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LIFE URBANGREEN

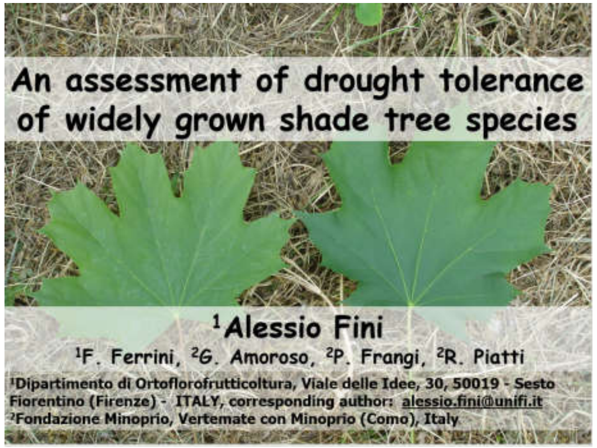
Measuring ecosystem services by urban species: the LIFE Urbangreen project

Preliminary results

Alessio Fini*, Jacopo Mori, Irene Vigevani, Francesco Ferrini, Alice Pasquinelli, Marco Gibin, Piotr Wezyk, Osvaldo Failla, Paolo Viskanic

** DISAA, Università di Milano, via Celoria 2, Milano*

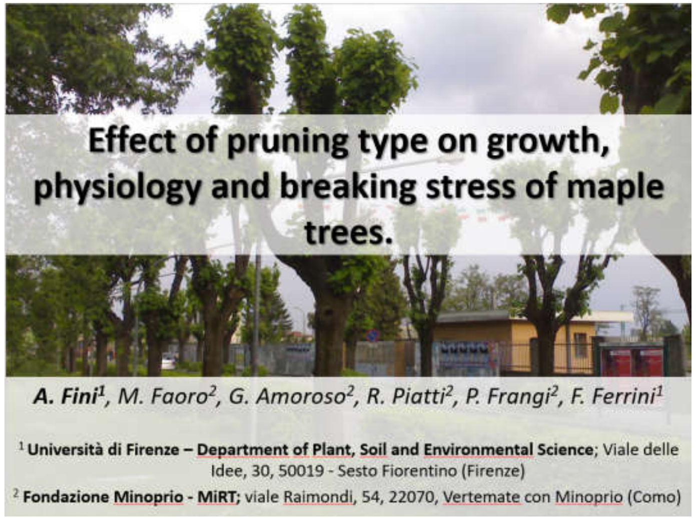
I used to torture lots of trees each year, to get data for the ISA conference…



St. Louis, 2008

Droughted

Chicago, 2010



Topped - Sydney, 2011

Sealed – Columbus, 2018

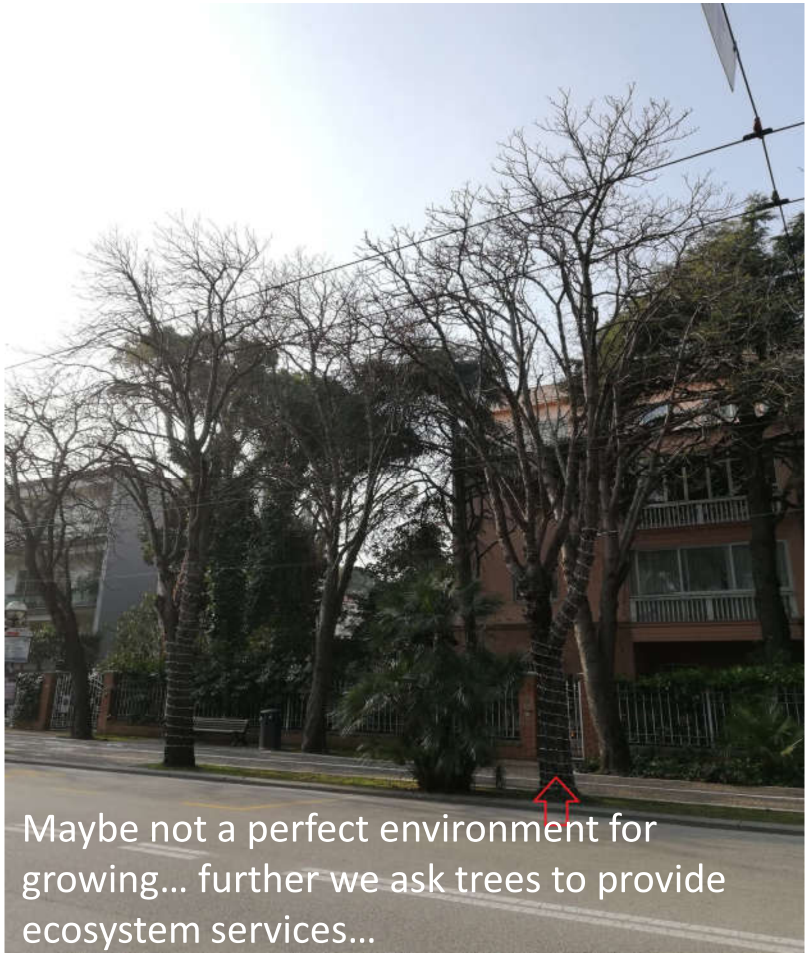
Root severed – Milwaukee, 2014

Sunburned– Washington, 2017

Not this time!

No tree was injured for this presentation!

Rather, urban trees were measured in situ in their growing environment



Ecosystem services

Green areas provide **ecosystem services** = **benefits arising from ecological processes which directly or indirectly increase human well-being**

CICES theme	*CICES class*	*TEEB categories*
Provisioning	• Nutrition	• Food, water
	• Materials	• Raw materials, genetic resources, medicinal resources, ornamental resources
	• Energy	
Regulating and maintenance	• Regulation of waste	• Air purification, waste treatment
	• Flow regulation	• Disturbance prevention, regulation of water flows, erosion prevention
	• Regulation of physical environment	• Climate regulation, maintaining soil fertility
	• Regulation of biotic environment	• Gene pool protection, lifecycle maintenance, pollination, biological control
Cultural	• Symbolic	• Information of cognitive development
	• Intellectual and experiential	• Aesthetic, inspiration for culture, art and design, spiritual experience, recreation and tourism

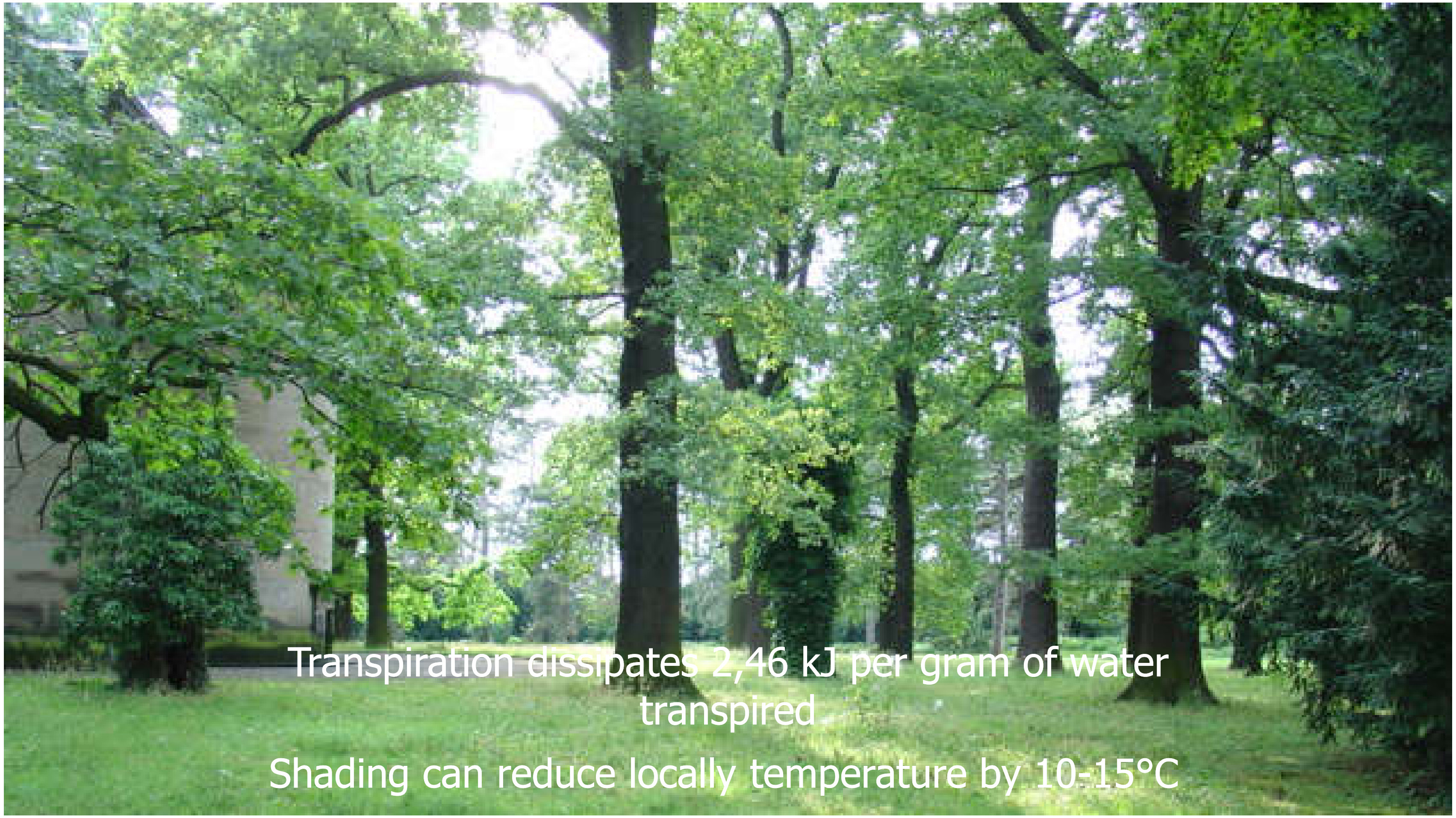
Cices, 2018

Provisioning of
Food, water, energy

Regulation and **maintenance** of the environment (climate regulation, disturbance prevention)

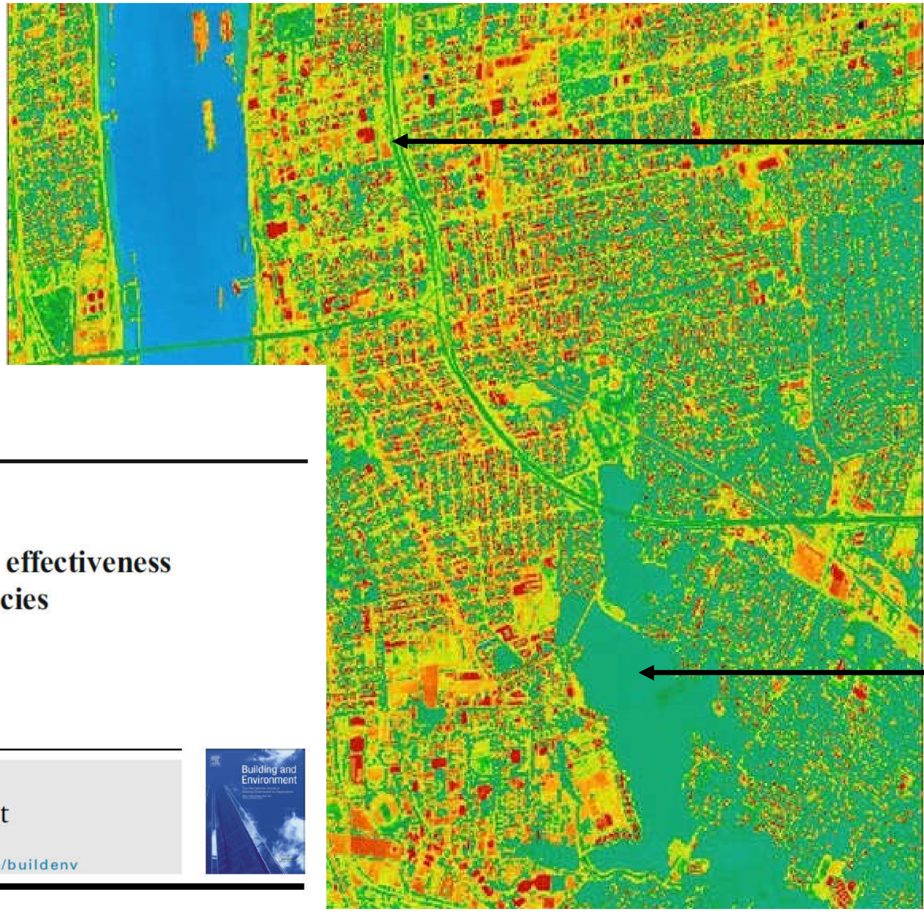
Cultural

Regulation and maintenance: microclimate amelioration



Regulation and maintenance: microclimate amelioration

IR-image of Baton Rouge (Louisiana) in mid June 1998



Very few studies measured the effects of different tree species on temperature

Urban Ecosyst (2015) 18:371–389
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

Building and Environment 114 (2017) 118–128

Contents lists available at ScienceDirect

Building and Environment

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

ELSEVIER

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]

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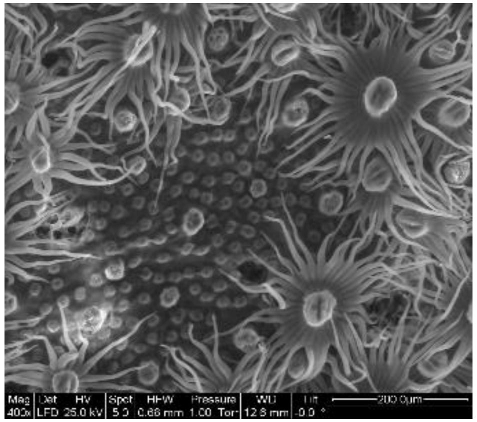
Regulation and maintenance: air quality amelioration

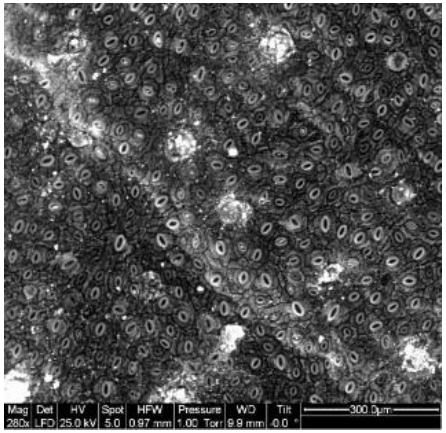
1 cm^2 leaf area typically adsorbes 10-70 μg PM per year.

Gaseous pollutants can also be absorbed through stomata (CO, NO_x, SO_2, O_3)

Regulation and maintenance: air quality amelioration

Eleagnus





Ligustrum

Several works modelled PM adsorption through dry deposition model..

Urban Forestry & Urban Greening 29 (2018) 40–48

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

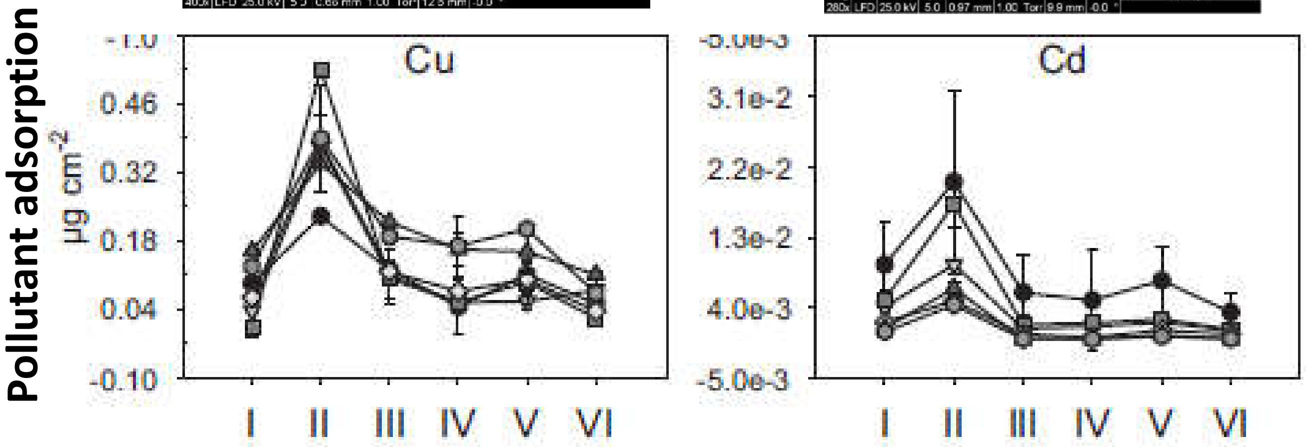
journal homepage: www.elsevier.com/locate/ufug

ELSEVIER

Original article

Air pollution removal by urban forests in Canada and its effect on air quality and human health

David J. Nowak, Satoshi Hirabayashi, Marlene Doyle, Mark McGovern, Jon Pasher



...but few measured trapping ability of different species

SCIENTIFIC REPORTS

OPEN

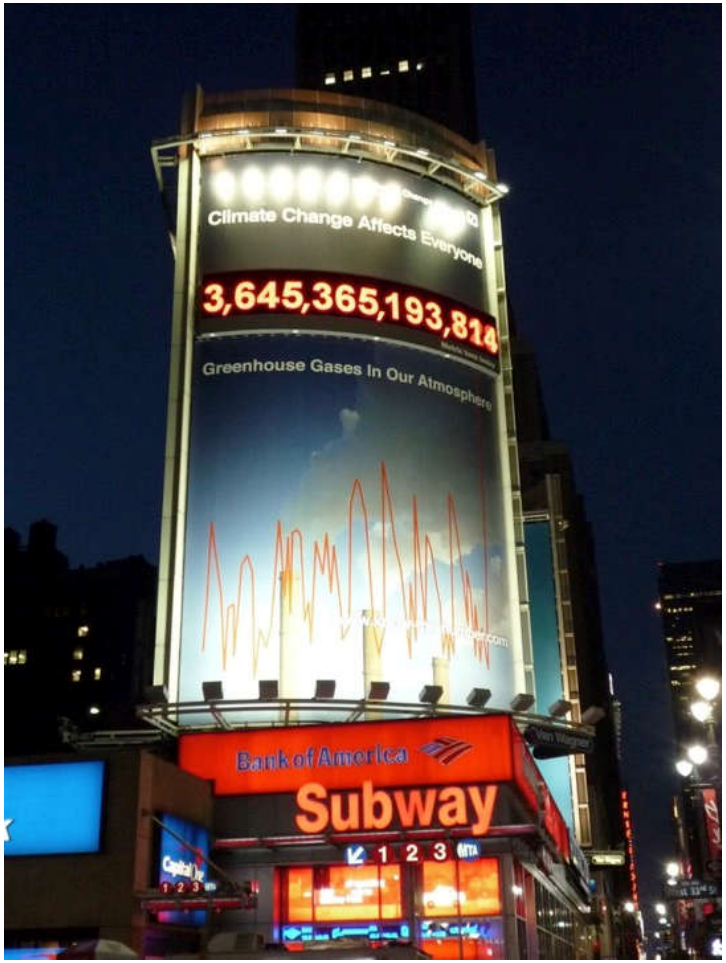
Variation in Tree Species Ability to Capture and Retain Airborne Fine Particulate Matter ($PM_{2.5}$)

Lixin Chen, Chenming Liu, Lu Zhang, Rui Zou & Zhiqiang Zhang

ived: 20 April 2016
pted: 28 April 2017

Leaf deposition of different elements in *Viburnum lucidum* (black circle), *A. unedo* (white triangle down), *P. × fraseri* (black square), *L. nobilis* (white diamond), *E. × ebbingei* (black triangle up) and *L. japonicum* (white circle). From Mori et al., 2015, 2016.

Regulation and maintenance: reduction of atmospheric CO_2



Trees are excellent sinks of CO2.

They **assimilate CO_2** (i.e. convert inorganic atmospheric carbon to carbohydrates through photosynthesis), and use it for making leaves, fruits, flowers, and to defend (secondary metabolism)

and

they **store carbon** (i.e. stock carbon as woody biomass of trunk, branches, and roots)

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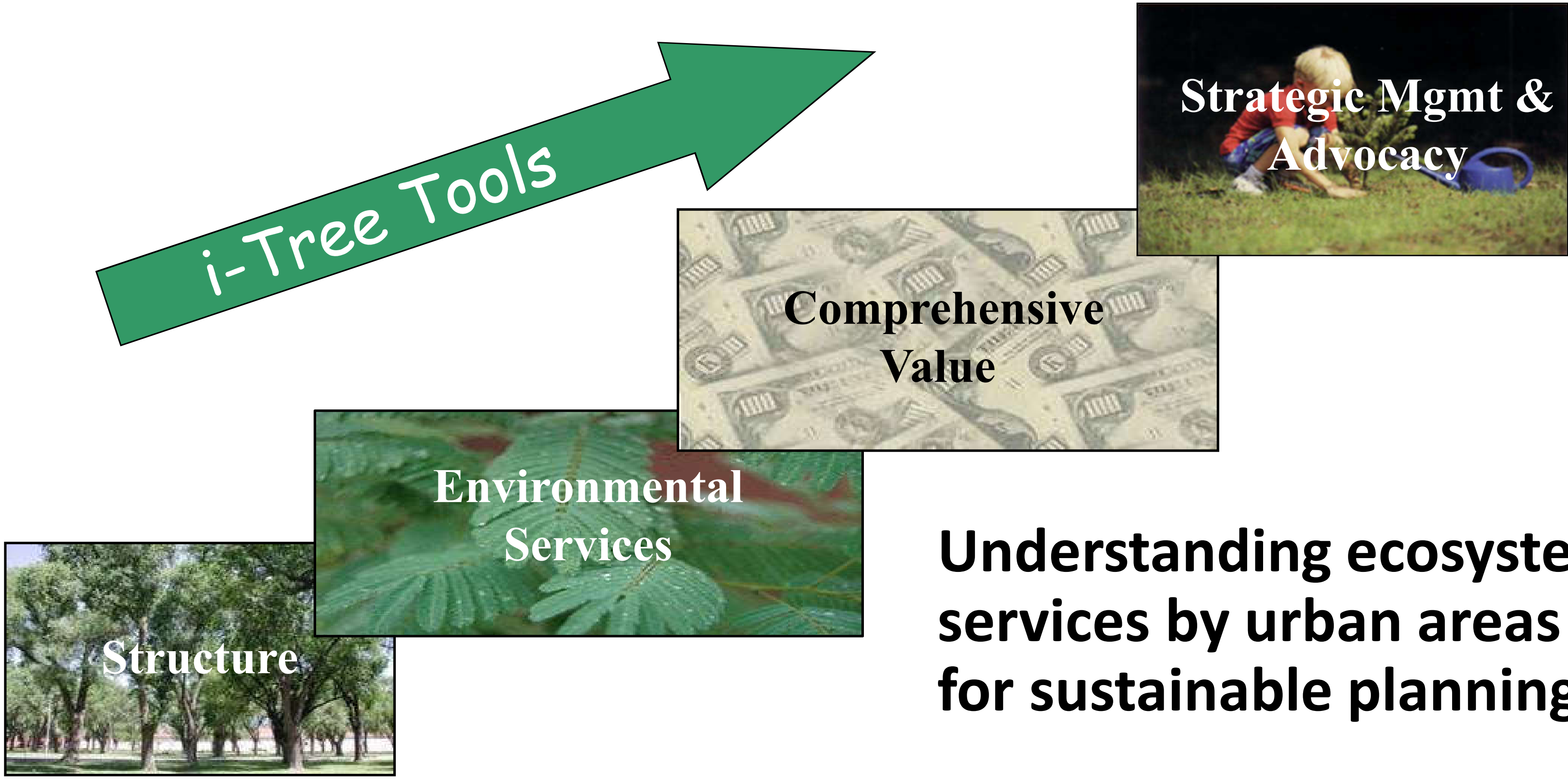
Quantifying benefits: I-Tree



Understanding ecosystem services by urban areas is key for sustainable planning

Regulation and maintenance: reduction of atmospheric CO_2

- CO_2 removal by urban trees has often been estimated using **empiric models**
- They estimate biomass fitting a large number of experimental observations on different trees
- Several equations have been developed for forest trees, and often are adapted to urban sites
- They lack a mechanistic approach, thus are only representative of the site where they were developed
- More equations are needed for urban tree species

E.G.:

Carbon storage

$$\text{Biomass} = a\,(\text{DBH})^b$$

CO_2 assimilation is proxied by **carbon sequestration**

Increase in biomass over consecutive years

Empiric models

Table 1 Parameter estimates for allometric equations relating volume (m^3) and diameter breast height (DBH, cm)

Tree species (Spp. Code)	a	b	R2	RMSE
Fraxinus pennsylvanica (FRPE)	5.9 E-04	2.206	0.987	0.175
Gleditsia triancanthos (GLTR)	5.1 E-04	2.220	0.988	0.188
Tilia cordata (TICO)	9.4 E-04	2.042	0.953	0.257
Quercus macrocarpa (QUMA)	2.4 E-04	2.425	0.938	0.365
Celtis occidentalis (CEOC)	1.4 E-03	1.928	0.959	0.293
Ulmus americana (ULAM)	1.8 E-03	1.869	0.924	0.268
Acer platanoides (ACPL)	1.9 E-03	1.785	0.940	0.280
Ulmus pumila (ULPU)	4.9 E-03	1.613	0.874	0.461
Populus sargentii (POSA)	2.1 E-03	1.873	0.991	0.181
Gymnocladus dioicus (GYDI)	4.2 E-04	2.059	0.816	0.411
Acer saccharinum (ACSA)	3.6 E-04	2.292	0.964	0.334

Parameter values are given for each individual species. The equation form is Volume = $a(DBH)^b$

McHale et al., 2009, Urban Ecosys

LIFE URBANGREEN (2018-2022)

2 municipalities: Rimini (Italy) and Krakow (Poland)

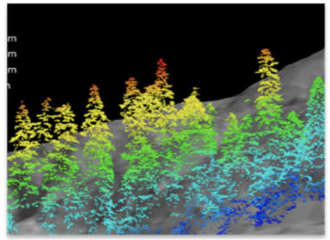
10 woody species

Goals: 1- measure some ecosystem services by urban trees;
2- investigate the effects of maintenance on ecosystem services (still to do)

1- Measuring ecosystem services

Two-week measurement campaigns have been conducted in the two cities to assess some ecosystem services by leaf gas exchange measurements and collection of leaves for pollution trapping efficiency determination. Lidar scanning is ongoing for determining biometrics

- Storage of CO_2
- Assimilation CO_2
- Adsorption of PM
- Microclimate improvement by transpiration



Research group

Project coordinator: R3 GIS srl – Merano (Italy)

Partners
University of Milano (IT)
Progea 4D – Krakow (PL)
Anthea srl (City of Rimini – IT)
Zarzad Zieleni Miejskiej (City of Krakow - PL)

Project begun on:
July 2018

Experimental sites

Parameter (30-y-average)	Rimini	Krakow
Climate zone (Koppen)	Cfa	Dfb
Tmin (°C)	8,6	3,8
Tmax (°C)	17,6	12,8
Rainfall (mm)	705	622

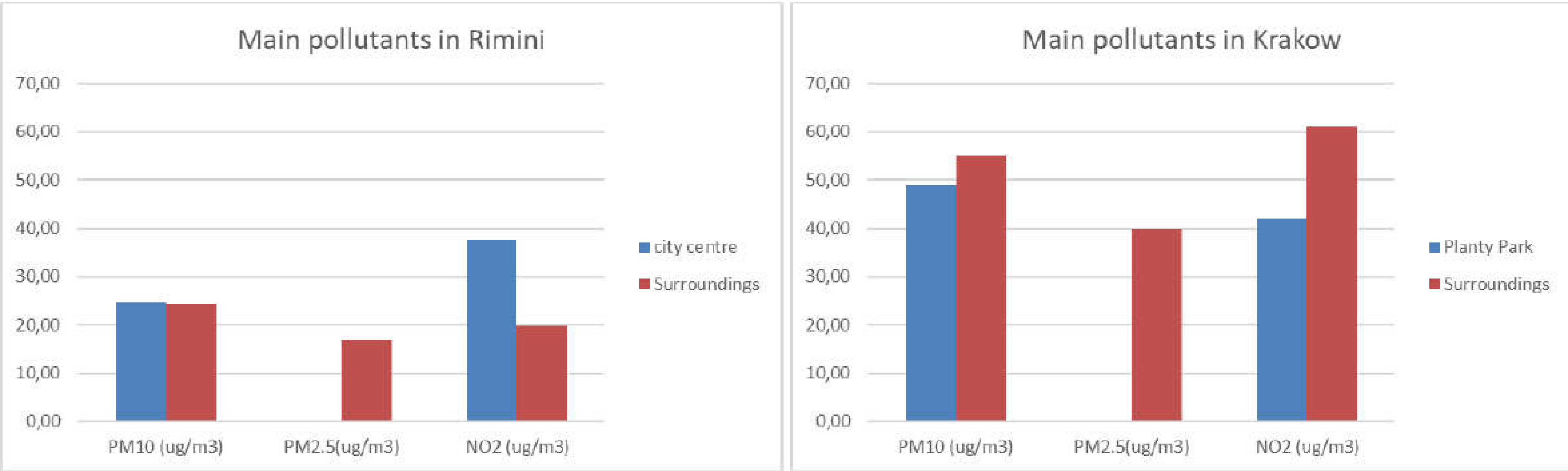
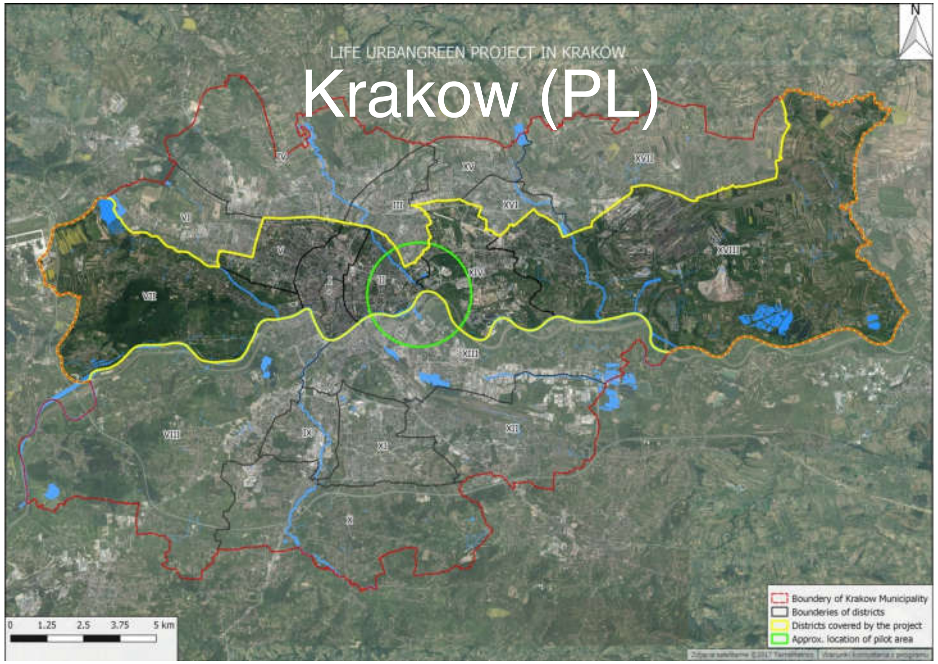


Fig. 1 - Average PM10, PM2,5, and NO2 in the two cities.[1]

Experimental areas

Before the project started, two city transects representative of the whole municipality were selected



Stratification

Experimental areas were stratified in:

Paved areas: street trees, trees in parking lots, tree planted in well-defined planting pits or with visible conflicts with the built environment

Unpaved areas: tree in parks and gardens, growing in unpaved soil with negligible conflicts with the built environment

Model species

10 model species per city were selected based on: 1) species relevance for the municipality; 2) tree size at maturity; 3) leaf persistence

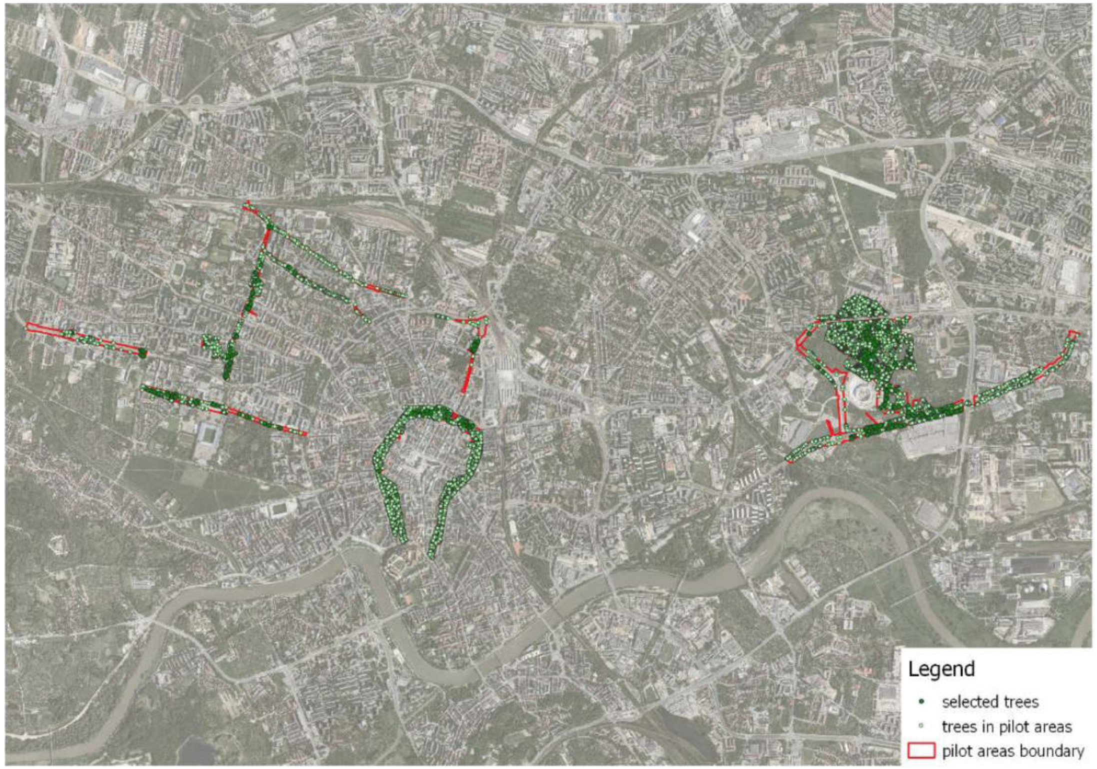
Specie	Habitus
Quercus robur	Large deciduous
Platanus x acerifolia	Large deciduous
Populus nigra	Large deciduous
Quercus ilex	Large evergreen
Pinus pinea	Large evergreen
Tilia x europaea	Medium-large deciduous
Aesculus hippocastanum	Medium-large deciduous
Acer negundo	Medium deciduous
Ligustrum lucidum	Small semi-deciduous
Prunus laurocerasus	Evergreen shrub

Specie	Habitus
Quercus robur	Large deciduous
Fraxinus excelsior	Large deciduous
Populus nigra	Large deciduous
Ulmus laevis	Large deciduous
Pinus nigra	Medium evergreen
Tilia cordata	Medium-large deciduous
Aesculus hippocastanum	Medium-large deciduous
Acer platanoides	Medium-large deciduous
Sorbus aucuparia	Small deciduous
Cornus alba	Deciduous shrub

Trees in the experimental areas

Trees of the selected species in the experimental areas were identified, plotted on gis, and aggregated in 12 replicate plots containing all species.

Krakow, PL



Rimini, IT

Trees in the experimental areas

Tree age was retrieved with the assistance of Anthea and ZZM (municipal tree care companies)

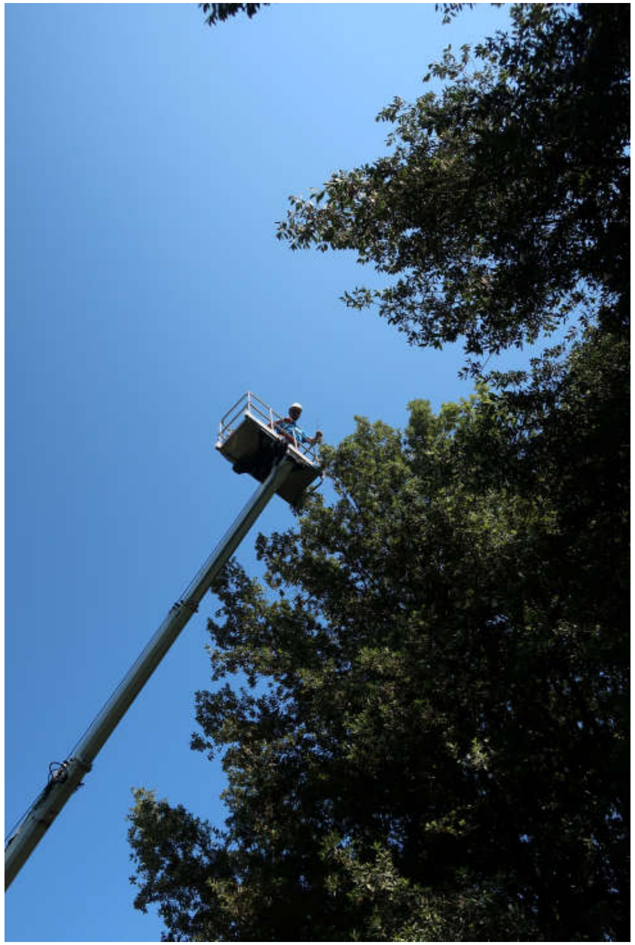
Stem DBH, tree height and **dripline area** (DLA) were measured on about 500 trees per city

Leaf Area Index (LAI) was measured using a LAI-meter

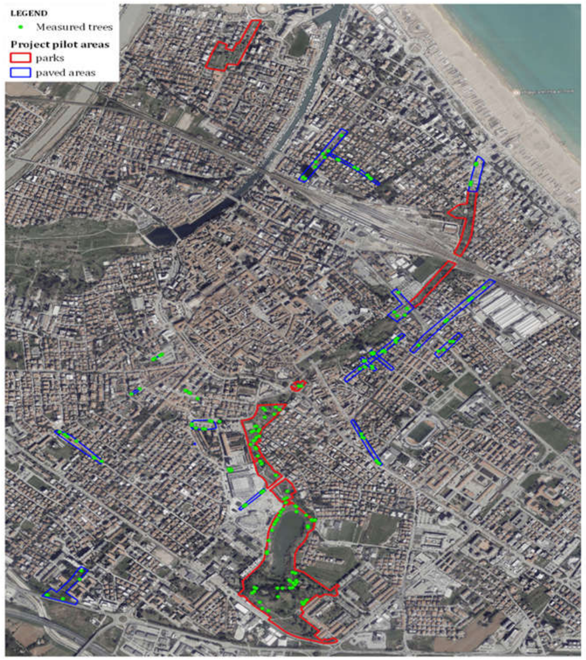
A provisional estimate of **total leaf area** was calculated as **LAI * DLA**

Based on biometrics, in each plot, **average young and mature trees were selected** for ecophysiological measurements

Screening CO_2 assimilation, transpiration, and PM adsorption using the big leaf model

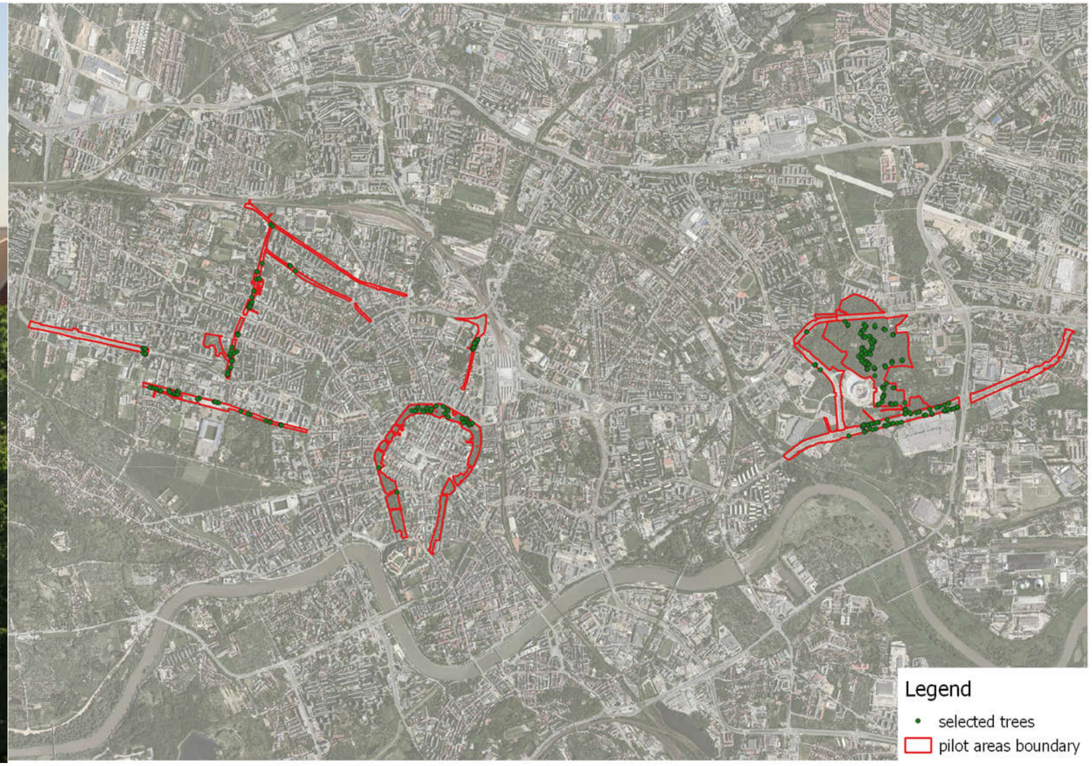


- **In Rimini**, measurements were conducted during **spring, summer, and fall** on about 650 leaves per season.
- **Fully expanded, full sun leaves** attached on basal, medial, and distal branches were sampled at 410 ppm CO_2 and saturating irradiance using a Licor-6400.
- Three-hundred cm^2 of leaves per tree were sampled from the basal, medial, and apical portion of the canopy to measure **pollution adsorption** (for detailed methods, see Mori et al., 2018, Science of The Total Environment)



Screening CO_2 assimilation, transpiration, and PM adsorption using the big leaf model

In Krakow, measurements were conducted in spring, summer and fall using the same methods as in Rimini



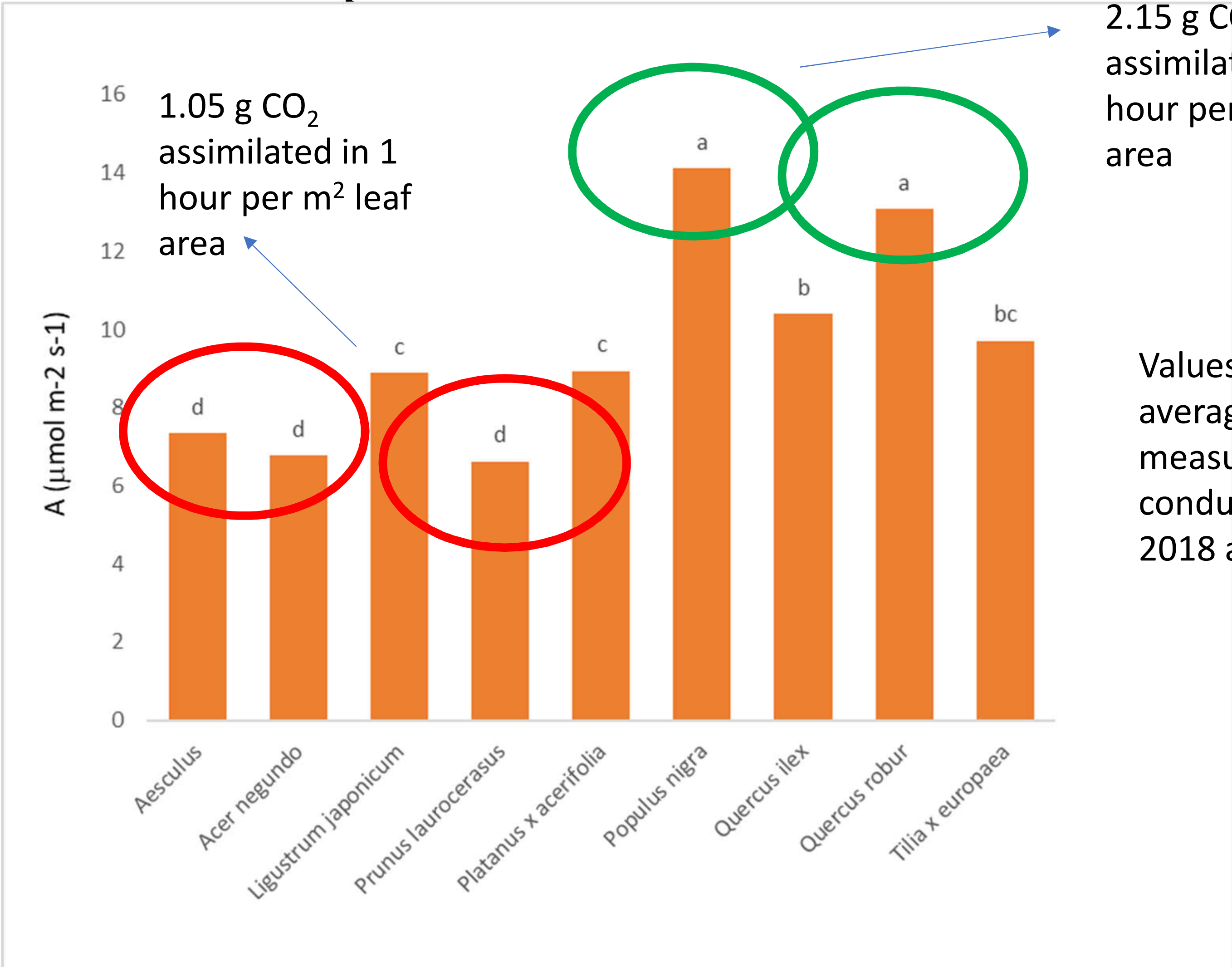
Results: CO_2 assimilation

Rimini beach from a poplar top!

CO_2 assimilation per unit leaf area: effects of **species** in Rimini

$P_{species}$ < 0.000

Species significantly affected the amount of atmospheric CO_2 converted into organic carbon by 1 m^2 leaf area exposed to full irradiance



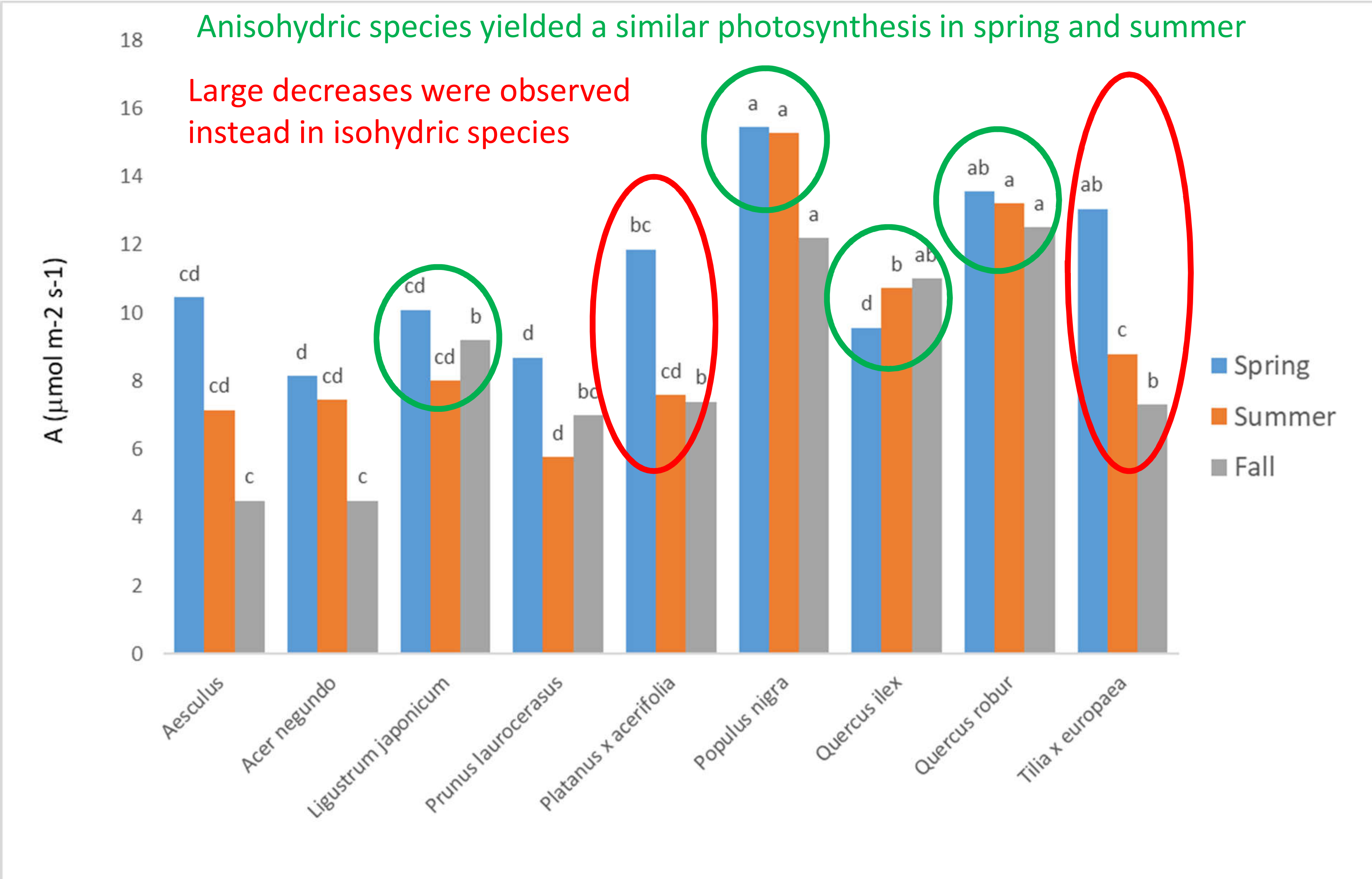
2.15 g CO_2 assimilated in 1 hour per m^2 leaf area

Values are the average of all measurements conducted in 2018 and 2019

CO_2 assimilation per unit leaf area: effects of **species and season** in Rimini

$P_{speciesXseason}$ < 0.000

A significant species x season interaction was found, indicating that species performances change over time



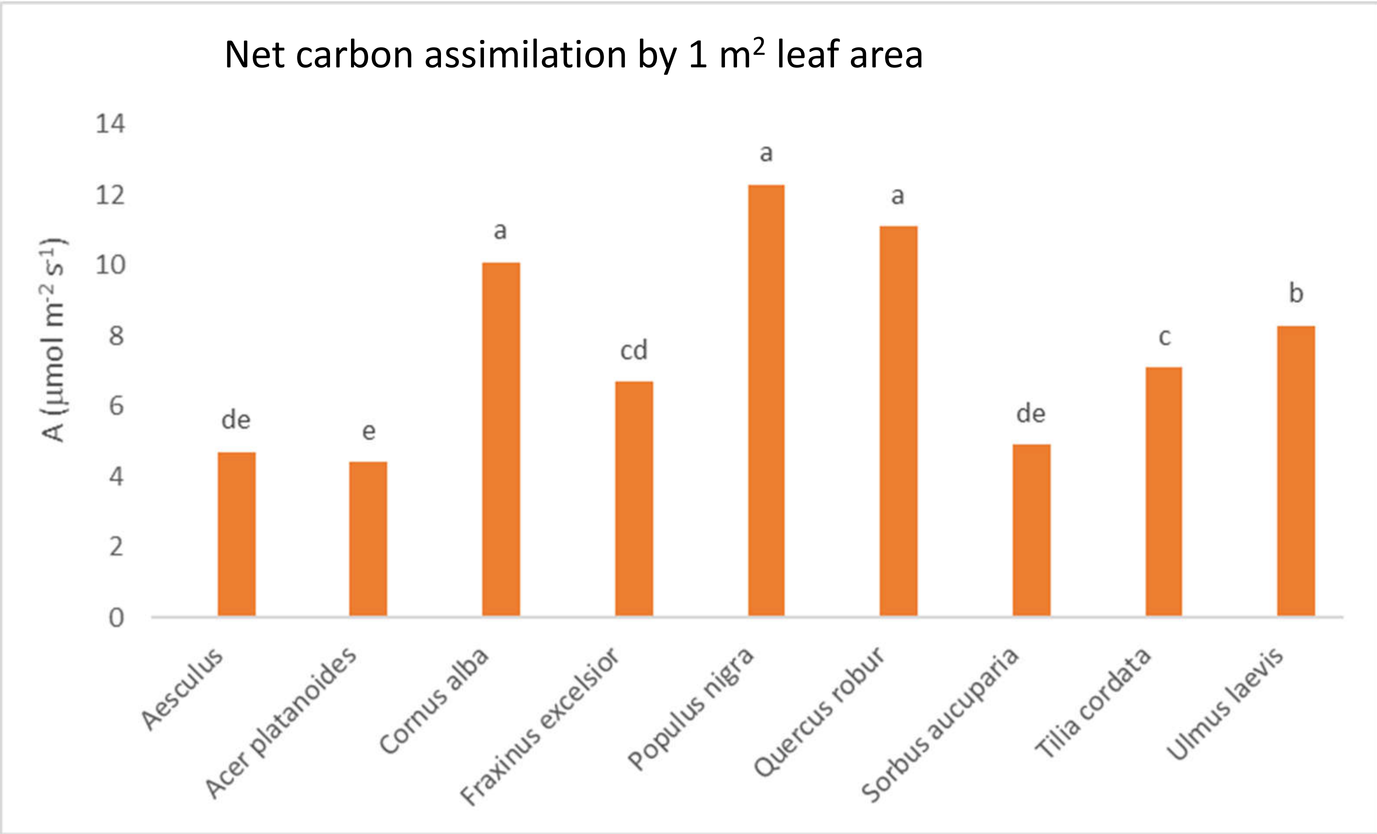
Young trees
vs.
mature trees

Park trees vs. street trees

CO_2 assimilation per unit leaf area: effects of **species** in Krakow

$P_{species} < 0.000$

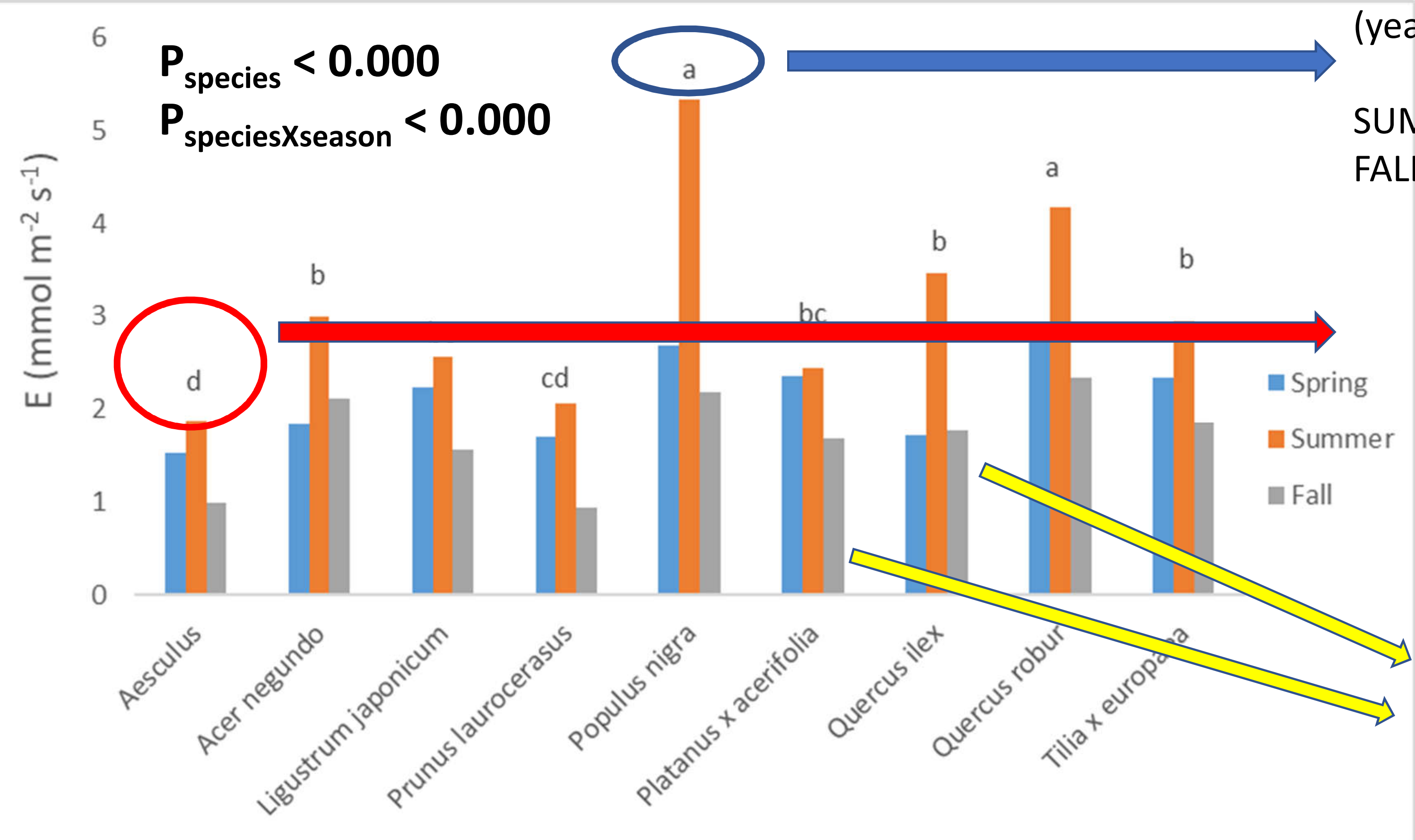
Best performing species for CO2 assimilation in Rimini confirmed in Krakow



Measurements were conducted during fall

Transpiration and microclimate improvement

Transpiration and microclimate improvement in Rimini: effect of **species and season**



488 kJ dissipated in 1 hour as latent heat (yearly average)

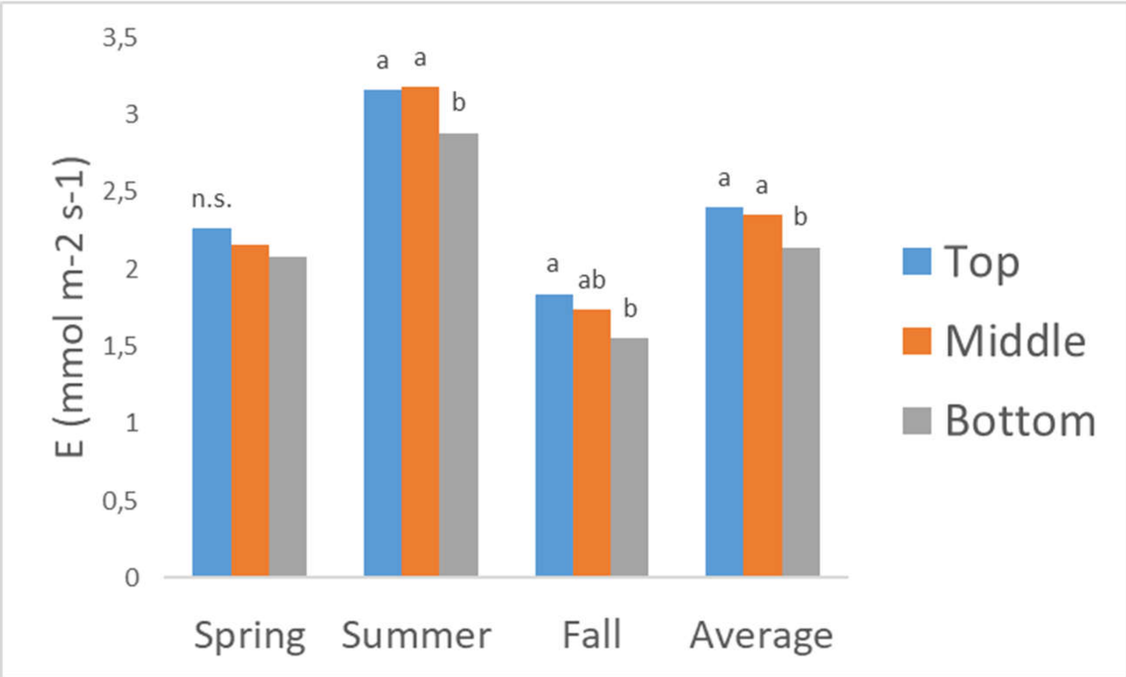
SUMMER: **784** kJ hour^{-1}
FALL: 145 kJ hour^{-1}

215 kJ dissipated in 1 hour as latent heat (yearly average)

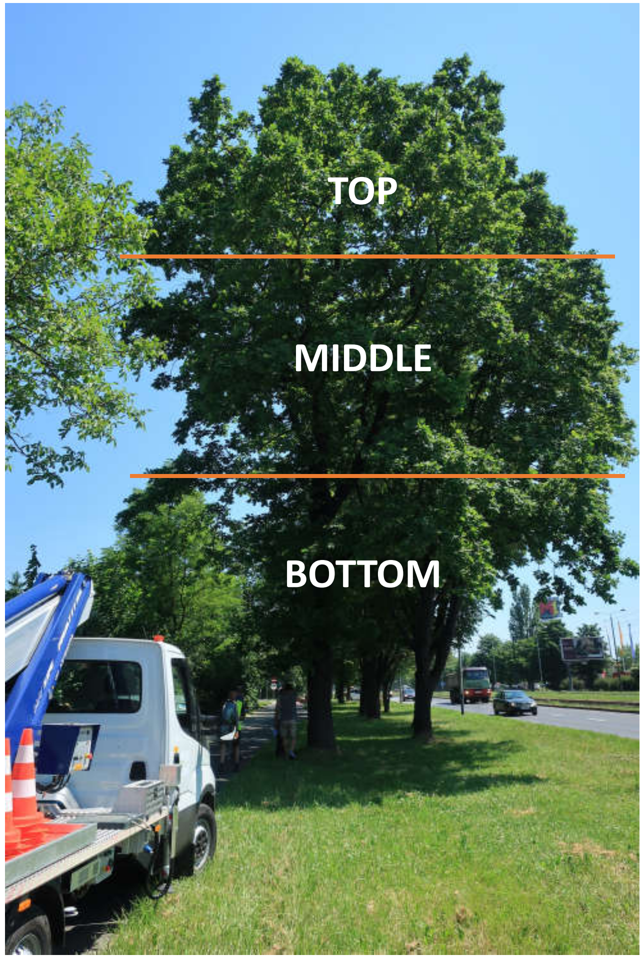
SUMMER: **275** kJ hour^{-1}
FALL: 322 kJ hour^{-1}

Anisohydric species provide greater cooling in summer than isohydric ones, despite the average annual cooling may not change

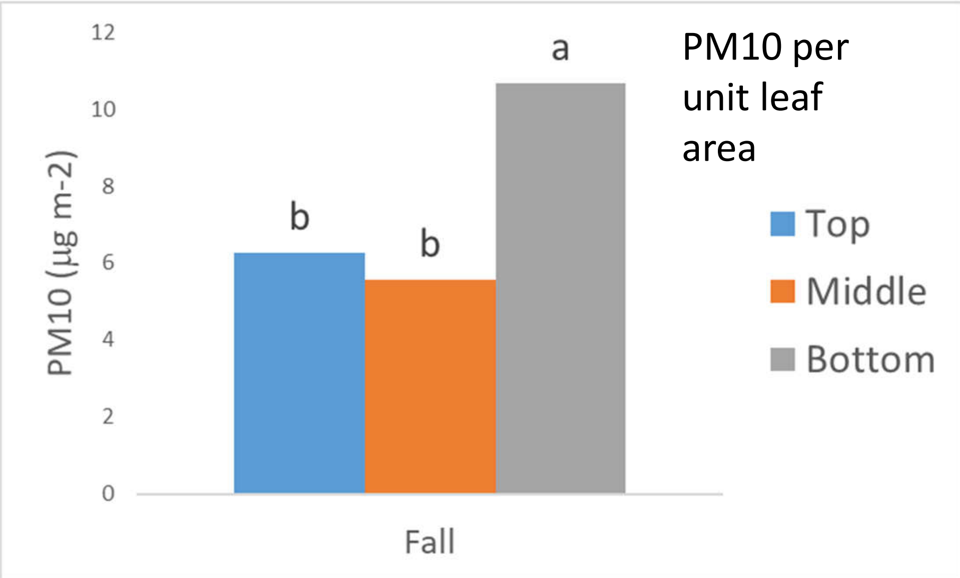
Transpiration and microclimate improvement in Rimini: effect of **leaf position**



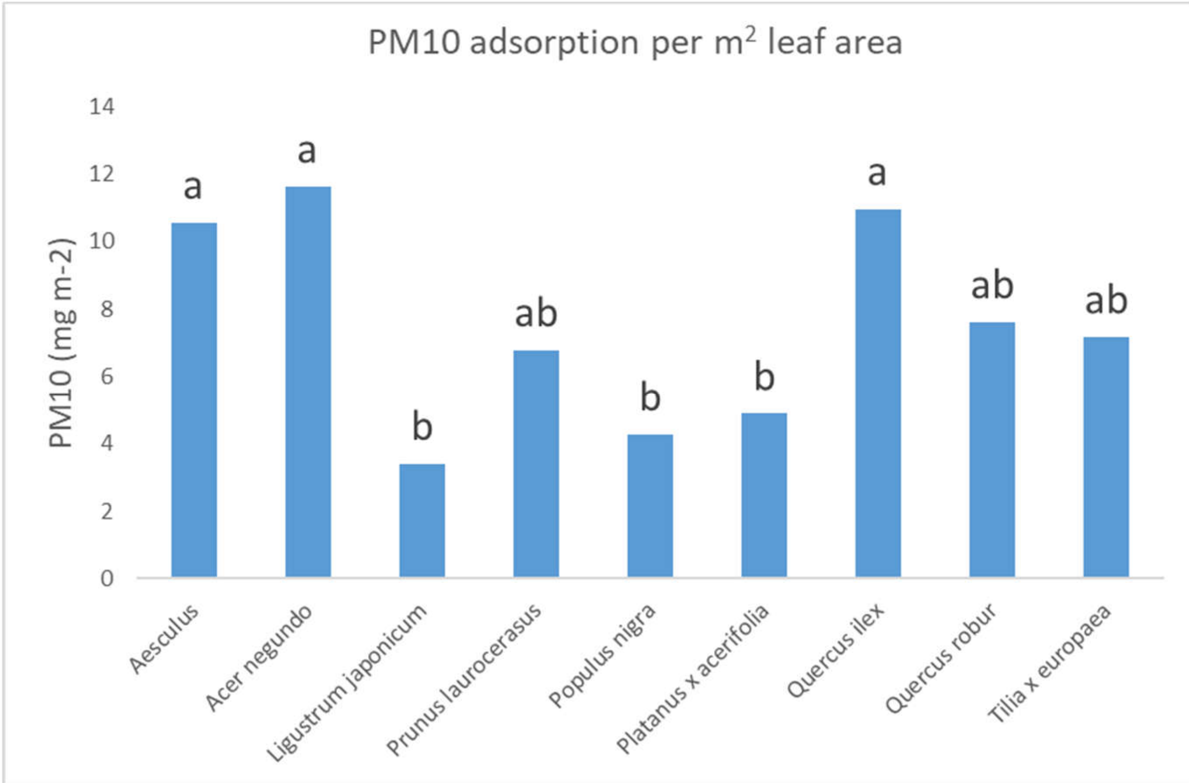
Leaves in the basal portion of the canopy transpired less water and assimilated less carbon than apical and medial leaves, regardless of species, strata, and plant age



Pollution



Aesculus, Acer and *Q. ilex* adsorbed more PM10 per unit leaf area than *Ligustrum, Populus*, and *Platanus*



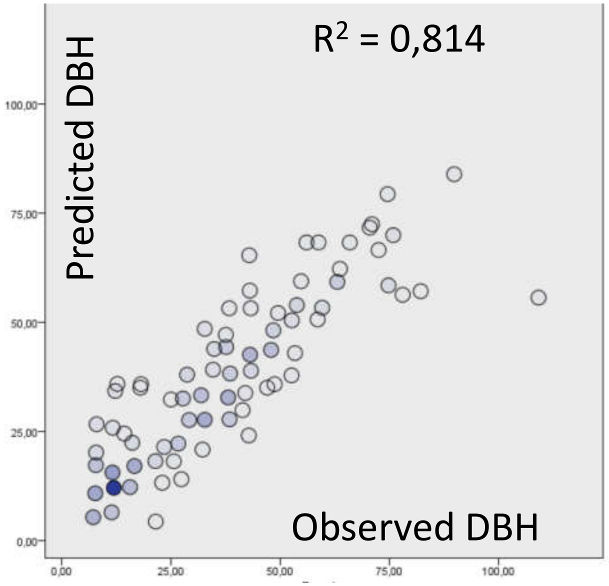
Lower leaves are the most effective to capture PM

Strata was not significant

Tree growth: age as a predictor of DBH

A machine-learning automated linear model procedure (SPSS) was used to identify significant predictors of DBH growth, then **DBH was expressed as a a function of age** using a curve estimation tool (SPSS)

$$DBH = a * age^b$$



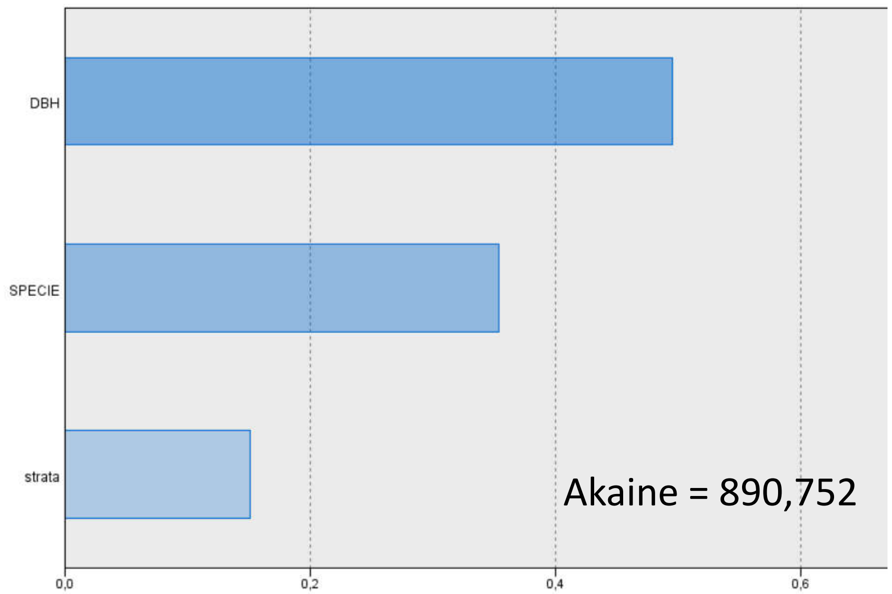
Species	a	b	R2
Acer	1,199136	0,904958	0,89
Aesculus	1,032612	0,982802	0,951
Quercus robur	2,626648	0,728181	0,888
Prunus laurocerasus	2,254608	0,614149	0,468
Quercus ilex	2,885335	0,666726	0,771
Ligustrum lucidum	3,649799	0,440109	0,526
Populus nigra	1,421086	0,998772	0,903
Platanus x acerifolia	1,184895	0,996511	0,826
Tilia x europaea	1,519631	0,900484	0,899

Age accounted for 87% of variability
Species accounted for 13%
Strata was not significant

Tree growth: DBH as a predictor of Total Leaf Area (TLA)

A machine-learning automated linear model procedure (SPSS) was used to identify significant predictors of Total Lead Area, then **TLA was expressed as a a function of DBH** using a curve estimation tool (SPSS)

$$TLA = e^{a\ *\ b/DBH}$$



Total leaf area was correlated to DBH, but the correlation depends on species and strata

Species	**Strata**	**a**	**b**	**R2**
Acer	Unpaved	7,521	-51,636	0,948
	Paved	6,881733	-39,2642	0,927
Aesculus	Unpaved	7,799567	-55,3401	0,95
	Paved	5,956216	-23,4743	0,935
Quercus robur	Unpaved	7,146393	-34,2247	0,968
	Paved	8,189543	-87,2398	0,807
Prunus laurocerasus	Unpaved	6,653643	-19,0259	0,502
Quercus ilex	Paved	7,280494	-37,3289	0,796
	Unpaved	6,354624	-48,048	0,926
Ligustrum	Paved	5,66981	-22,1225	0,612
	Unpaved	4,062086	-18,1414	0,563
Populus nigra	Paved	4,946129	-27,3438	0,862
	Unpaved	7,661452	-96,4858	0,996
Platanus x acerifolia	Paved	9,807912	-119,141	0,94
	Unpaved	6,455244	-32,6496	0,905
Tilia x europaea	Paved	6,815241	-34,9559	0,975
	Unpaved	6,595278	-36,8099	0,98

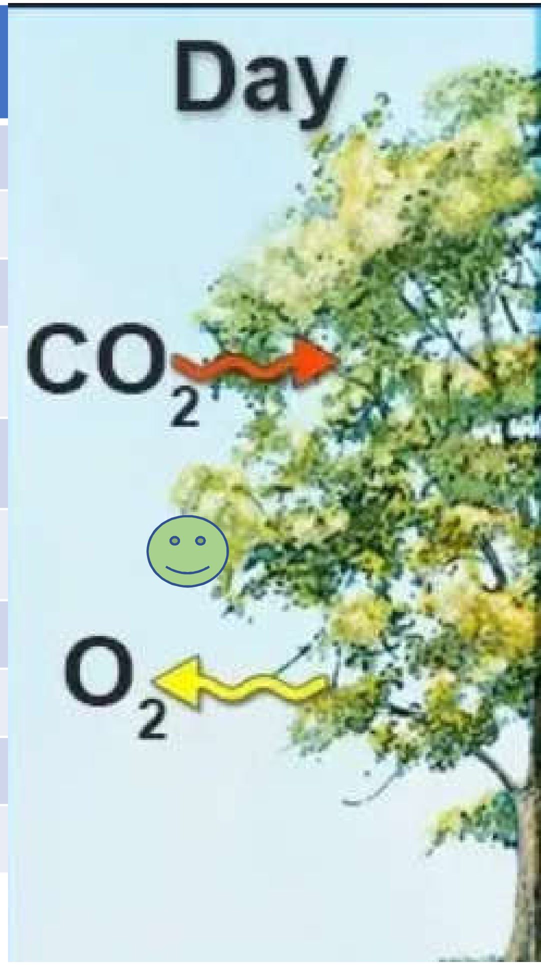
How many benefits would my 40-year-old tree provide, if it was…

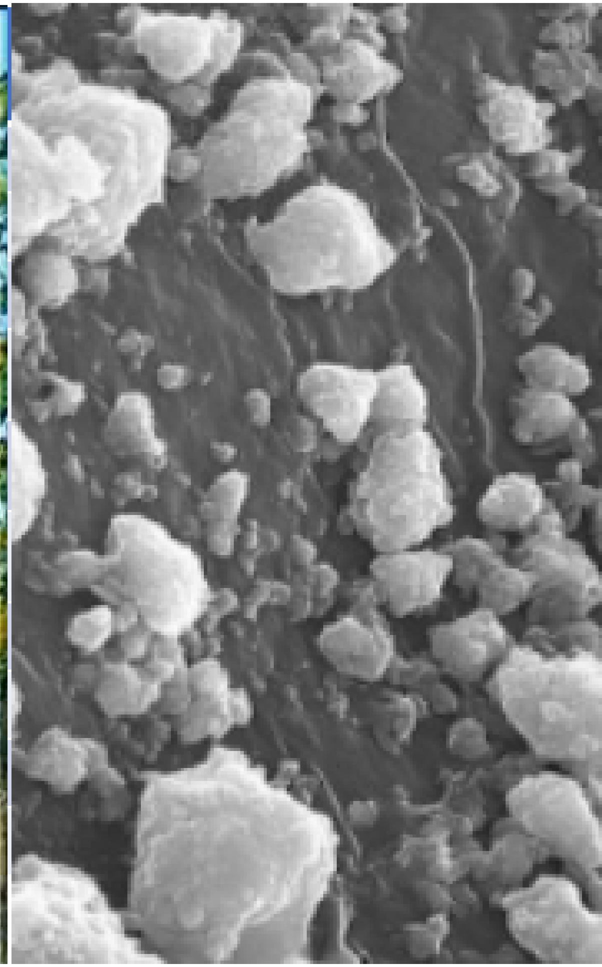
LIFE URBANGREEN

Benefits!

How many benefits would my 40-year-old tree provide, if it was…

Species	DBH (cm)	Leaf area (m2)	
	Both strata	Paved	Unpaved
Aesculus	38,8	161	518
Acer negundo	33,8	211	444
Ligustrum japonicum	18,5	20	59
*Prunus laurocerasus**	21	239	239
Platanus x acerifolia	46,8	270	608
Populus nigra	56,6	133	119
Quercus ilex	33,8	160	470
Quercus robur	38,5	192	334
Tilia x europaea	42,1	261	368





LIFE URBANGREEN
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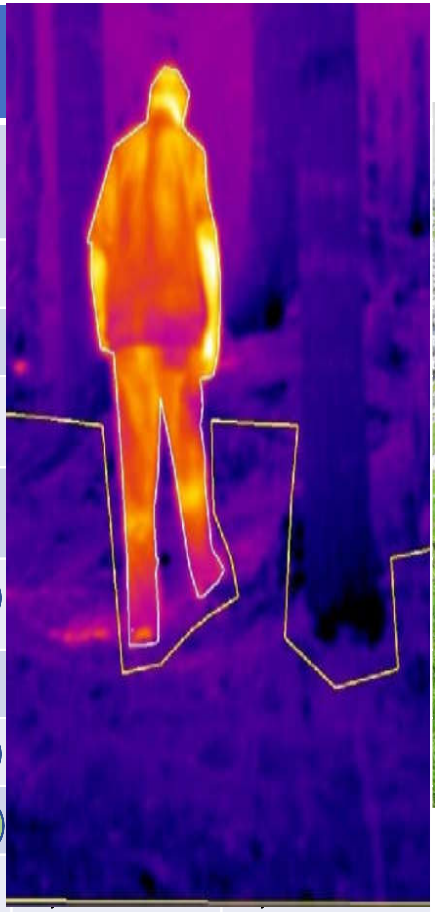
* Free form, unpruned

Benefits!

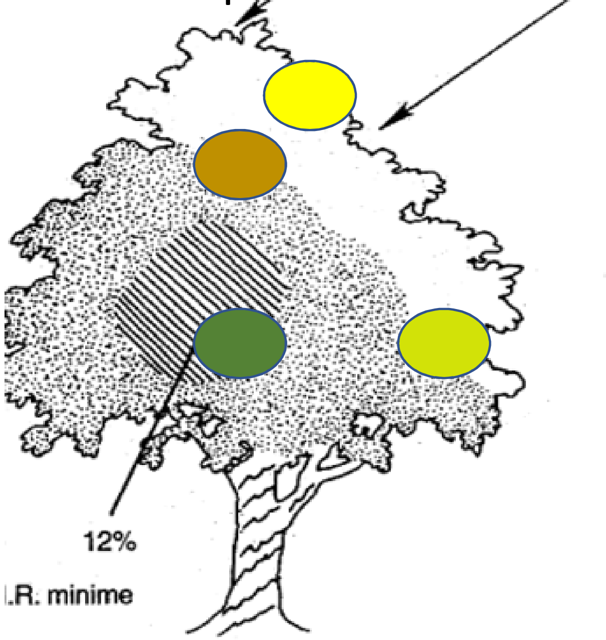
Species	DBH (cm)	Latent heat dissipated (MJ h^{-1})	
	Both strata	Paved	Unpaved
Aesculus	38,8	34,2	130,4
Acer negundo	33,8	97,0	124,2
Ligustrum japonicum	18,5	13,0	8,1
*Prunus laurocerasus**	21	55,7	55,7
Platanus x acerifolia	46,8	96,7	190,2
Populus nigra	56,6	70,8	62,5
Quercus ilex	33,8	61,0	167,2
Quercus robur	38,5	102,6	151,3
Tilia x europaea	42,1	97,6	139,7

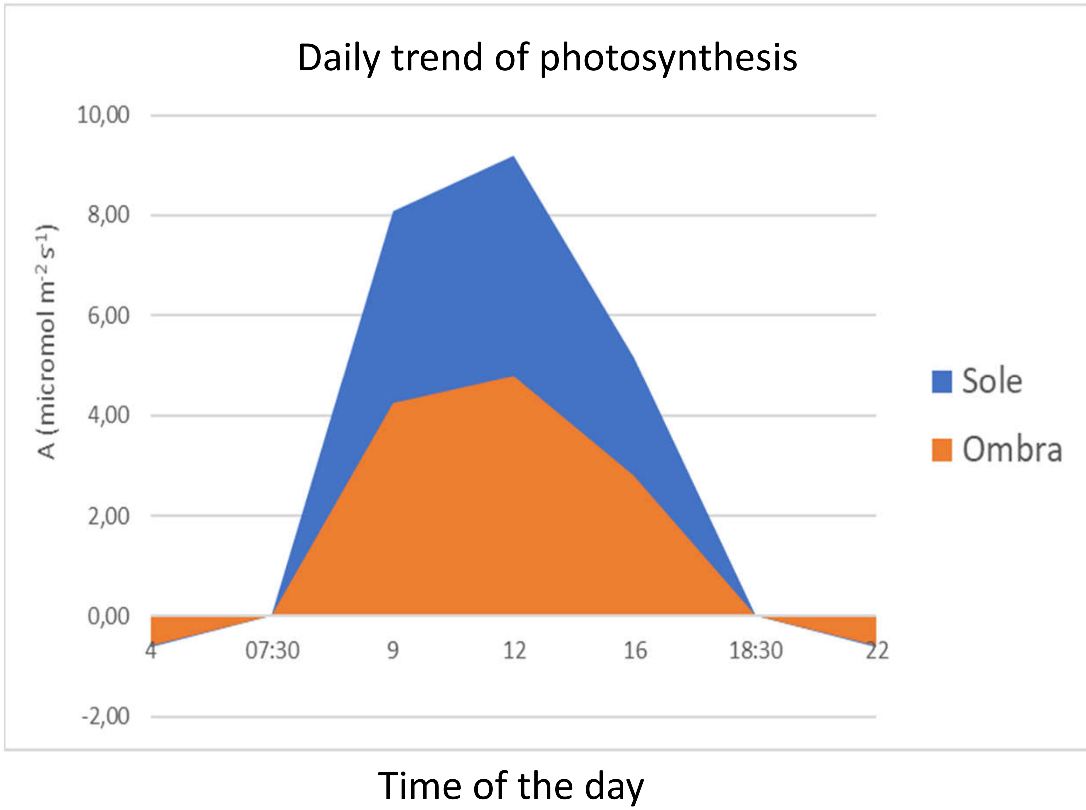


* Free form, unpruned

Ongoing activities

1- From big leaf to real canopy: up to date, measurements have been conducted on full sun leaves, and data integrated assuming negligible self-shading.
Daily trend of leaf gas exchange are currently under measurements on leaves sampled in the outer and inner portions of the canopy





Ongoing activities – Management

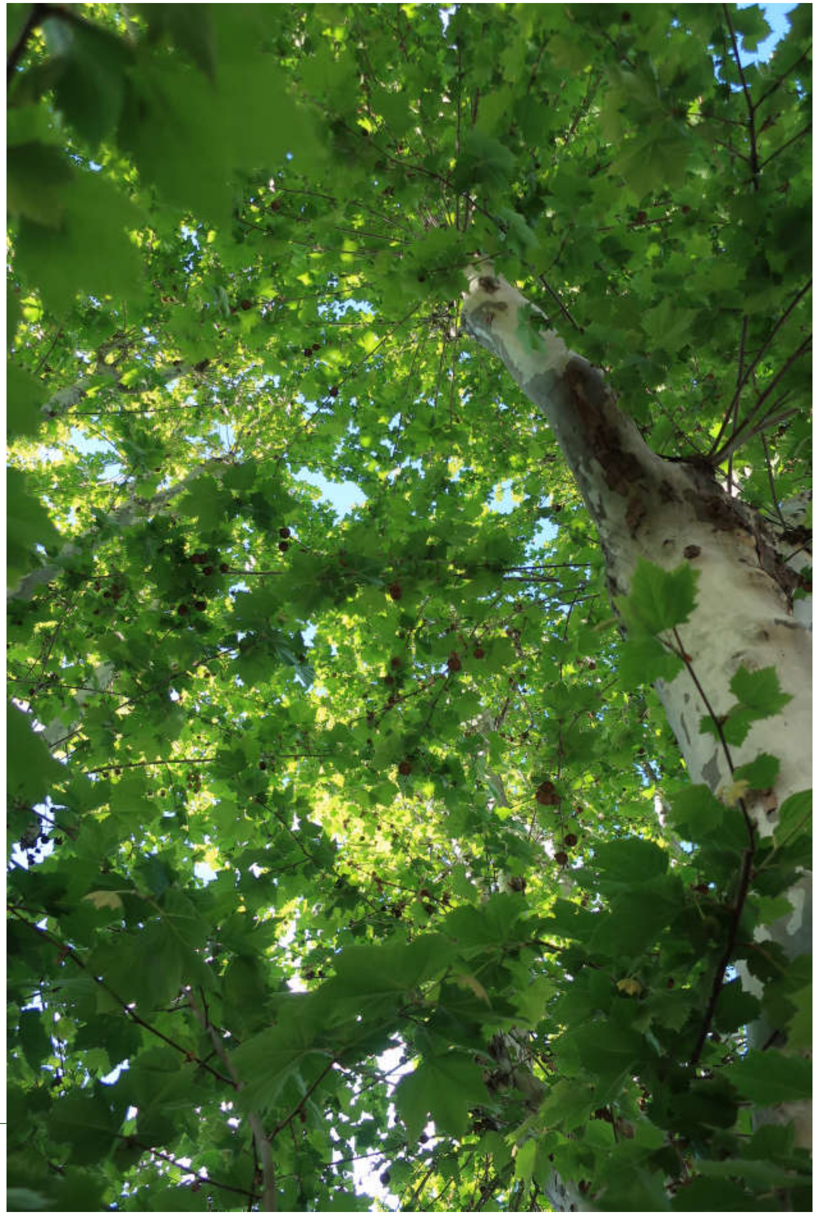
Benefits do not only depend on species selection, but also on the way trees are managed.

Half of trees will be managed in the city's traditional way, the other half according to best management practices for:

- Irrigation
- Mulching
- Pruning
- Soil decompaction

Conclusions

- Physiological measurements conducted *in situ* provided novel information about benefits provided by urban tree species
- These data may assist a benefit-oriented planning of urban green areas
- Future research should expand physiological data collection to other species in different location



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