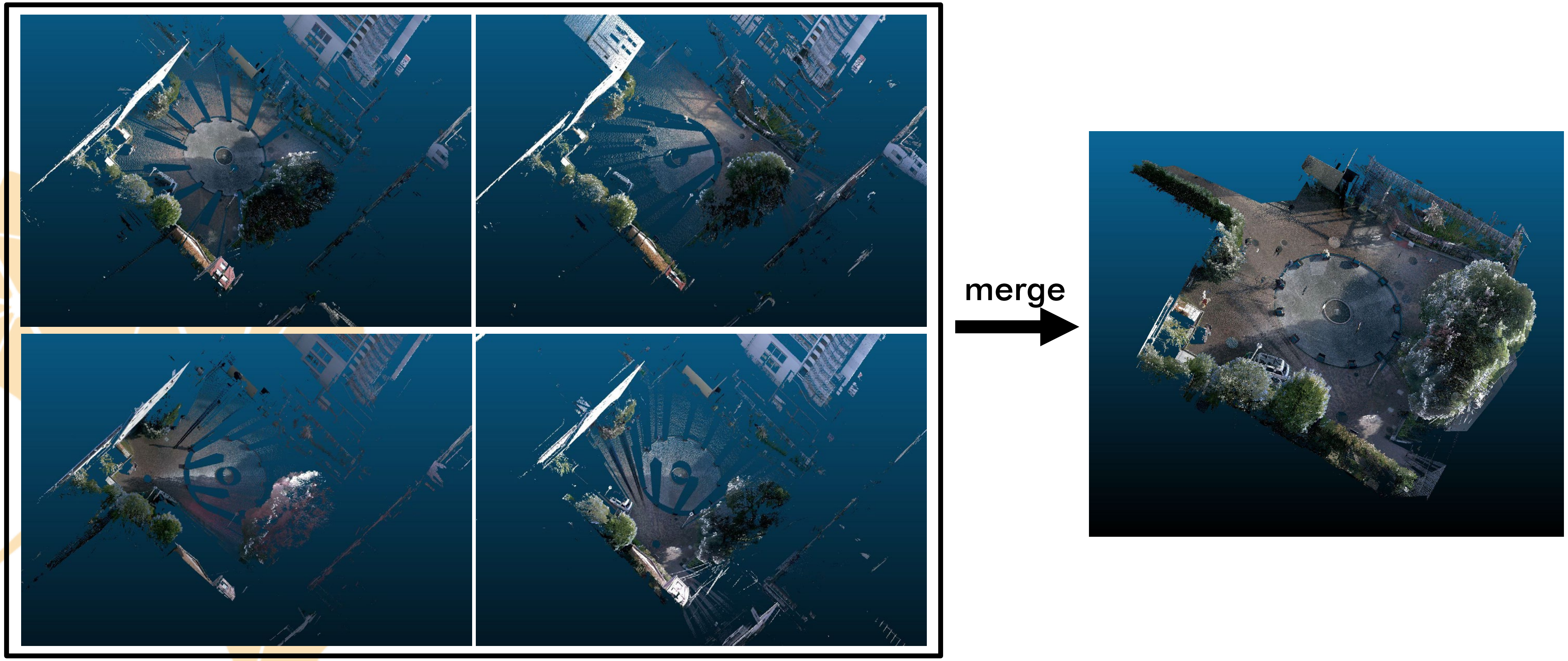
WatchDog 2400 Mini Station

PET values and corresponding thermal perception

PET (°C) (Lin et.al., 2013)	Thermal perception
18~22	Cool
22~26	Slightly cool
26~30	Comfortable
30~34	Slightly warm
34~38	Warm
38~42	Hot
>42	Very hot

Evaluate park visitors' thermal experience

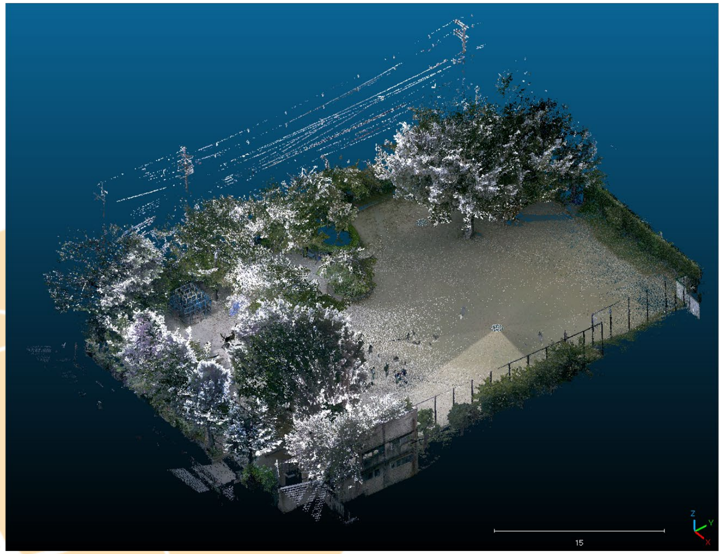
Leiser scanning with Leica BLK360

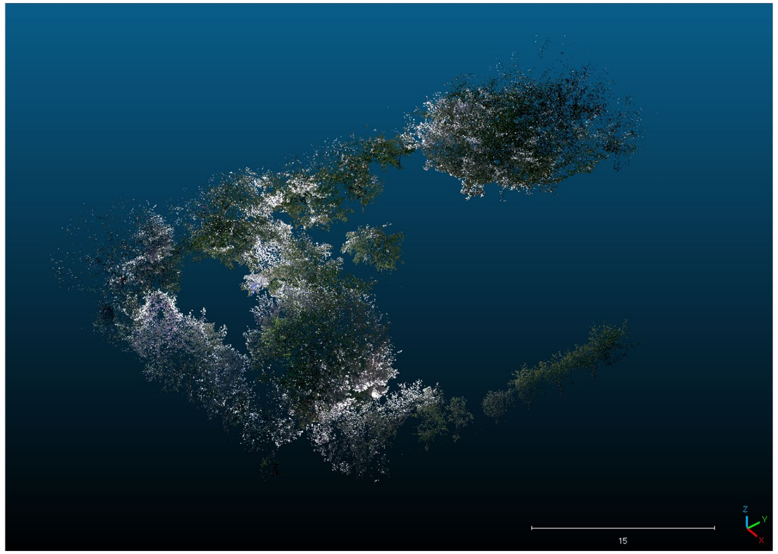


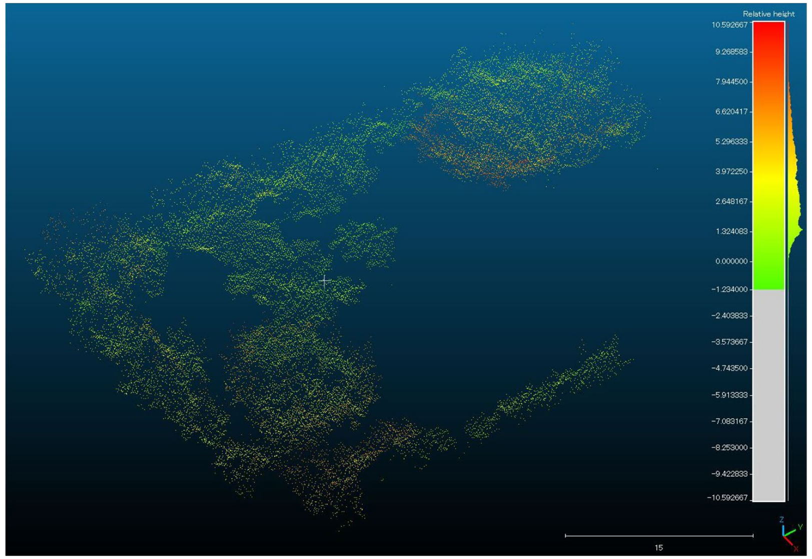
Tree canopy volume measurement

CloudCompare

3D point cloud and mesh processing software
Open Source Project



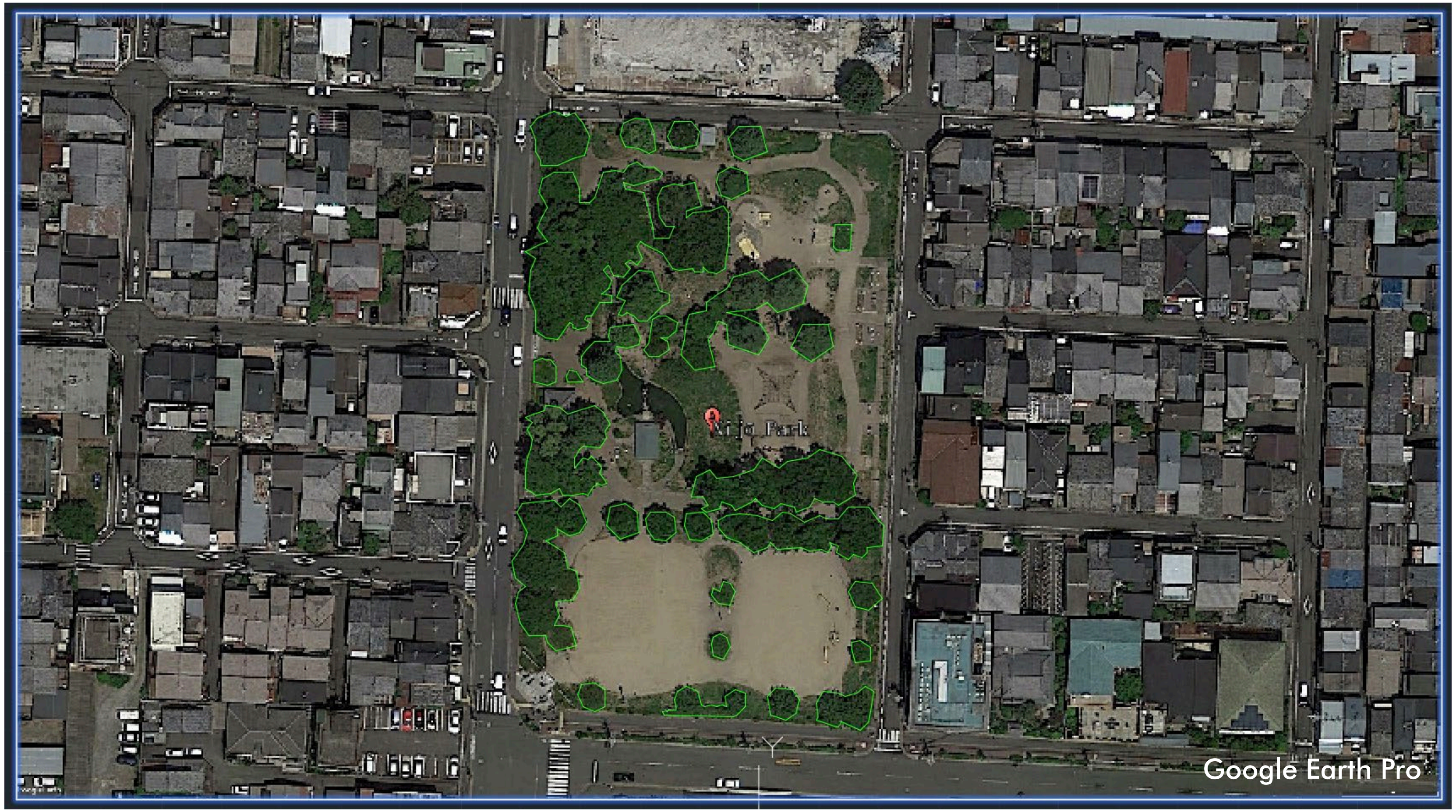




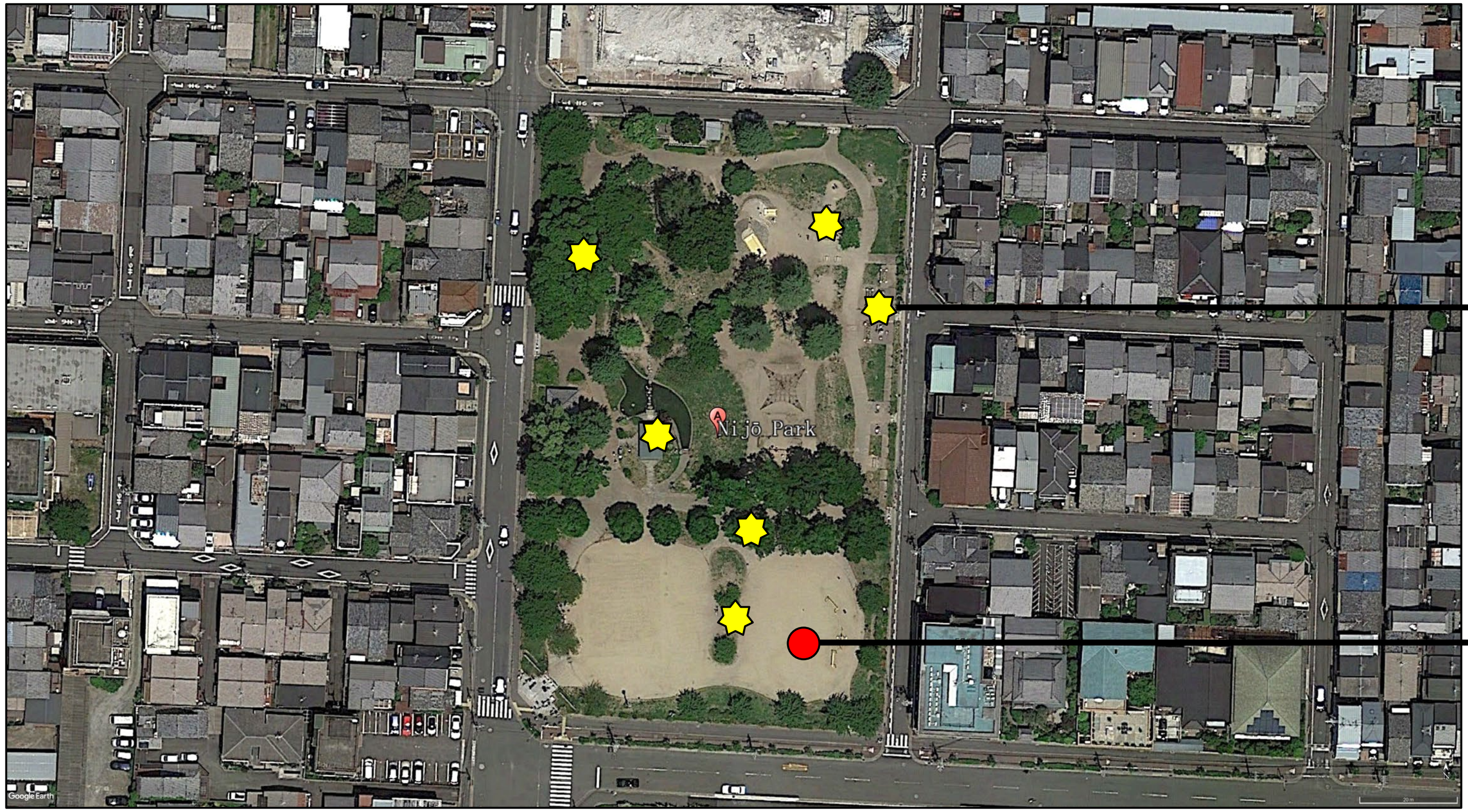
$$\boxed{\mathit{Park\ tree\ canopy\ volume}\ (m) = \mathit{Tree\ canopy\ volume} \div \mathit{park\ area}}$$

Tree canopy area measurement

AutoCAD



$$Park\ tree\ canopy\ coverage\ (\%) = Tree\ canopy\ area \div park\ area$$



Resting areas

Reference point

$$Cooling\ effect = PETreference - PETresting$$

$$Cooling\ effect = Tareference - Taresting$$

Tree canopy coverage (%)

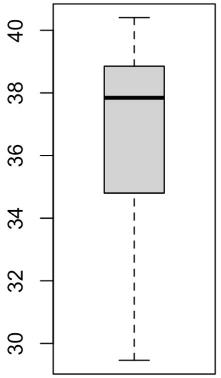
Tree canopy volume

Results and discussion

Ta and PET in block parks

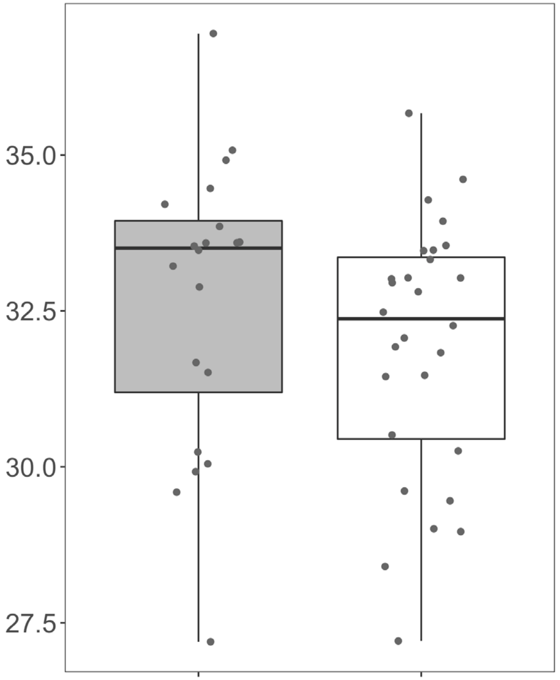
Nearly half of the parks were hot during the survey period

Daily maximum Ta (°C)



37.0 °C

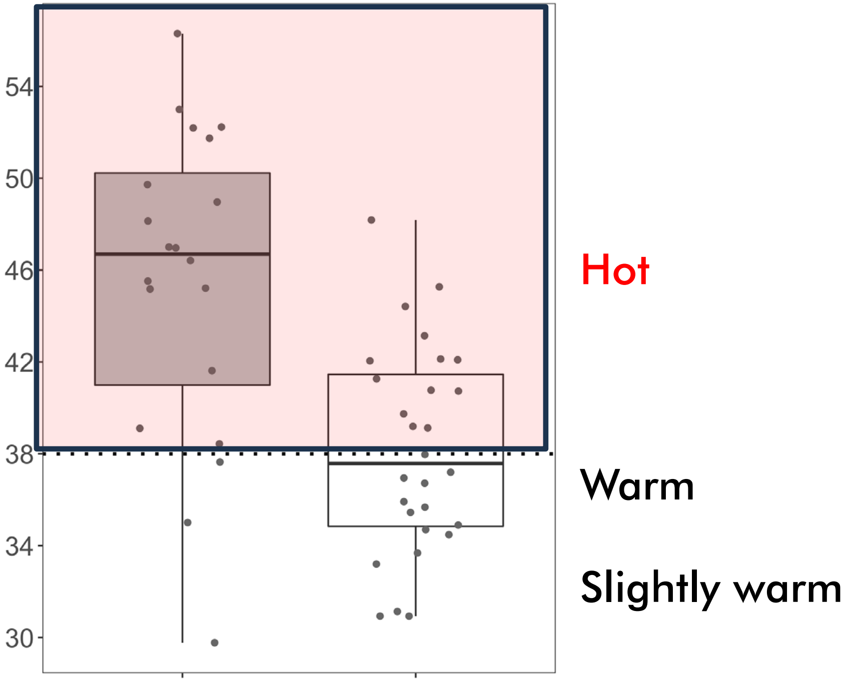
Mean Ta (°C)



Reference point
32.7 °C

Resting area
31.9 °C

Mean PET (°C)

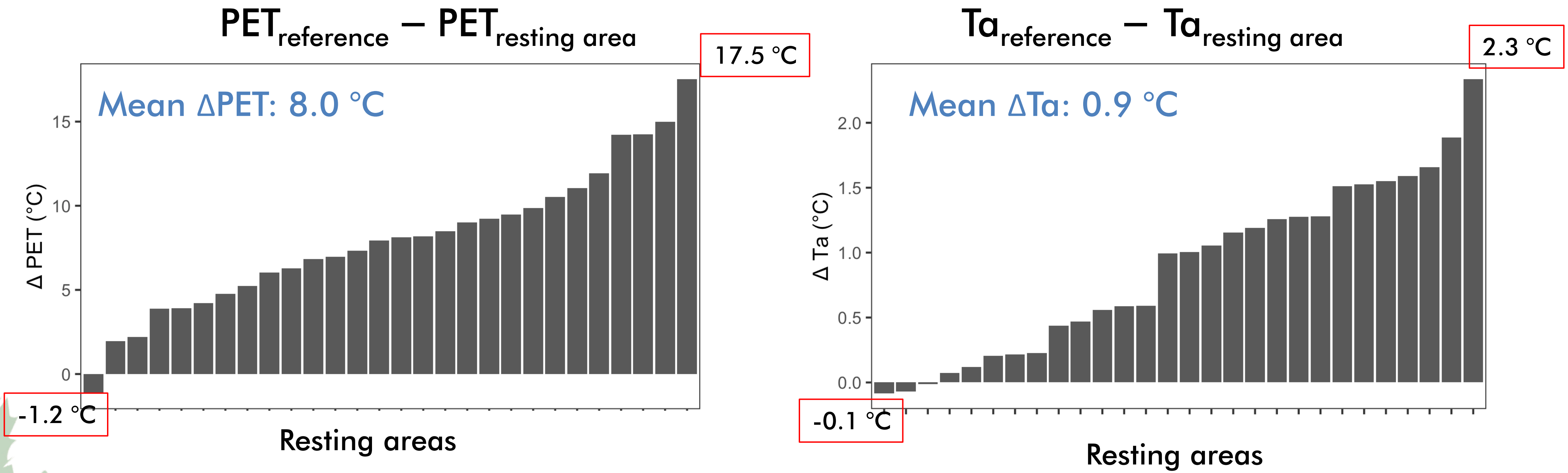


Reference point
45.5 °C

Resting area
38.0 °C

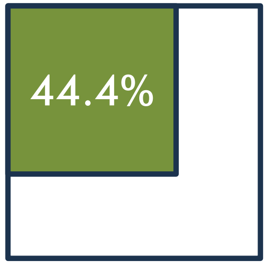
Cooling effects

- The majority of parks were cooler than reference points during the survey period.

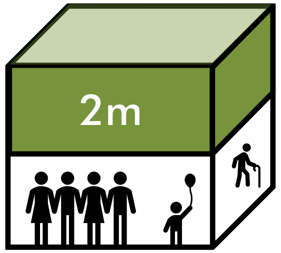


Tree canopy area and volume

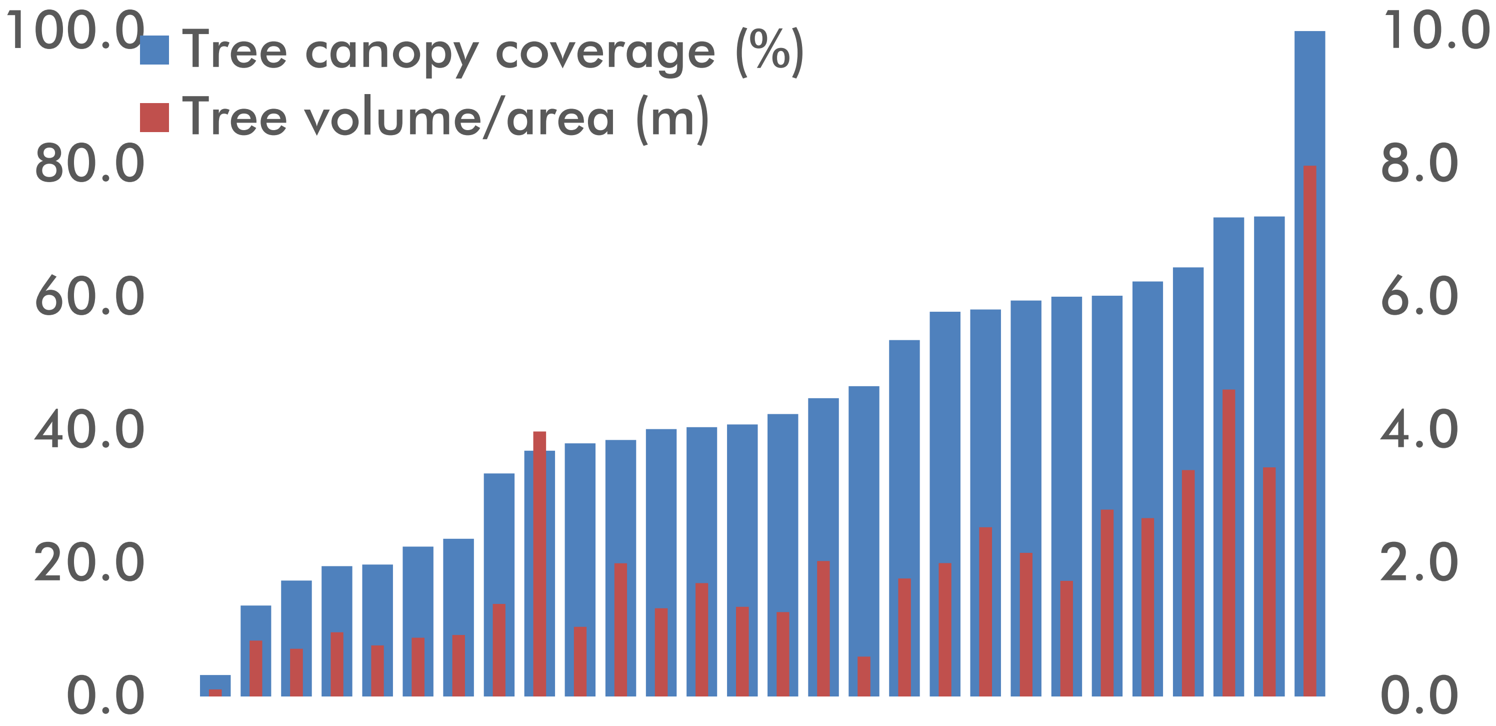
Mean tree canopy area:



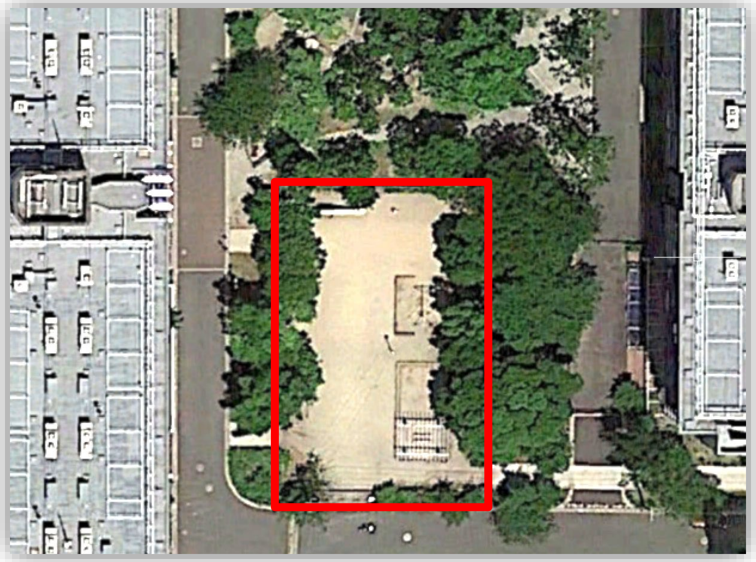
Mean tree canopy volume/park area:



7 <30%
10 <50%
11 >50%



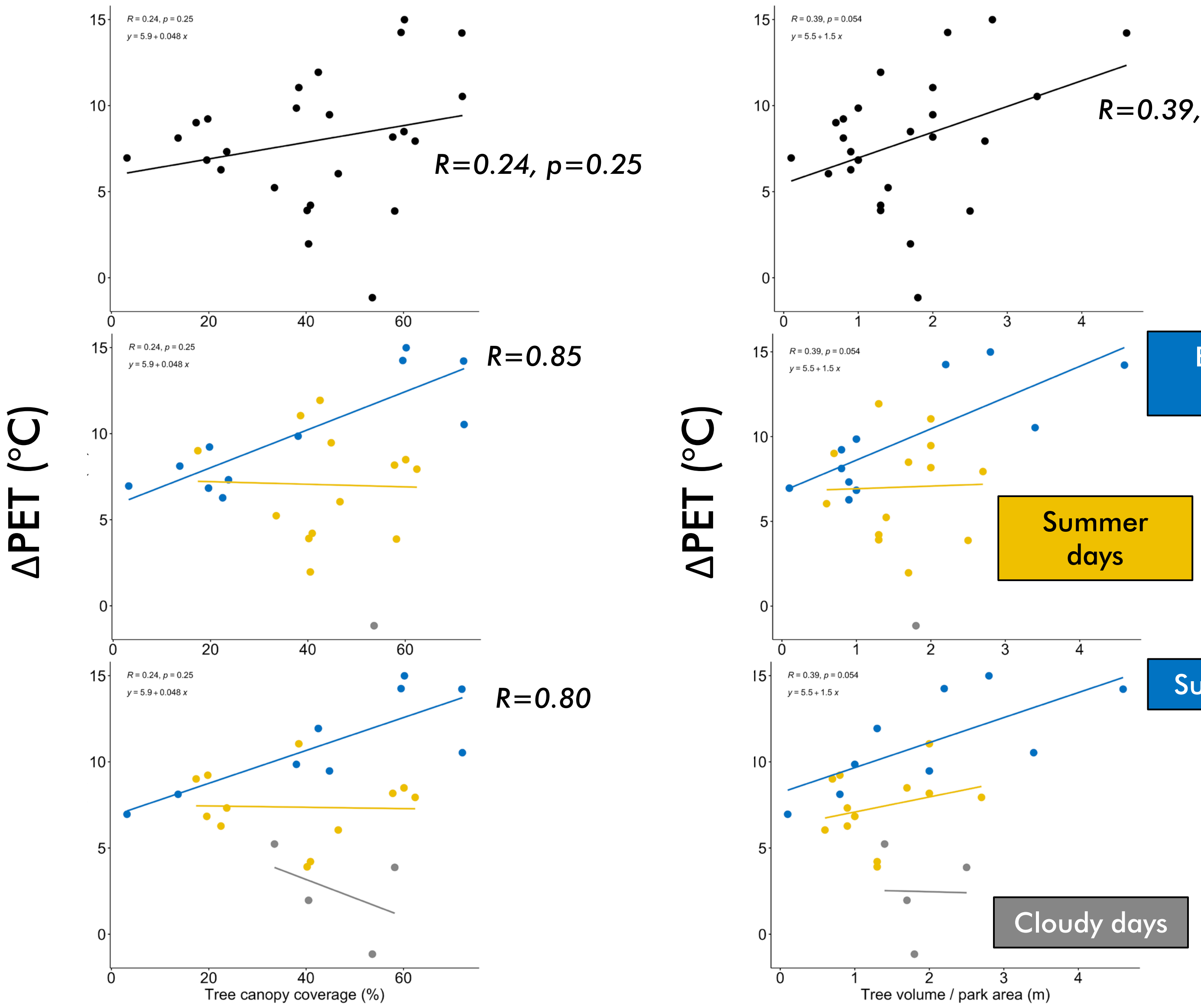
Excluded in regression analysis!
(3 parks)



25 block parks

Tree canopy coverage (%)

Tree canopy volume / area (m)



R=0.24, p=0.25

R=0.39, p=0.054

R=0.85

Extremely hot days

R=0.79

Summer days

Extremely hot day: Max Ta >35°C

Summer day: Max Ta > 30°C

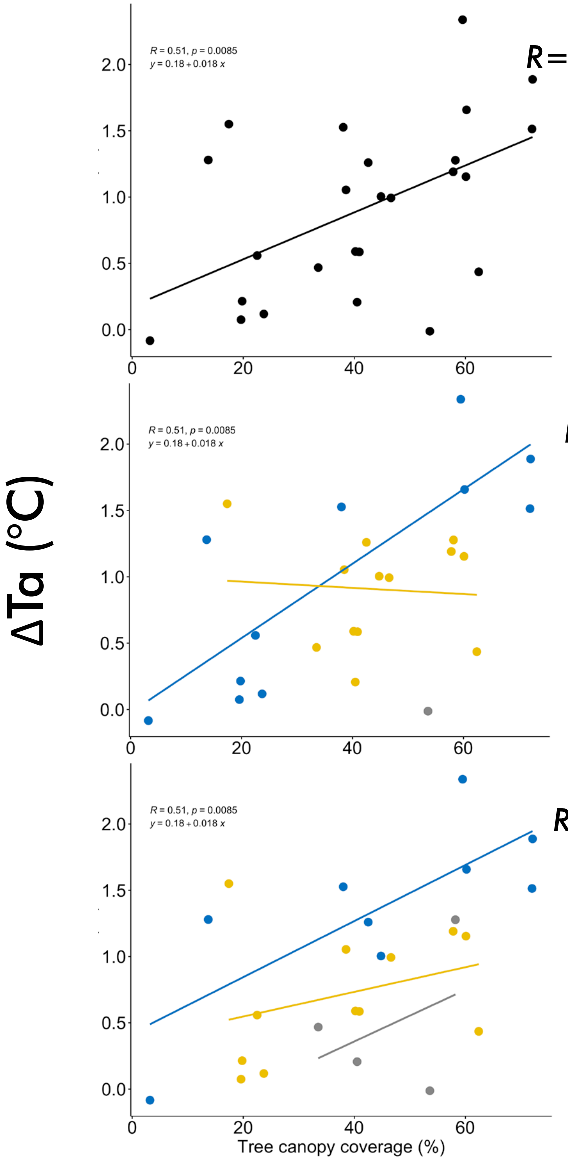
R=0.80

Sunny days

R=0.71

Cloudy days

Tree canopy coverage (%)

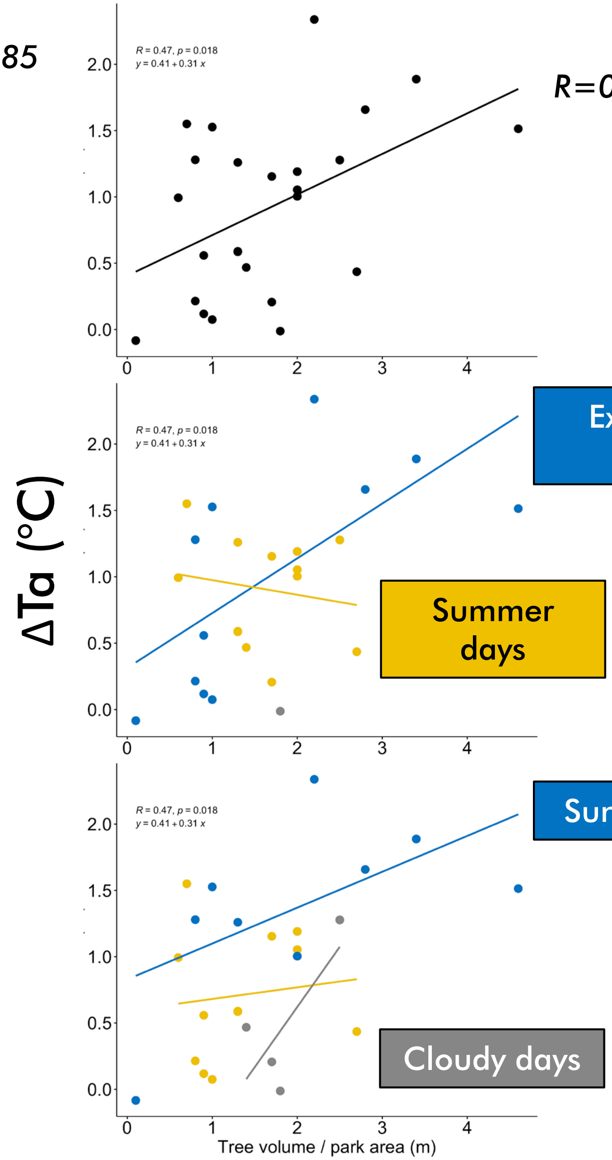


$R=0.51,\ p=0.0085$

$R=0.82$

$R=0.76$

Tree canopy volume / area (m)



$R=0.47,\ p=0.018$

Extremely hot days

$R=0.67$

Extremely hot day: Max Ta >35°C

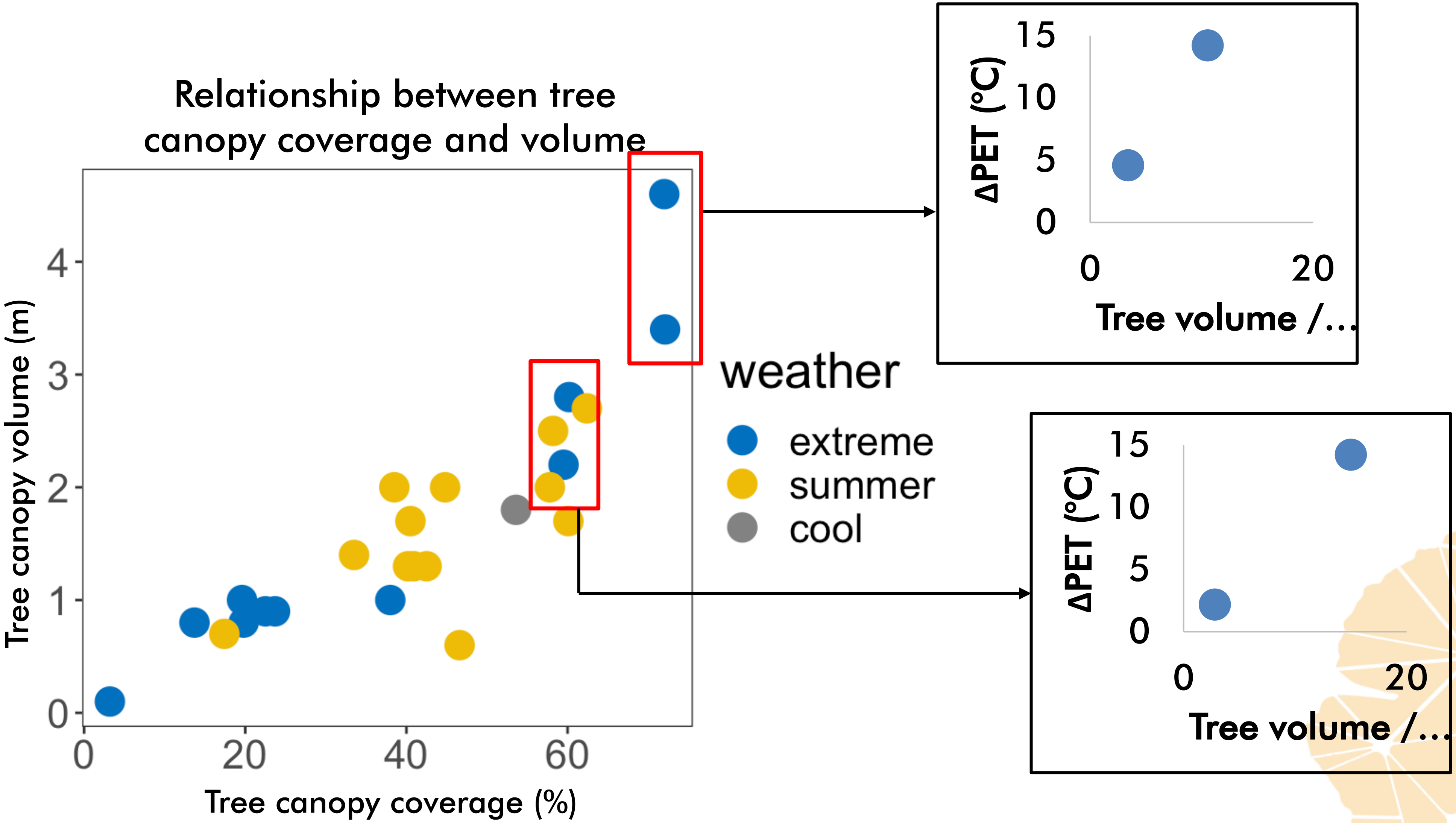
Summer day: Max Ta > 30°C

Summer days

Sunny days

$R=0.57$

Cloudy days



Relationship between tree canopy coverage and volume

Conclusion

1. Evaluated summer thermal conditions of resting areas within 28 urban parks in Kyoto, Japan.
   - Most open areas without mitigation measures: “very hot”
   - Resting areas: half “warm”, half “hot”
   - <u>The summer thermal condition of urban parks in Kyoto needs further improvement.</u>

Ta 0.9°C ↓
PET 8.0°C ↓

2. Measured tree canopy cover and volume.
   - 75% of study parks had tree <u>canopy cover</u> >30%
   - 40% of study parks had tree <u>canopy cover</u> >50%
   - More than half of parks had tree canopy volume $<2m^3/m^2$

3. Parks have larger tree canopy cover and volume have better summer thermal conditions.

The cooling effect of trees is most significant during extremely hot days or sunny days.

Increasing tree canopy volume might be an effective heatwave adaptation strategy in highly urbanized areas.

4. We recommend future studies examining the cooling effects of trees with different volumes but similar canopy areas (under similar weather conditions).

Thank you

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Shozo Shibata
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2023

World Forum on
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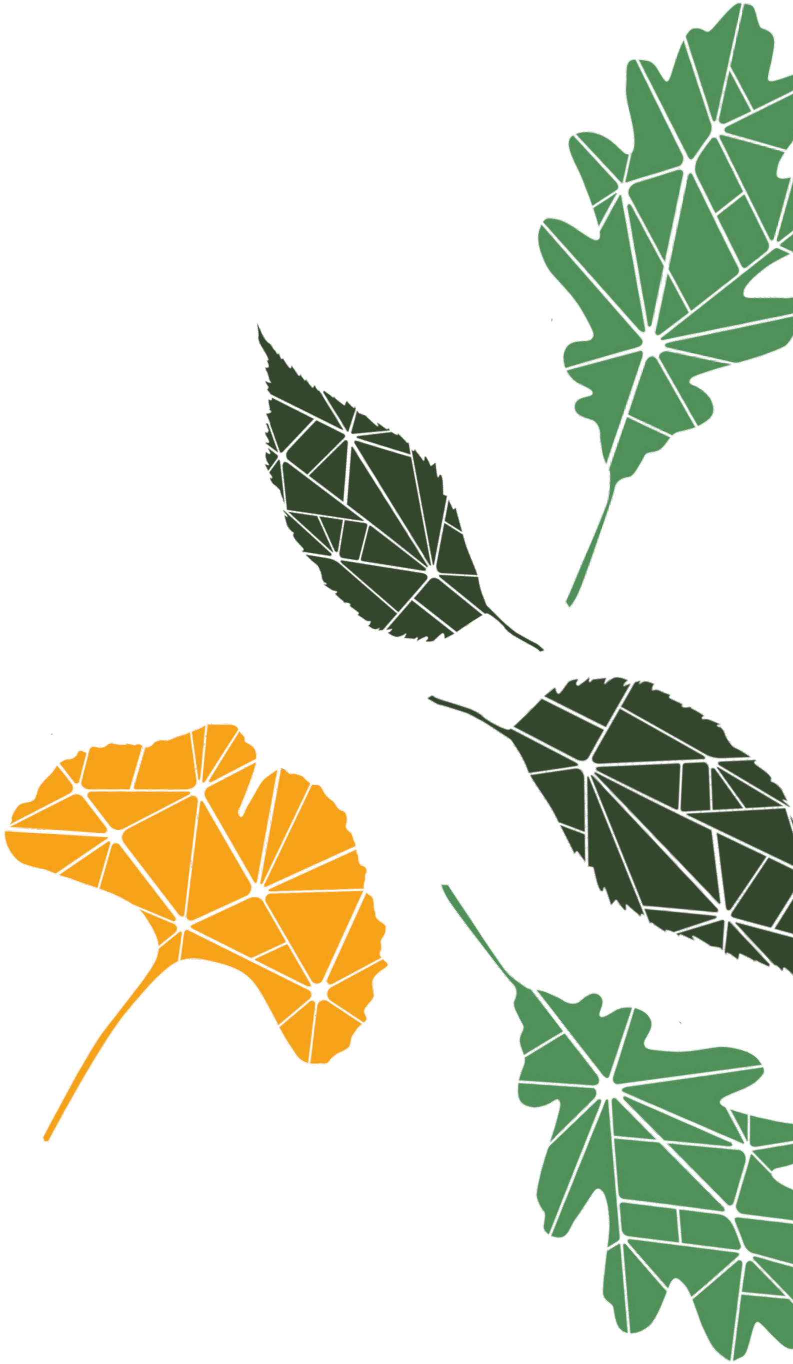
2nd World Forum on Urban Forests

Washington DC, 2023

Melting cities and our cool city trees – mitigation potentials

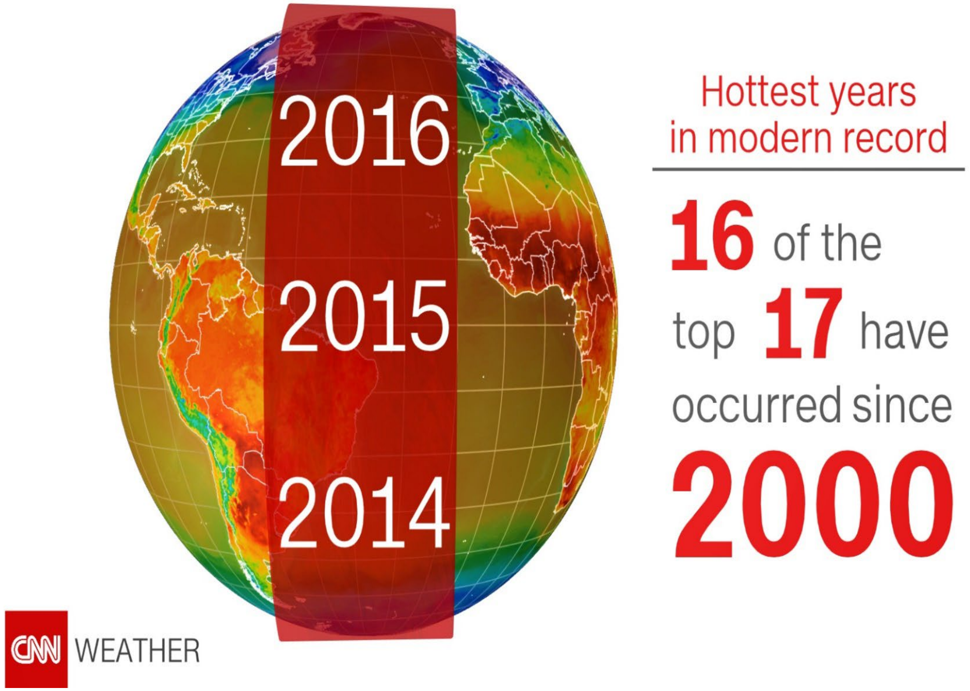


Presented by

Dr Mohammad A Rahman

Technical University of Munich, Germany

A century of urbanized world

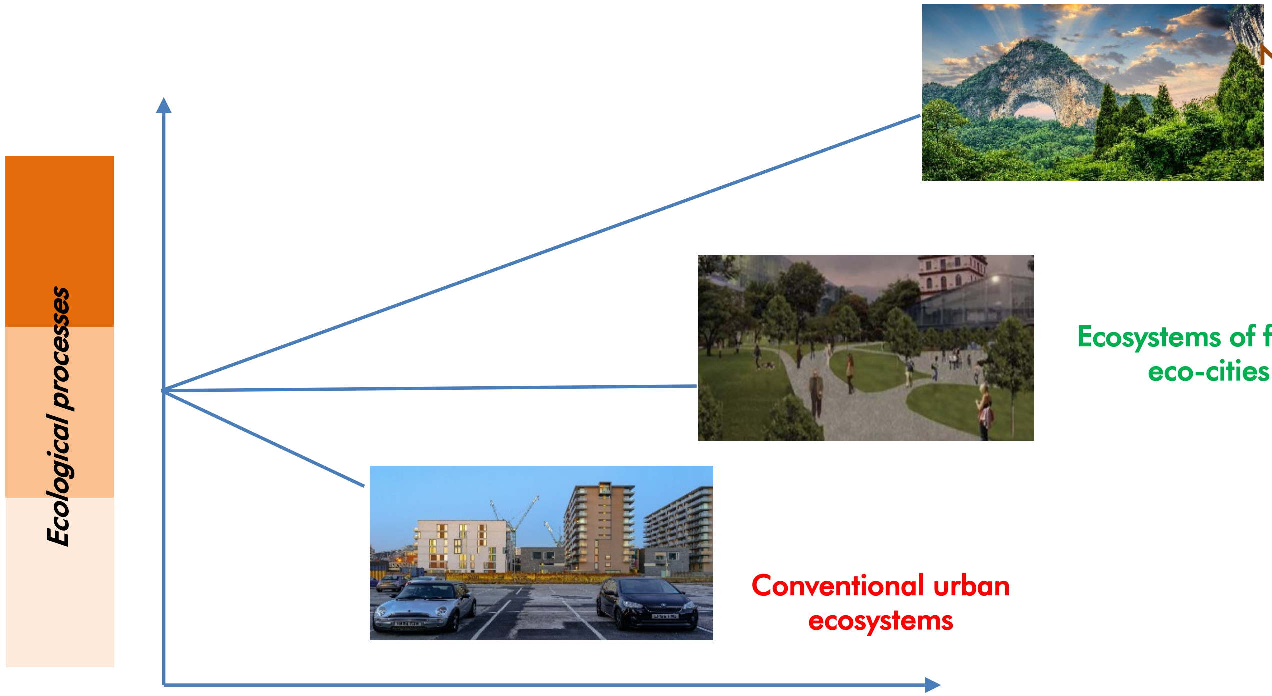


https://edition.cnn.com/2017/01/18/world/2016-hottest-year/index.html

https://scitechdaily.com/most-extreme-heatwaves-ever-recorded-globally-revealed-in-new-research/

https://eu.usatoday.com/story/news/world/2022/07/18/extreme-heat-wave-europe-uk/10087274002/

Sustainable urban future



Natural ecosystems

Ecosystems of future
eco-cities

Conventional urban
ecosystems

Ecological processes

Urban sustainability

Thermal regulation

1. Surface reflectance

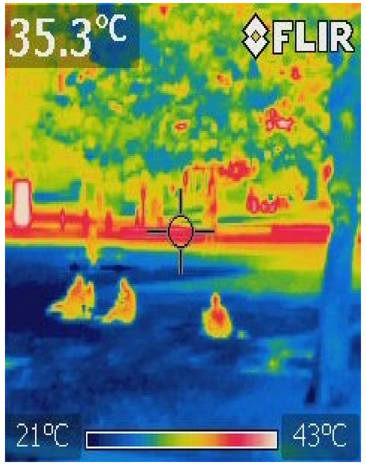
2. Misters

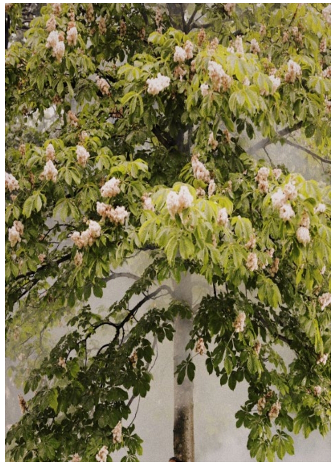
3. Urban greening

Urban Ecosyst
DOI 10.1007/s11252-014-0407-7

A comparison of the growth and cooling effectiveness of five commonly planted urban tree species

M. A. Rahman • D. Armson • A. R. Ennos

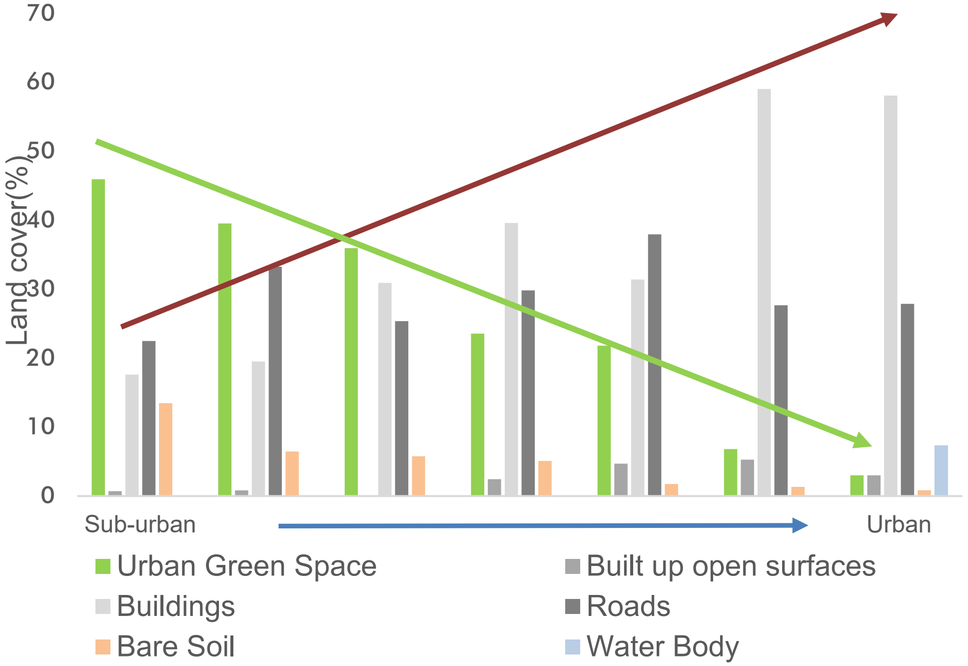


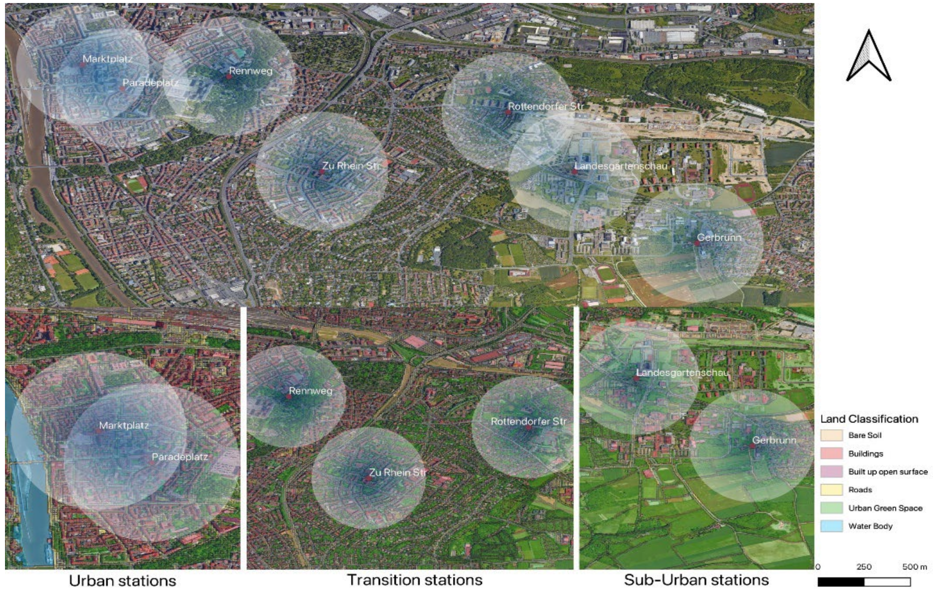


Techniques used

- Eco-physiological techniques: sap flow, dendrometers
- Meteorological, soil science techniques
- Forest growth and yield techniques

Urban greenspaces and thermal stress






www.nature.com/scientificreports

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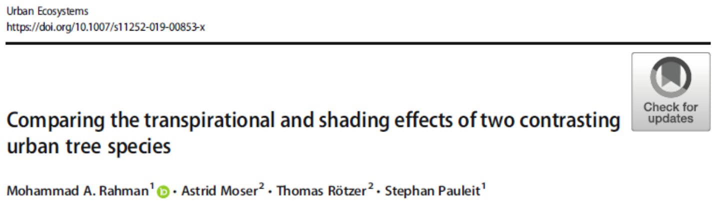
OPEN

Spatial and temporal changes of outdoor thermal stress: influence of urban land cover types

Mohammad A. Rahman[1], Eleonora Franceschi[2], Nayanesh Pattnaik[1], Astrid Moser-Reischl[2], Christian Hartmann[3], Heiko Paeth[3], Hans Pretzsch[2], Thomas Rötzer[2] & Stephan Pauleit[1]

Shading effect

- With 30% higher LAI, linden trees provided surface cooling up to 23 °C compared to 13 °C by locust trees over asphalt street.
- A decrease in grass surface temperature of 3 °C with every unit of LAI but for asphalt, the reduction in surface temperature was about 6 °C.

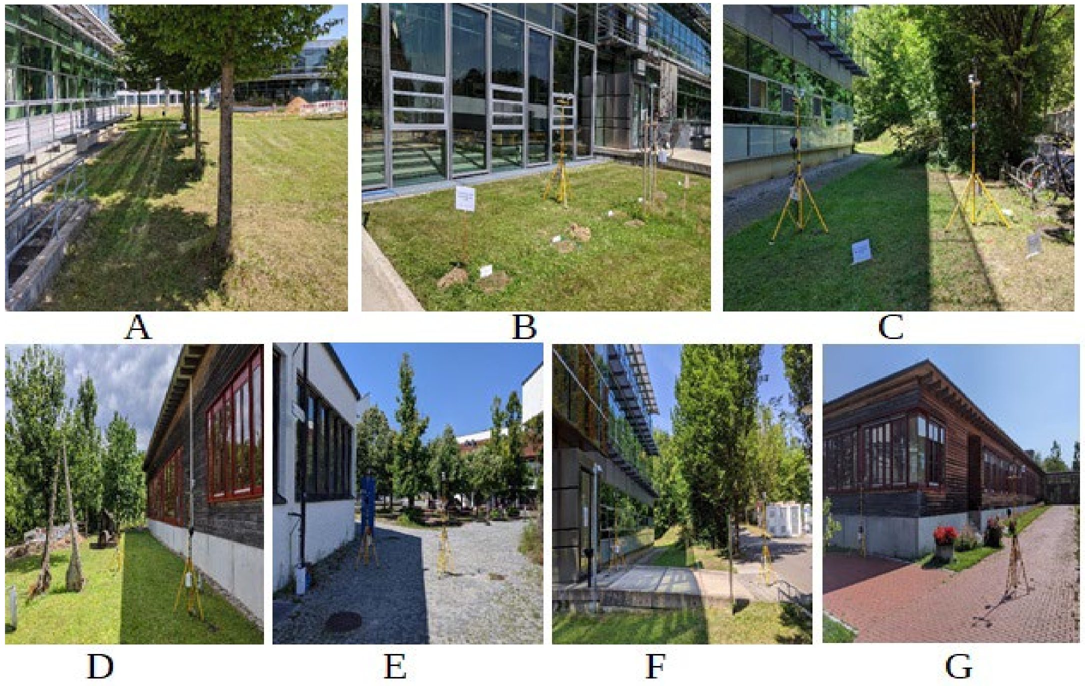


Urban Ecosystems
https://doi.org/10.1007/s11252-019-00853-x

Comparing the transpirational and shading effects of two contrasting urban tree species

Mohammad A. Rahman[1] · Astrid Moser[2] · Thomas Rötzer[2] · Stephan Pauleit[1]

Shade and underlying surfaces



Urban Forestry & Urban Greening 63 (2021) 127223

ELSEVIER

Contents lists available at ScienceDirect

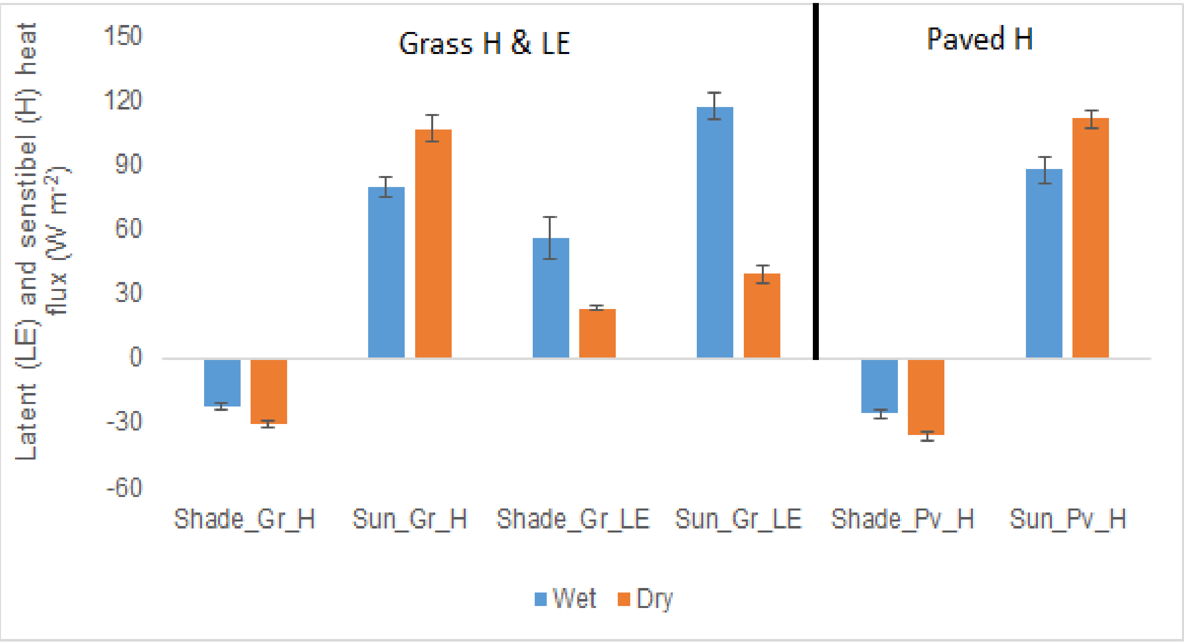
Urban Forestry & Urban Greening

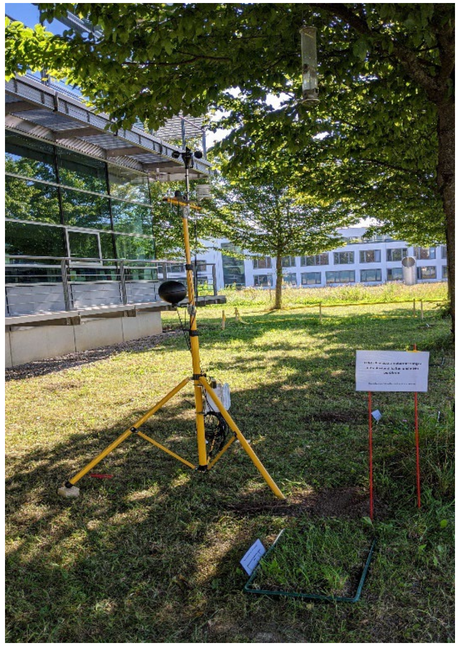
journal homepage: www.elsevier.com/locate/ufug

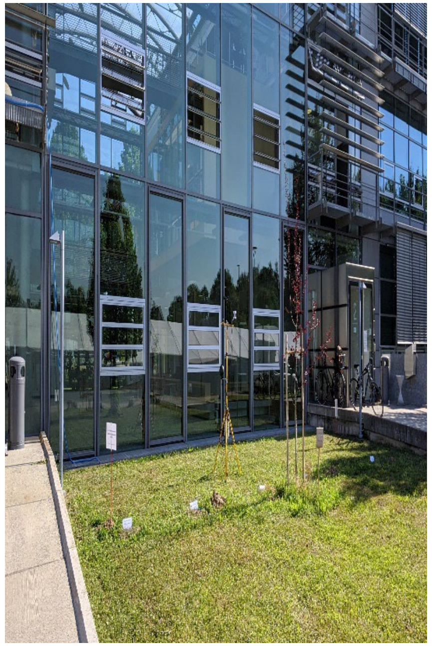
Comparative analysis of shade and underlying surfaces on cooling effect

Mohammad A. Rahman[a,*], Vjosa Dervishi[b], Astrid Moser-Reischl[b], Ferdinand Ludwig[c], Hans Pretzsch[b], Thomas Rötzer[b], Stephan Pauleit[a]

Heat fluxes under shade







Temperature reduction under building and tree shade

Weather	Shaded by	AT Shade	AT Sun	PET shade	PET sun
Wet	Tree	19.9 ± 0.1	21.7 ± 0.2	21.6 ± 0.2	34.1 ± 0.7
	Building	23.9 ± 0.2	25.1 ± 0.2	24.4 ± 0.3	36 ± 0.5
Dry	Tree	30 ± 0.2	32.6 ± 0.2	32.4 ± 0.3	46.7 ± 0.5
	Building	28.2 ± 0.1	30.4 ± 0.2	29.1 ± 0.1	41.8 ± 0.5

12.5

0.9

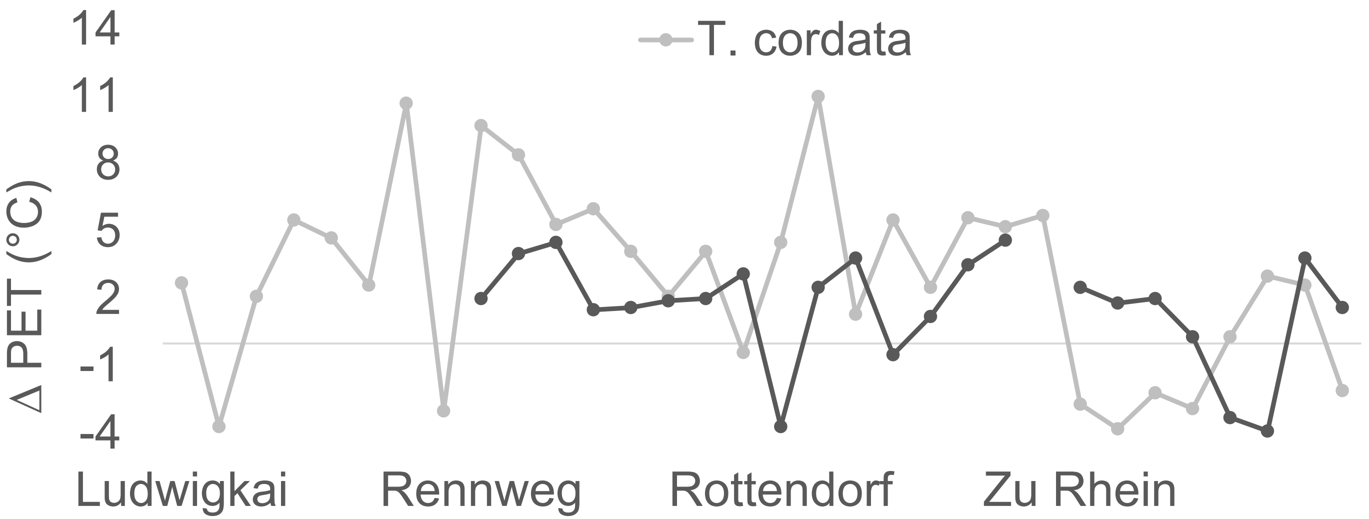
11.6

14.3

1.6

12.7

PET under two contrasting species



We found differences of 4 and 11 °C physiological equivalent temperature (PET) between the shade of locust and lime trees.


Agricultural and Forest Meteorology 287 (2020) 107947

Contents lists available at ScienceDirect

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Agricultural and Forest Meteorology

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

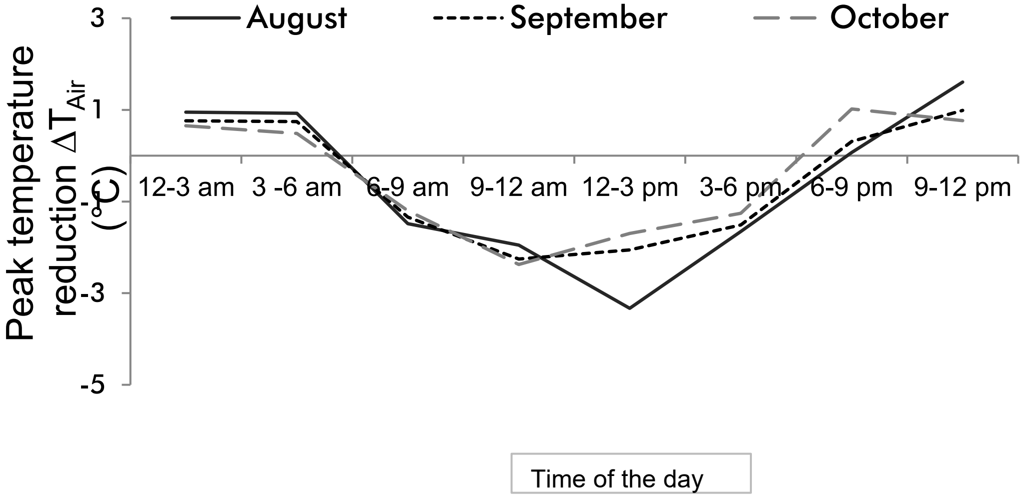
Tree cooling effects and human thermal comfort under contrasting species and sites

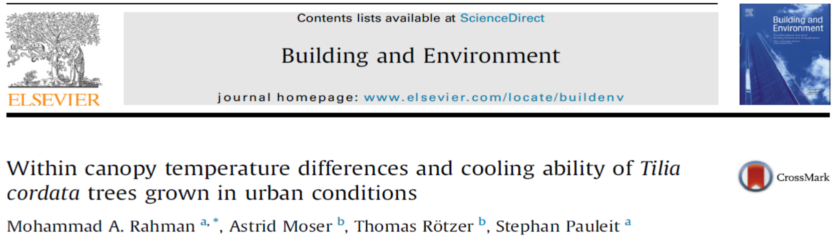
Mohammad A. Rahman[a,*], Christian Hartmann[b], Astrid Moser-Reischl[c],
Miriam Freifrau von Strachwitz[c], Heiko Paeth[b], Hans Pretzsch[c], Stephan Pauleit[a], Thomas Rötzer[c]

Magnitude of cooling from a single tree

Water loss	Energy loss	ΔT within canopy *	ΔT Underneath tree *
55-68 l day^{-1}	1.6-2 Kw tree^{-1}	3-4 °C	1-2 °C

* ΔT = Air temperature reduction





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Building and Environment

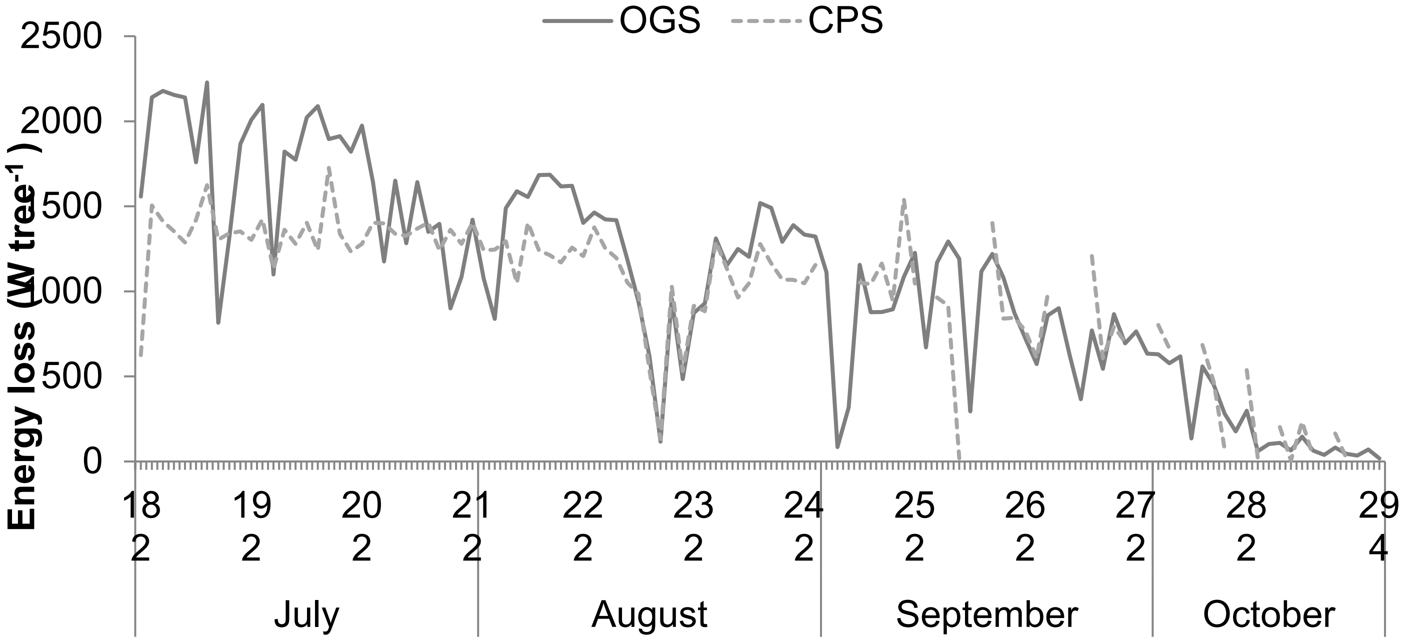
journal homepage: www.elsevier.com/locate/buildenv

Within canopy temperature differences and cooling ability of *Tilia cordata* trees grown in urban conditions

CrossMark

Mohammad A. Rahman [a,*], Astrid Moser [b], Thomas Rötzer [b], Stephan Pauleit [a]

…… site conditions



Contents lists available at ScienceDirect

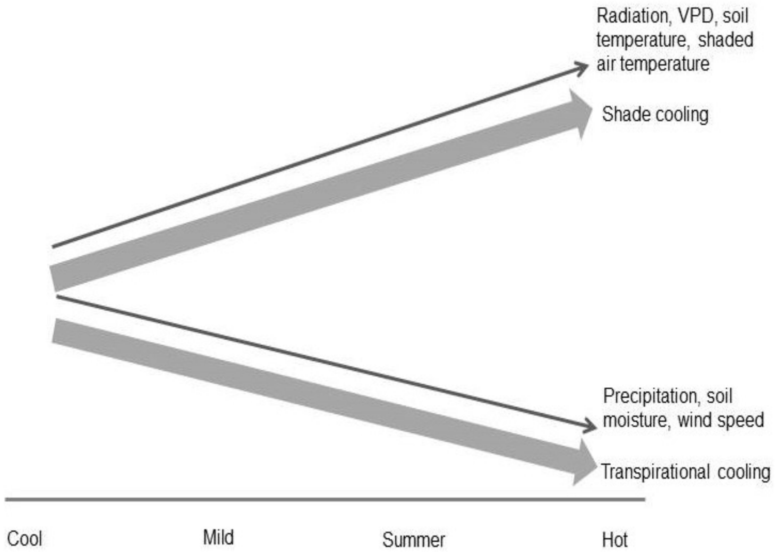
Agricultural and Forest Meteorology

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

Microclimatic differences and their influence on transpirational cooling of *Tilia cordata* in two contrasting street canyons in Munich, Germany

Mohammad A. Rahman[a,*], Astrid Moser[b], Thomas Rötzer[b], Stephan Pauleit[a]

Preferred cooling mechanism



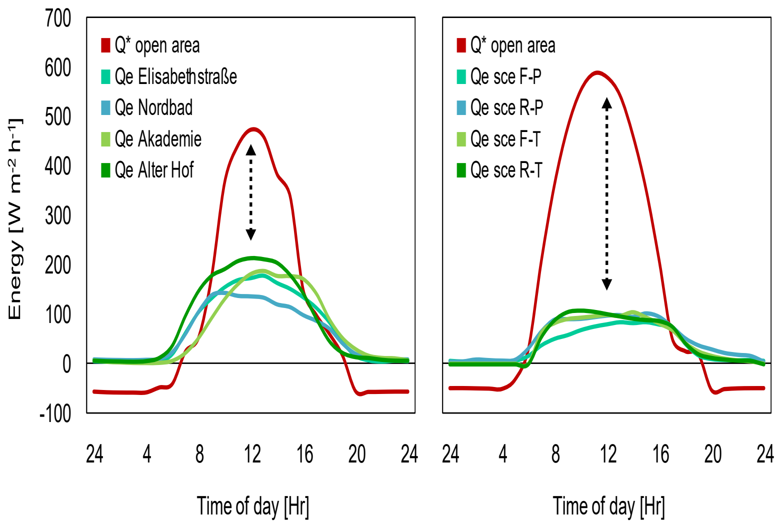
Radiation, VPD, soil temperature, shaded air temperature

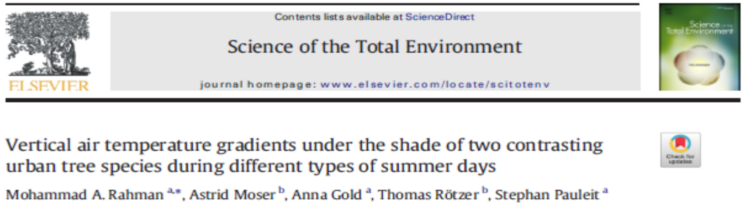
Shade cooling

Precipitation, soil moisture, wind speed

Transpirational cooling

Cool Mild Summer Hot





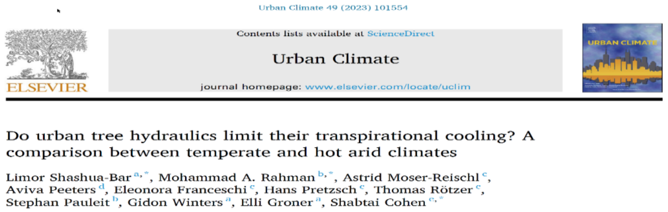
Contents lists available at ScienceDirect

Science of the Total Environment

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

Vertical air temperature gradients under the shade of two contrasting urban tree species during different types of summer days

Mohammad A. Rahman [a,*], Astrid Moser [b], Anna Gold [a], Thomas Rötzer [b], Stephan Pauleit [a]



Urban Climate 49 (2023) 101554

Contents lists available at ScienceDirect

Urban Climate

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

Do urban tree hydraulics limit their transpirational cooling? A comparison between temperate and hot arid climates

Limor Shashua-Bar [a,*], Mohammad A. Rahman [b,*], Astrid Moser-Reischl [c], Aviva Peeters [d], Eleonora Franceschi [c], Hans Pretzsch [c], Thomas Rötzer [c], Stephan Pauleit [b], Gidon Winters [a], Elli Groner [a], Shabtai Cohen [c,*]

Take home message

1. Cooling effect is both **site and species specific**. **Shade and grass surfaces are equally important** in reducing the urban heat loads. In particular, the added benefits of tree shade during the summer droughts are important for human thermal comfort.

2. Trees with **dense canopies** especially over built surfaces are better both for surface cooling and human thermal comfort.

3. Even though, water availability is the prerequisite for transpiration cooling; however, **species traits** might dictate the transpirational cooling across climate zones.

4. To understand the energy flux partitioning across climate zones and species traits, **global study** following standard study protocol is important.

Thank you

Alexander von Humboldt
Stiftung / Foundation

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MÜNCHEN

TREE FUND
Cultivating Innovation

DFG
Deutsche
Forschungsgemeinschaft

funded by
Bavarian State Ministry of the
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redroseforest

The University of Manchester
Sustainable
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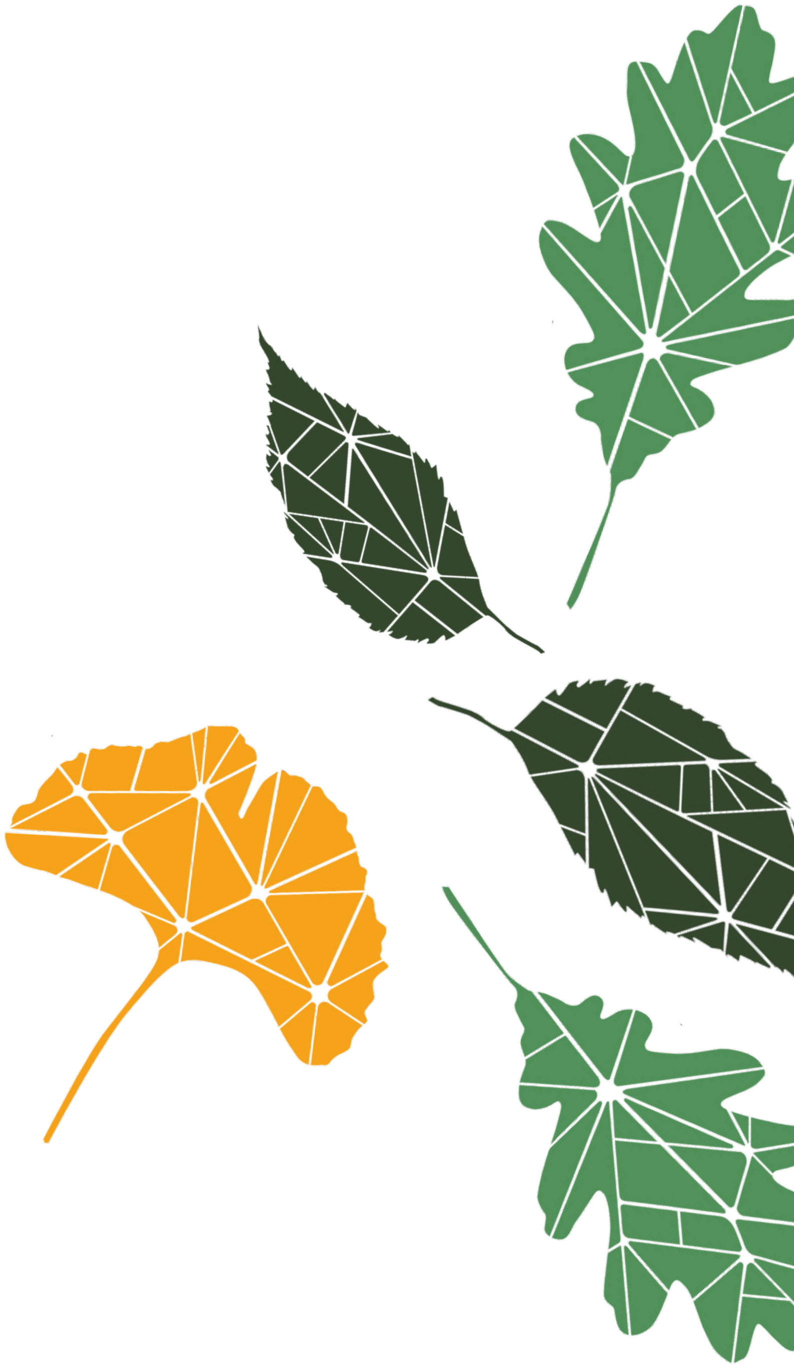
Washington DC, 2023



Case Studies from Australia

How many trees and where to reach canopy cover targets and maximise benefits

Presented by

Dr Jenni Garden

Principal Consultant – Liveable Cities Lead

Edge Impact (www.edgeimpact.global)

Land Acknowledgement

As an Australian visiting from the ancestral lands of the Kaurna people of the Adelaide Plains in South Australia, I'd like to take a moment to acknowledge the Nacotchtank (Anacostan) and Piscataway people, whose ancestral lands we gather on today.

In the spirit of reconciliation and gratitude, I pay respect to their elders, past and present.

Like Australia's First Nations peoples' ongoing connection to Country, the deep connection of Native American communities to this land, its rivers, and its forests is a testament to their enduring culture and resilience.

As we gather here this week and discuss the connections between our cities, people, and nature, may we all strive to be responsible stewards of our collective lands, and to learn from the indigenous peoples, not only in Washington, D.C., but across the world.

Let us work together to build a future that celebrates diversity, preserves traditions, and respects the interconnectedness of all living beings.

Introducing the Tree Planting Predictor (TPP) tool

How many trees do I need to plant?

Common challenges to meeting canopy cover targets

- How many trees are needed?
- What species mix?
- How much space do we need/have?
- What will it cost?
- How do we garner support for plantings (elected members and community)?

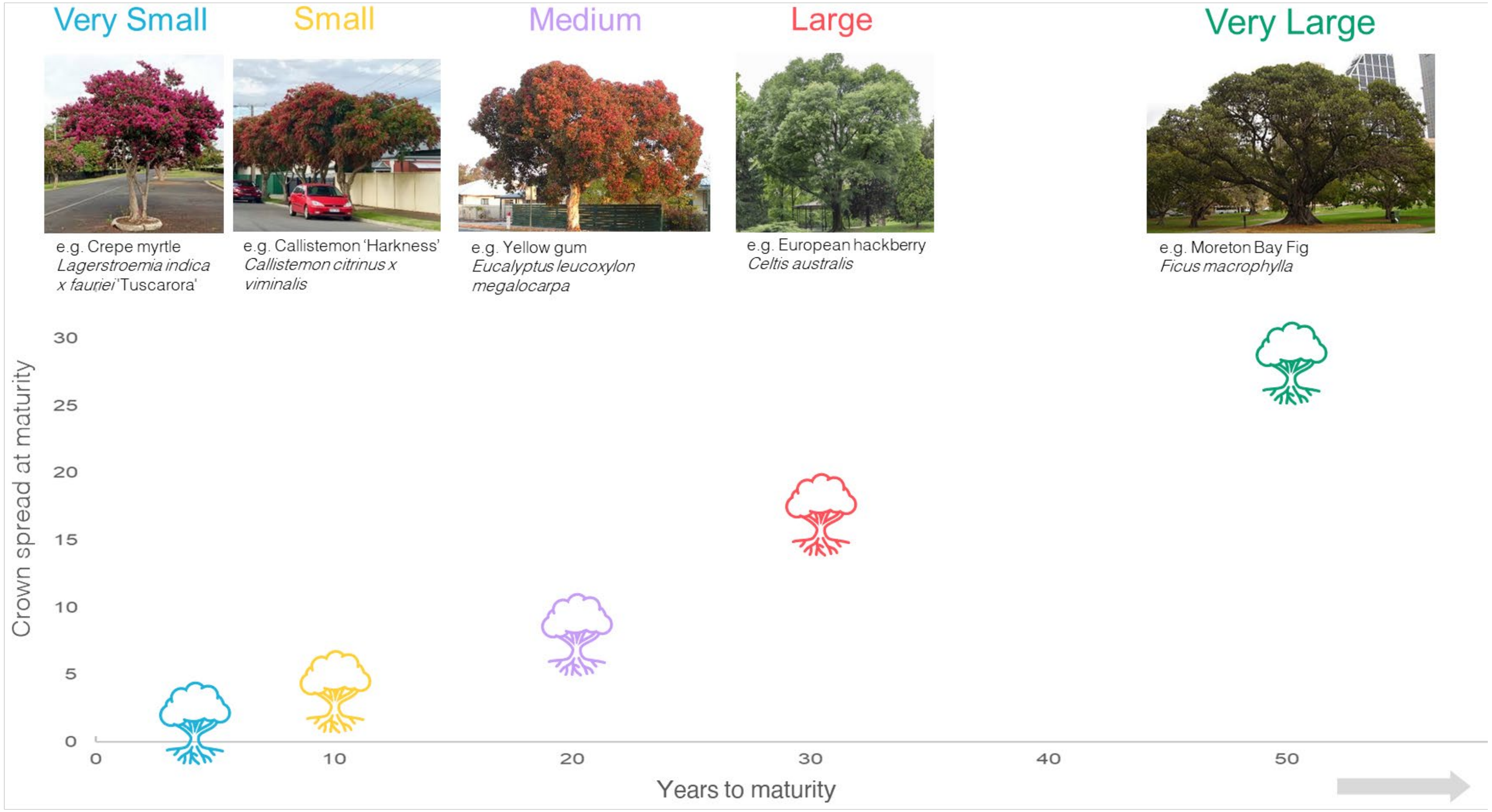
TPP Objective

Provide the **evidence-base for achievable canopy-cover targets**

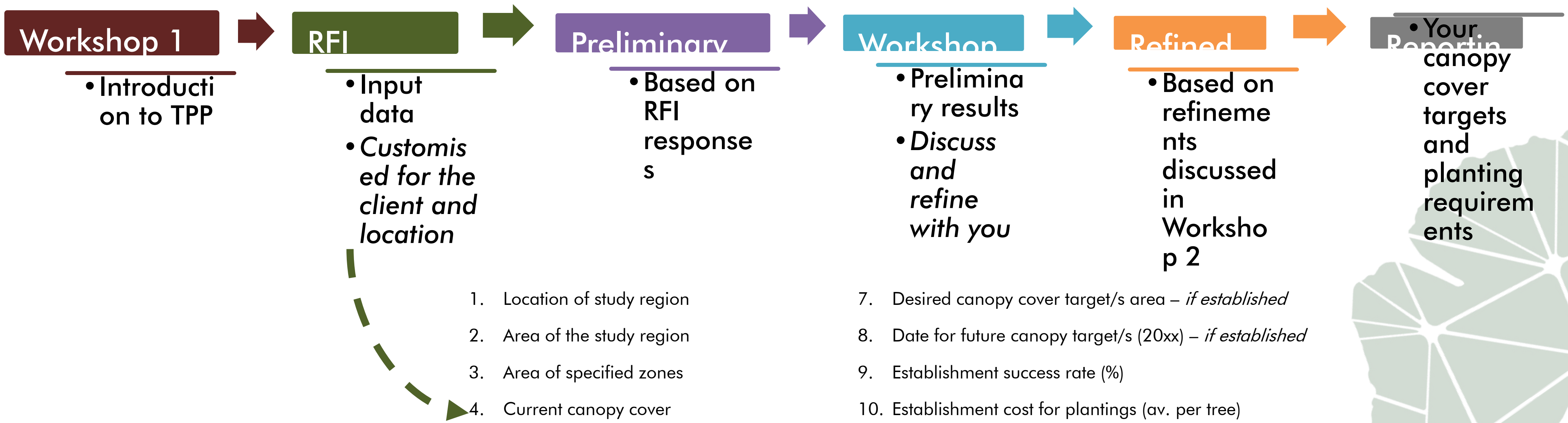
Applies planting program scenarios

where, scenario = species mix + annual planting effort + annual planting rate

Five Tree Categories



TPP Project Approach



Workshop 1
- Introduction to TPP

RFI
- Input data
- *Customised for the client and location*

Preliminary
- Based on RFI responses

Workshop
- Preliminary results
- *Discuss and refine with you*

Refined
- Based on refinements discussed in Workshop 2

Reportin
- Your canopy cover targets and planting requirements

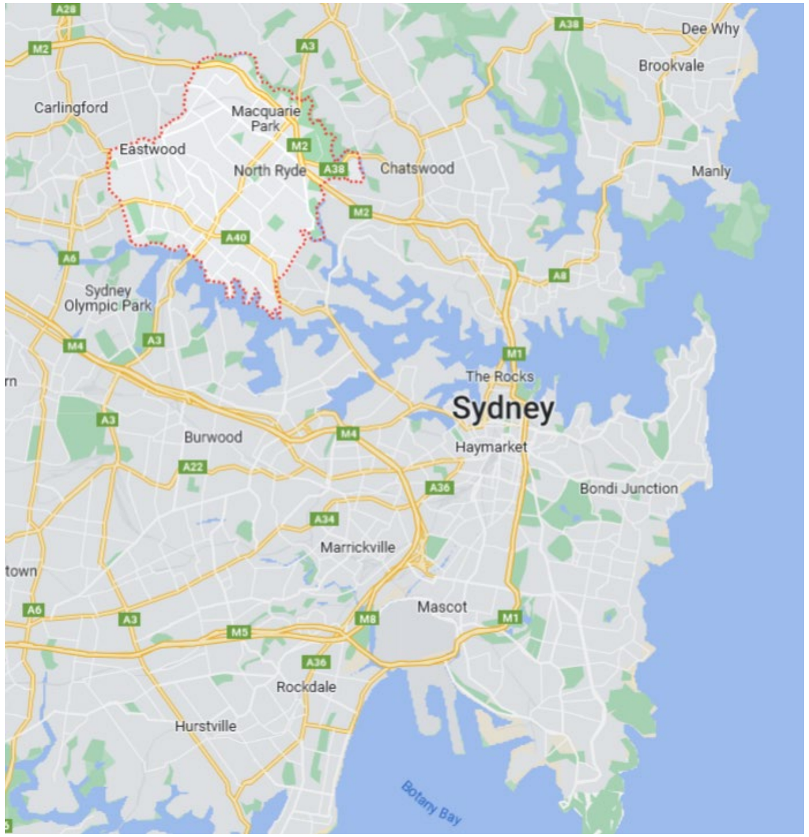
1. Location of study region
2. Area of the study region
3. Area of specified zones
4. Current canopy cover
5. Average annual change in canopy cover (%)
6. Plantable space cover
7. Desired canopy cover target/s area – *if established*
8. Date for future canopy target/s (20xx) – *if established*
9. Establishment success rate (%)
10. Establishment cost for plantings (av. per tree)
11. Species to be planted in average year (mix and quantity)

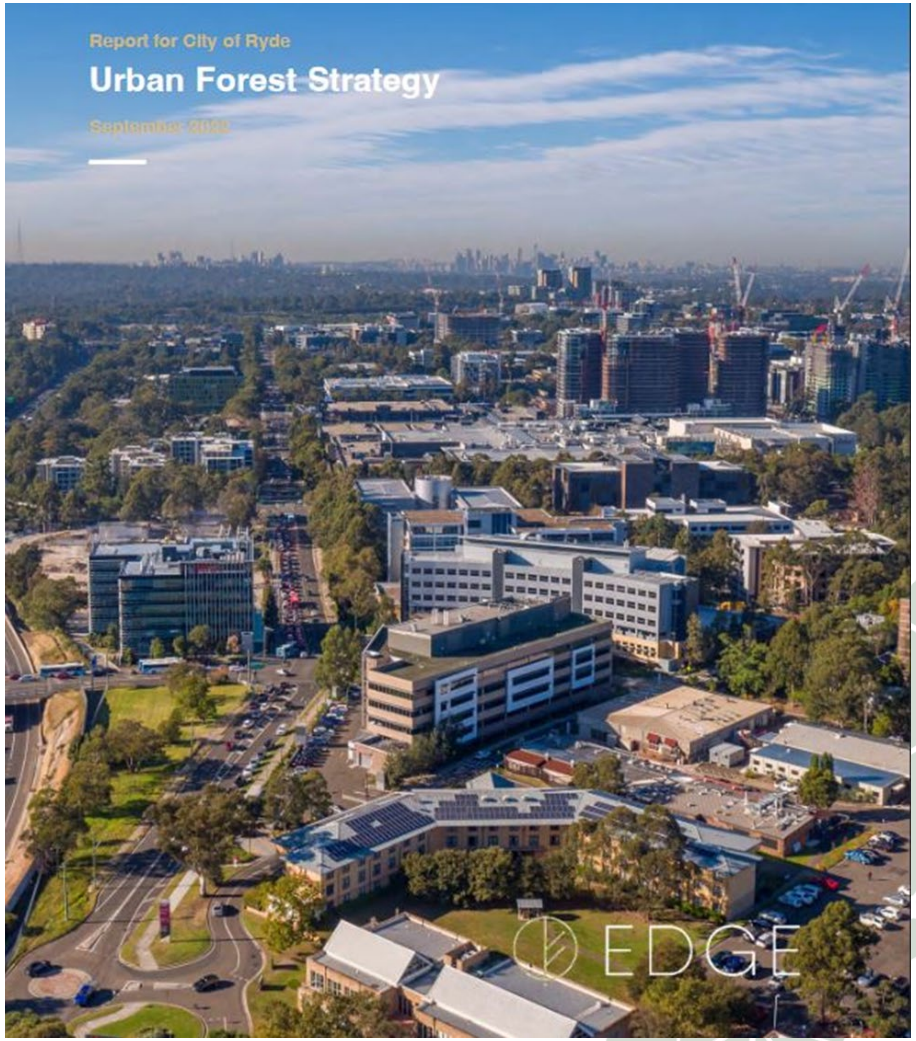
Case Studies

City of Ryde, NSW – Urban Forest Strategy

(April 2023)

- Canopy cover target of 40% cover by 2030
- Current canopy cover = 28.9%
- Currently plant 750 trees per year (~ 50% small and very small trees)
- Background rate of canopy loss = 0.183%




Report for City of Ryde

Urban Forest Strategy

September 2022

EDGE

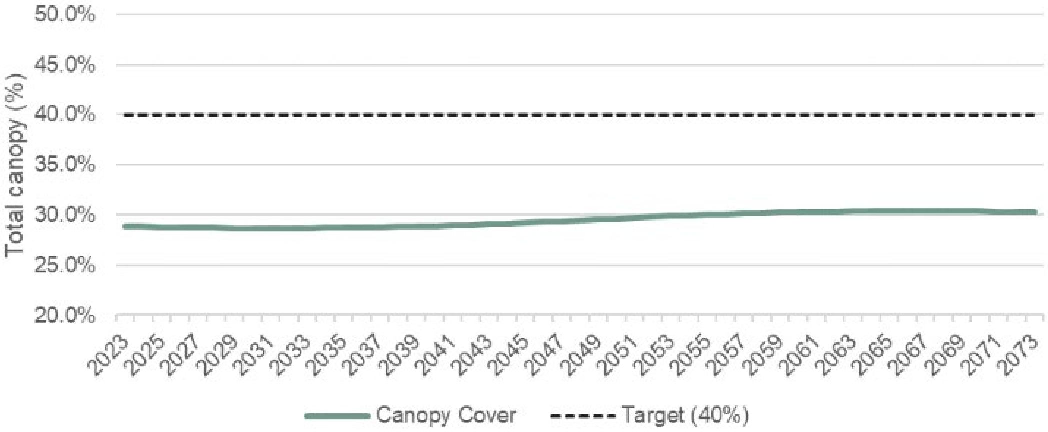
https://www.ryde.nsw.gov.au/files/assets/public/have-your-say/environment/plans-policies-amp-strategies/draft-urban-forest-strategy/202210-hys-strategy-draft-urban-forest-strategy.pdf

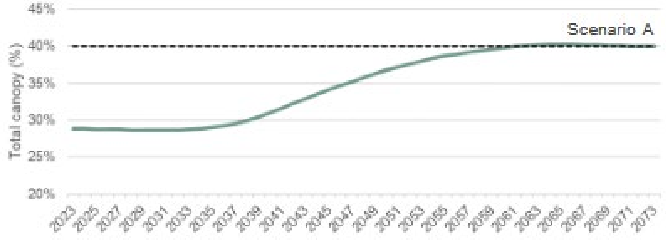
TPP findings:

- BAU will not achieve canopy cover target
- 40% target is achievable → 2030 timeframe is not
- Trade-offs between planting effort and species mix
- Need at least a 3-fold increase in investment

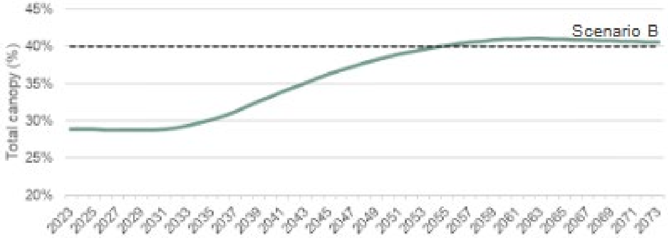
BAU

Mix = 7% small; 42% very small; 16% medium; 24% large; 11% very large
Rate/Effort = 750 trees per year
Target achieved: never
Total trees planted: 20,250
Total cost: ~ AUD$6M

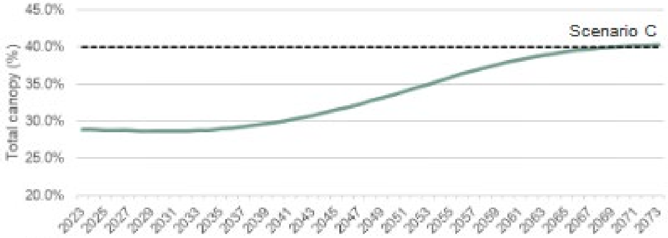




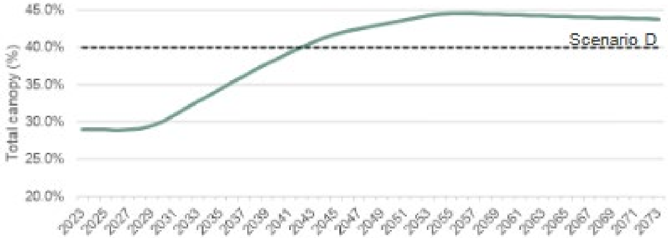
Mix = BAU
Rate/effort = + 30% per year to 2035 then cease plantings
Target achieved: 2059
Total trees planted: 71,875
Total cost: ~ AUD$18M



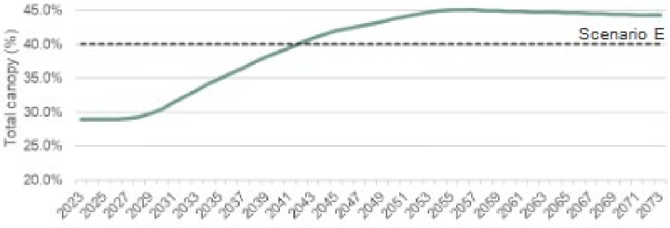
Mix = BAU
Rate/effort = Intensive front loading (200%, 1005, 50%...)
Target achieved: 2053
Total trees planted: 75,169
Total cost: ~ AUD$17.5M



Mix = BAU
Rate/effort = + 30% per year to 2029, then maintain effort to 2050
Target achieved: 2069
Total trees planted: 75,567
Total cost: ~ AUD$22M



Mix = more large trees
Rate/effort = + 65% per year for first year, then 1 year constant, then decrease effort by 50% and 70%
Target achieved: 2042
Total trees planted: 80,762
Total cost: ~ AUD$16.7M



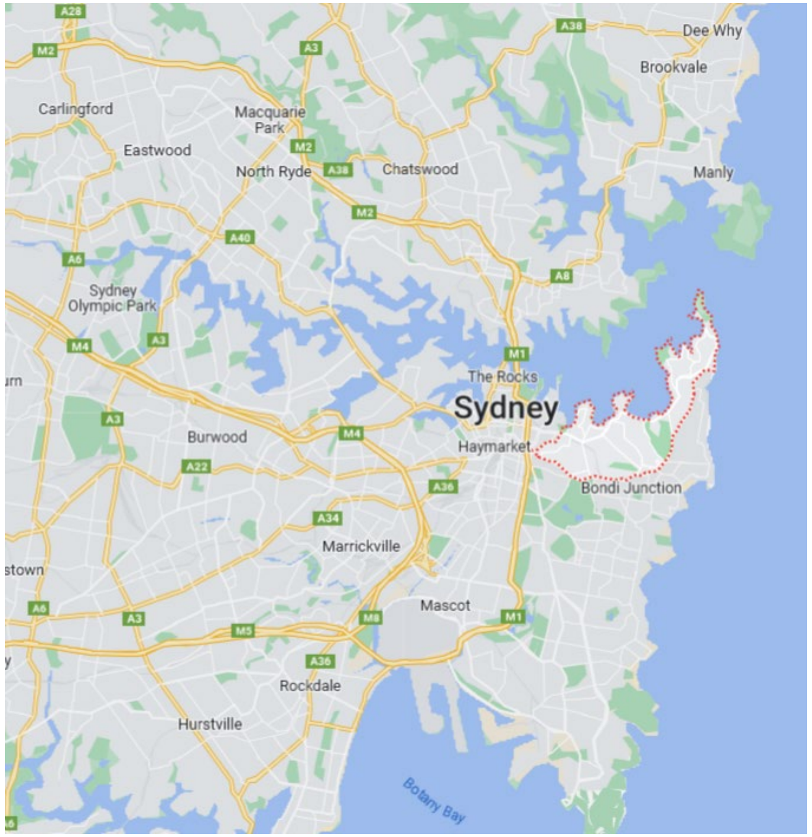
Mix = BAU
Rate/effort = + 80% for first year, then decrease by 30% and 80%
Target achieved: 2041
Total trees planted: 94,864
Total cost: ~ AUD$19.5M

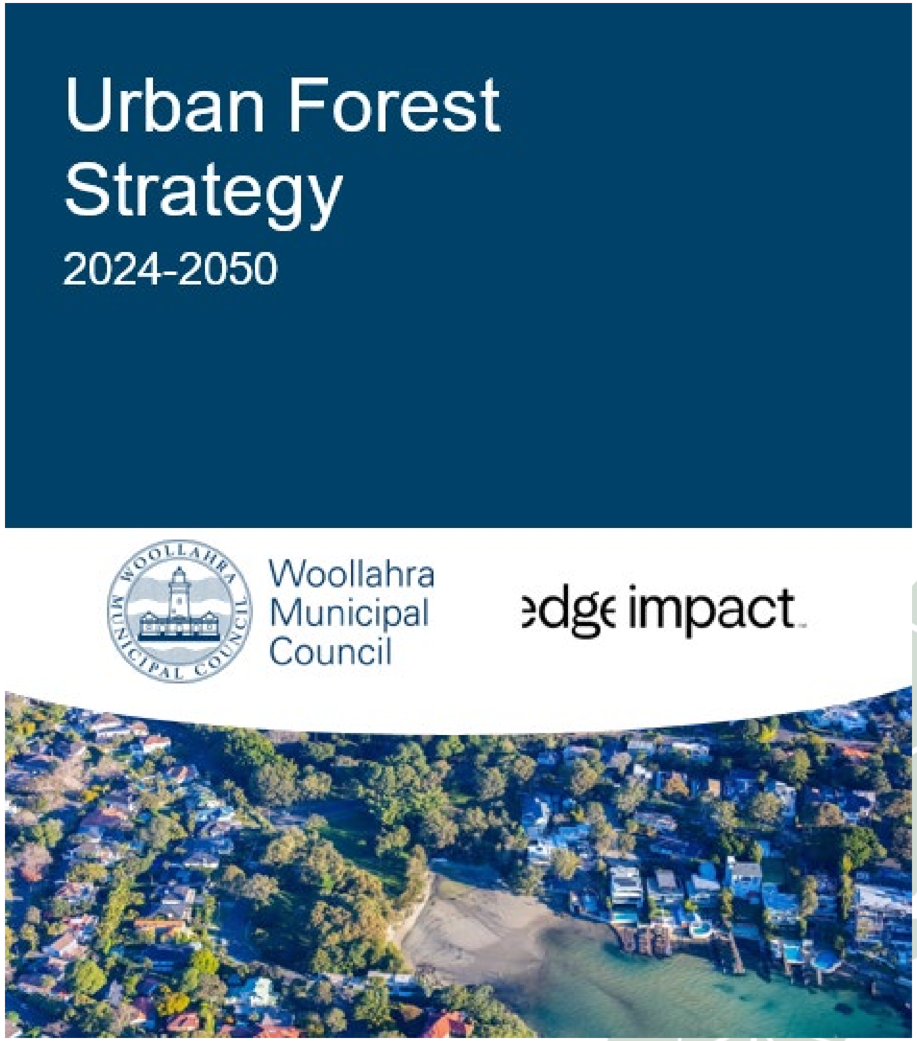
Case Studies

City of Woollahra, NSW – Urban Forest Strategy

(July 2023)

- Canopy cover target of 40% cover by 2046
- Current canopy cover = 27.4%
- Currently plant 200 trees per year (~50% large and very large trees)
- Background rate of canopy loss = 0.75%





Urban Forest Strategy

2024-2050

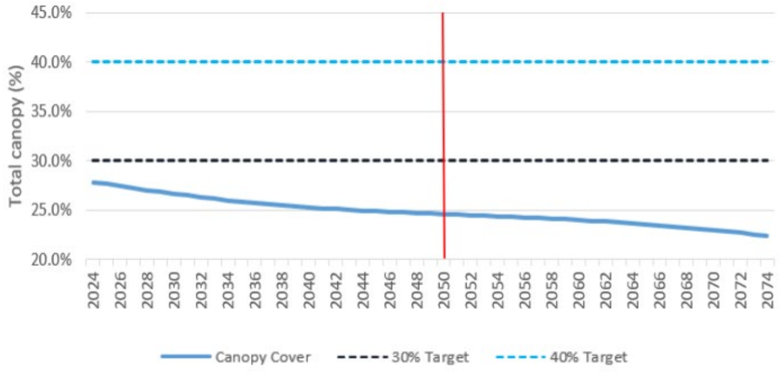
Woollahra Municipal Council

edge impact

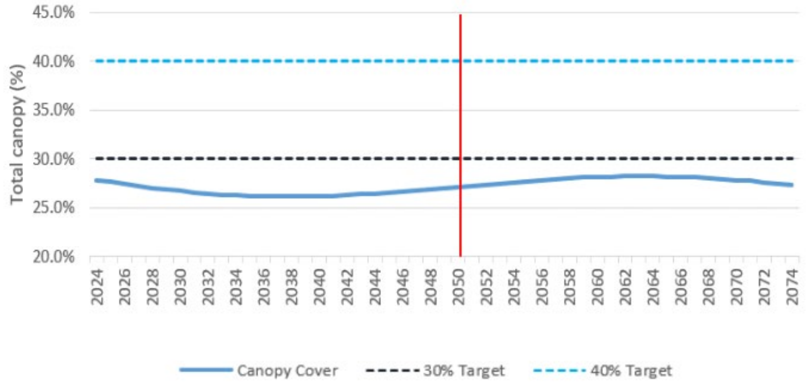
https://hdp-au-prod-app-woollahra-yoursay-files.s3.ap-southeast-2.amazonaws.com/4316/8956/5453/DRAFT_Urban_Forest_Strategy_-_17_July_2023.PDF

TPP findings:

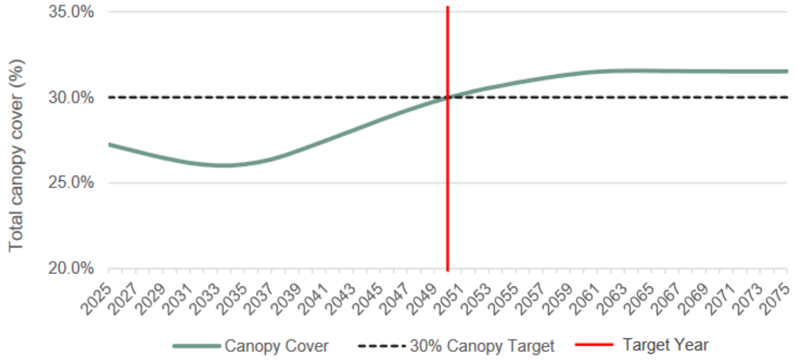
- BAU fails to achieve target and canopy continues to decline
- Just to balance out the rate of background canopy loss would require planting twice as many trees as they currently do
- 40% target is not achievable due to planting effort required being unrealistic and not enough plantable space
- New canopy cover target established: 30% by 2050
- To achieve new target:
  - Alter planting mix to include more large trees
  - Plant more trees (~2.5 times more than BAU)
  - Front-load plantings in initial 9 years of planting (80% of total trees planted)
  - Increase financial investment to ~ AUD$14.8M (1.5 times BAU) – for public tree plantings (60% of required plantings)



BAU – fails to achieve canopy cover increase



Breaking even requires at least double the number of trees to be planted



New realistic target:
30% canopy by 2050

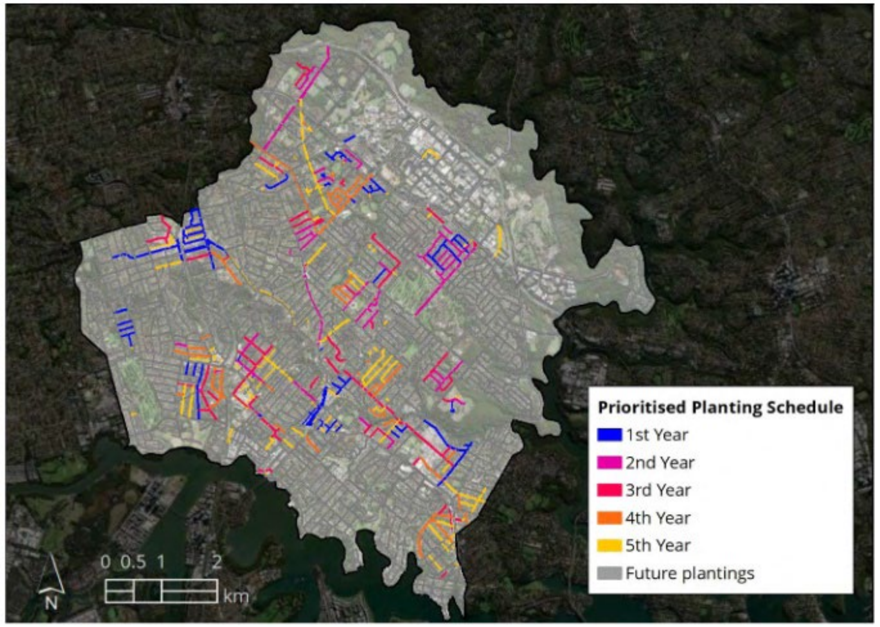
https://hdp-au-prod-app-woollahra-yoursay-files.s3.ap-southeast-2.amazonaws.com/4316/8956/5453/DRAFT_Urban_Forest_Strategy_-_17_July_2023.PDF

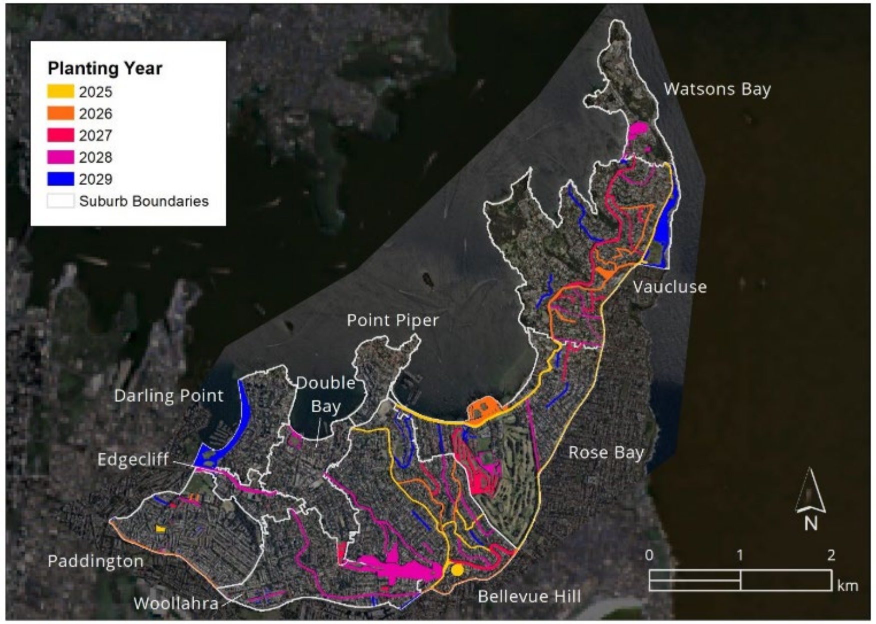
Key messages

- TPP provides a clear, customised evidence-base for how to achieve canopy cover targets

- Has been successfully applied to:
  - Inform decision-making and effectively communicate with elected members and communities
  - Adjust canopy cover targets and increase long-term financial commitments and resourcing for tree plantings
  - Better explore complimentary activities to help achieve canopy cover targets (e.g. incentivising tree plantings/retention on private land; improving establishment success rates of public plantings)

- Can be powerfully combined with plantable opportunity prioritisations to develop an evidence-based annual prioritised planting plan which will achieve canopy cover targets and maximise the co-benefits of tree plantings





Thank you

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Session 1.3: In the Cool of the Day: The role of urban forests in improving microclimate and reducing the heat island effect

PP-23-3557

World Forum on Urban Forests